Proceedings of the 2006 Winter Simulation Conference
L. F. Perrone, F. P. Wieland, J. Liu, B. G. Lawson, D. M. Nicol, and R. M. Fujimoto, eds.

USING RFID TECHNOLOGIES TO CAPTURE SIMULATION DATA IN A HOSPITAL EMERGENCY DEPARTMENT

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ABSTRACT

Simulation professionals understand the importance of accurate data for model validation. Traditional sources of simulation data come from information technology systems, manual records from staff, observations, and estimates by subject matter experts.

This paper discusses how Radio Frequency Identification (RFID) technologies were used on a recent consulting engagement at a hospital. Data collected through RFID can validate or replace activity duration estimates from traditional sources. However, the accuracy and cost effectiveness of RFID is not guaranteed. A sound methodology was developed, which included rigorous planning and testing of hardware, processes and data analysis.

Hardware vendors needed to understand what the simulation required so they could properly setup equipment and software. Also, ED staff needed to understand the purpose of this data collection to avoid anxiety about personnel evaluations. Finally, efficient and reliable issue and collection of patient tags was crucial to the success of this effort.

1 INTRODUCTION

1.1 Data Collection Background

Healthcare professionals typically collect large amounts of data to model and improve Emergency Departments (ED), particularly when using simulation (Miller, Ferrin and Messer 2004). Traditionally, much of the data collection is done manually. However, busy EDs do not have sufficient personnel to make manual entries for all data requirements. Some data (e.g., patient demographics or lab/imaging results) may come from other computer systems via interfaces, but usually a person enters patient and resource tracking manually into a hand-written chart or computer workstation. Ironically, this data collection system does not simplify patient flow because staff must constantly interrupt patient care to enter data. Also, when the ED becomes busy, staff either stop making entries to the system altogether, or staff will enter multiple entries in a batch after the events occur. Therefore, the most critical data can become the least reliable.

Traditional methods of data collection include database queries from Information Technology (IT) systems, time and motion studies by individuals, and estimates from ED staff (White 2005). IT systems provide the easiest and most cost effective source for data. However, previous experience shows the right data isn't always available (Miller, Ferrin and Szymanski 2003), or the client cannot query their vendor owned databases (i.e., only paper-based summary reports exists). RFID technology can eliminate the vast majority of manual entry and provide a large quantity of valuable data.

1.2 Project Background

FDI leadership met with client stakeholders to explore the potential benefits of using computer simulation, including passive data gathering technology such as RFID, as a powerful analytical tool to help improve throughput in the Emergency Department. These meetings resulted in an agreement to conduct a pilot project to test the usefulness of the simulation tool to that end. FDI partnered with MGM Data Solutions, because of their proven ability to deliver successful passive data collection infrastructure (MGM Data Solutions 2006). MGM's technical skills complimented FDI functional and project management acumen.

The project team defined the objective, scope, approach, deliverables, staffing, fees and expenses, and other business arrangements for this effort. The project kicked off the first week with process modeling workshops, where

the process is mapped from beginning to end (see Figure 1). The process map helps identify the data needed for a simulation model.

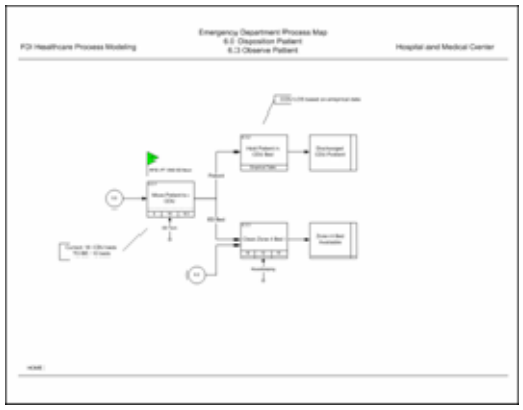

Figure 1: Sample of ED Process Map

Typically, a project team must then decide which data collection technique will provide the most accurate and cost effective means. Successful process improvement projects depend on accurate data because it provides an objective means of knowing when change is successful (Crosslin 1995, General Electric 2005). Our project team decided to use a passive, Infrared (IR) data collection technique. This data was used to validate estimates provided by Subject Matter Experts (SME) during the process modeling workshops. The team created data definitions to specify exact events in the process which RFID tags should collect data. For example, time to ED bed was the difference between a) the recorded arrival time and b) the first time the patient's IR tag was recognized in the ED bed.

The team collected sample data during two days of trial observations. The sample data yielded a mean and standard deviation which the team used to help determine a minimum sample size for full observations (see Equation 1).

$$n = \frac{\left(z_{\alpha/2}\right)^2 \sigma^2}{E^2} \tag{1}$$

The team calculated that the minimum sample size should be 60. The team estimated that it would take two weeks to collect this much data in the ED due to the limited number of patients and IR equipment.

2 DATA COLLECTION STRATEGY

The project team planned for the collection of process data in three ways:

1. From historical records gathered by the hospital
2. From field data collected by the project team
3. From data collected passively in the field through RFID technology (a vendor would install hardware in at least one third of the existing ED)

The hardware would include electronic tags that are placed on patients, doctors, nurses, staff and selected medical equipment that may include beds and other mobile devices. Placement of tags only occurred after approval by ED management. Additionally, the vendor would also install a series of transceivers located throughout selected areas of the ED. These transceivers intermittently determine the physical location of the RFID tags and transmit their location to receiving stations that compile the data for use by tracking software. The project analysts fed this data into the simulation program. It was anticipated that the entire project would last six to eight weeks.

3 TECHNOLOGY

3.1 How RFID Technology Works

RFID and IR are tracking systems employing small tags placed on entities, such as products or people. Sensing equipment track these entities and record their movement over time. RFID help staff and management make more informed decisions when managing department resources (MGM Data Solutions 2006). It gives managers timely, accurate information for the roles they oversee. Specifically, it provides up-to-the-second information about:

- The physical location of people and equipment.
- The overall movement of these entities.
- The utilization and status of locations.
- The utilization of people resources.
- The work queues for individual resources.
- The bottlenecks that may affect throughput.

Managers can view this information using special software which displays status and summary information.

3.2 Infrared Tracking Systems

There are several types of RFID tracking systems. The project team at this hospital used an IR system. ED patients and staff wore IR tags (see Figure 2) that sent an active, line-of-sight signal to sensing equipment, similar to a television remote control. These badges send a signal every three seconds which uniquely identifies the tag to sensors located in ceilings and at exits throughout the emergency department. Each sensor then forwards a signal through wiring in the ceiling to a central machine that converts the signal which in turn forwards the data to a server. The server was connected to the internet to help team members working remotely to manage the volume of data on the server's database.

Figure 2: IR Badge Worn By Patients and Staff

3.3 Infrared Tracking Installation

Infrared sensors were located in several key locations, including Triage, Fast Track, Registration and one zone of exam rooms. Installation of the hardware took less than one day and the team tested it to ensure it accurately collected data.

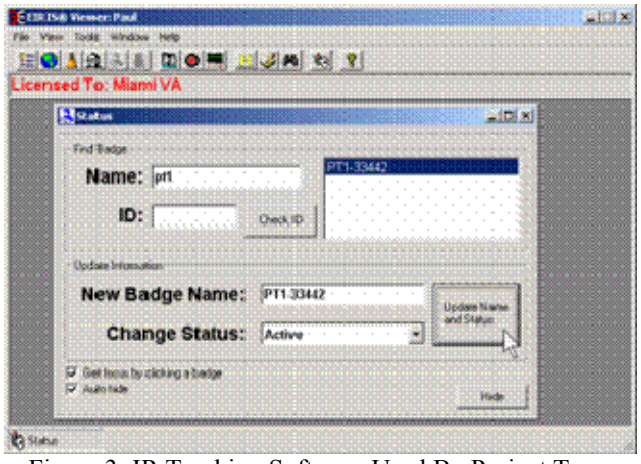

Figure 3: IR Tracking Software Used By Project Team

MGM Data Solutions provided simple, easy to learn software which enabled the team to input, modify, delete and record movement of the tags (see Figure 3). Doctor, Nurse, and Registration tags were entered into the software with IDs that described their job title (e.g. DR1-doctor, RN3-registered nurse, RG7-registration clerk, etc.). Also, patient tags were entered into the software with the patient tag number followed by the patient's medical record number (e.g. PT1-1234567, PT15-7654321, etc.). Tag movements were recorded in raw text files which contained the tag number and a timestamp of the movement (see Figure 4).

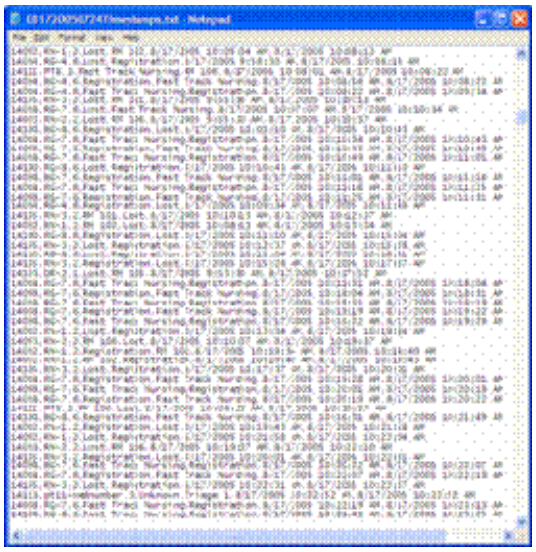

Figure 4: Raw Text File of IR Tag Movement

3.4 Technology Lessons Learned

The team discovered several issues with the technology during this project. One issue dealt with the close proximity of the Triage area and the Waiting Room which prevented the accurate determination of whether a patient was being triaged or waiting. Also, the IR tags were fairly large and had a tendency to get covered up by patients and staff. Many data points were lost since these tags could not send a signal strong enough to penetrate clothing. Patients and staff should wear IR tags above their waist and keep them uncovered at all times or else data points will be lost. The IR sensors could track tags more easily if they were in the form of a wrist band or some other form that could not be covered up. Other tags were considered but deemed too costly.

The hospital's IT department did not grant internet access to the server until after the project completed. This made data inaccessible to programmers located remotely. Local project team members manually downloaded movement data directly from the server and emailed the data to programmers instead. Better coordination with the hospital's technical service provider prior to project kickoff will ensure future success.

Another issue involved managing the volume of data collected during the day. Rather than manage tens of thousands of rows of data for each tag event, the team programmed the software to ignore tracking in a location for less than 1 minute. However, too much valid data was lost so the team eliminated this filter and recorded all events, electing to filter this data later using queries.

Finally, the team lost numerous IR tags because patients did not return them before leaving the ED. The project team setup drop boxes at each exit, but this did not resolve the issue. The team decided during the project to keep the tags with the patients, but not on the patient. A

team member stayed with the patient placing the tag on a counter in the exam room. Although this eliminated the issue with lost tags, it created too much manual intervention with data collection. Losing tags will always be an issue until the tags become inexpensive enough to dispose. A team must assume a significant number of patients will forget to return the tags.

4 DATA COLLECTION PROCESSES

4.1 Plan the Process

Hardware alone cannot gather the data about patient throughput in the ED. The technology needs a well defined process that works harmoniously with it. Therefore, the team prepared a plan to issue and collect IR tags, pilot the process and verify the data quality. Team members also needed to analyze the IR data, summarize it, and develop automated tools to reduce analysis time for future RFID efforts.

Development of an effective plan was needed to ensure a successful IR data collection effort. A pilot, or walk-through, of the IR data collection effort was required to identify issues before the team spent significant time and effort collecting data. This process plan needed to address how the staff would issue and collect IR tags from the patients.

4.2 Test the Process

Once the process plan was created, detailed scripts were needed to walk through "a day in the life of an ED patient" sequentially. The team could then execute these scripts during the pilot to generate expected data results which in turn could be compared with actual IR data. The pilot could also identify any process issues with the IR tags, so that these could be resolved as well.

An efficient process was developed for issuing and collecting IR tags. A script was written that stress tested this process so that the team could resolve potential issues before the larger data collection effort began. The script listed a sequential number of steps from patient arrival to patient departure.

To test during non-peak times, the team met at the ED in the morning. The team executed the test scripts, writing down the time that each event occurred (e.g., time arrived, time placed in an ED bed, and time seen by a physician). These expected results were then compared to the data collected by the IR equipment, ensuring its validity. Once the test scenarios were complete, the team identified and resolved issues.

4.3 Execute the Process

Tag receptacles were set up at exit points and registration for the return of patient tags. The receptacles, which encompassed the tag, would block the IR signal from being picked up by a reader and creating false data. The blocked signal decreased error caused by patients who had already dropped off their tag.

For staff tags, a bulletin board was placed in an area away from the IR readers. Patient level staff was observed to ensure they were wearing the tags. The flowchart was amended to show points where IR could acquire the data point (such as a visit by a physician or nurse). Tags were issued to patients at the initial triage stage. EMS patients were not tagged.

Patients who were routed to areas without readers had their tags collected by the on-site FDI staff. Patients who were routed to the Main ED and the Fast Track area, where they could be tracked, wore their tags until they were transferred to an area without readers or routed through registration for discharge. If a patient was admitted to the hospital or transferred, the transport technician or nurse would drop the tag in a tag receptacle.

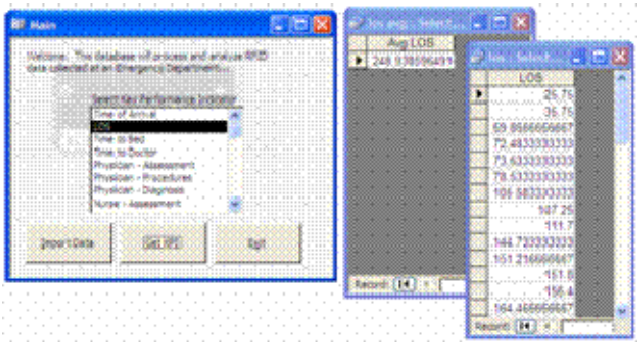

Figure 5: Database Queries of Raw Data

If a patient was routed to registration to check out, the registration staff collected the tags and placed them in the tag receptacles. FDI staff collected the removed tags and disabled them in the software. Raw data was dumped into a Microsoft Access database and queries were performed to determine activity times and wait times (see figure 5). Queries were created in Access to sort the raw timestamp files into a more useable form.

4.4 Analyze the Data

After the extended IR data collection effort concluded, the team would need to analyze a large amount of patient process data. Automated techniques for analysis were desired, considering the large volume of patient process data available after the two week IR data collection finished. This data was in text format and included the timestamp data for each time a patient's location changed. The queries

yielded data points for each patient tracked. These data points were fed into distribution fitting software which produced a curve for activity times.

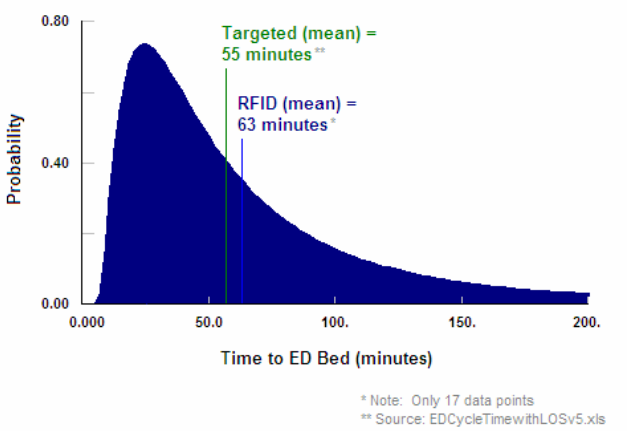

Figure 6: Comparison of IR Data and Actual Mean Time to ED Bed

The mean IR Time to ED Bed was compared to historical values and found to vary by only 15% (see Figure 6). Also, Figure 7 shows how closely IR results compare to SME estimates. The blue bars show minimum and maximum SME estimates with the blue square identifying the value they felt was most likely. The red squares are the average values for IR data collected. The team automated the data analysis using Microsoft Access to import the text files and a series of queries to extract the relevant data.

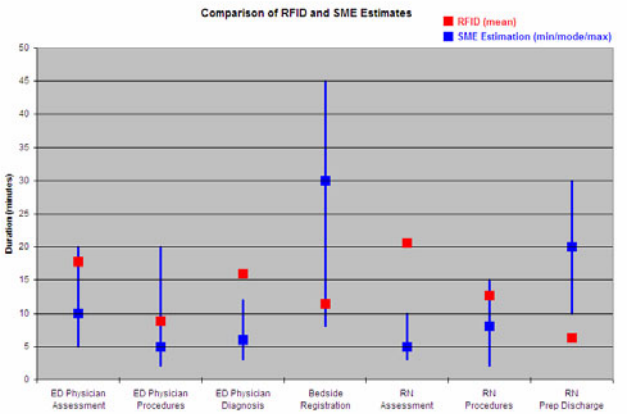

Figure 7: Comparison of IR Data (Red) and SME Estimates (Blue)

4.5 Benefits

After sufficient reminding, the staff was very receptive about wearing their tags. Fast Track data was fairly easy to get due to high volume of FT patients in areas with readers. Once an adequate sample of FT patients was acquired, tags were placed in the tracked rooms and turned on and off when patients entered, thus taking the patient out of the process while still collecting the data. This dramatically decreased the number of lost tags. With the MS Access queries, activities used in creating the simulation were easily found. Activity distributions gathered were then available to the simulation, thus providing a more valid model of the ED.

4.6 Process Lessons Learned

Patients who Leave Without Being Seen (LWBS) would occasionally leave without returning their IR tags. Often, patients would change out of their street clothes and into a patient gown and would not put their tag back on. The process varied slightly from what the staff described, which changed the way the IR tags were issued. Many patients left their tags in their room, sometimes in their sheets. Some tags were thought to have been lost when housekeeping did not see them. Some patients vandalized the tags. Tags required cleaning between each patient use. Tags that are worn as necklaces or wristbands would lessen the likelihood of a tag being taken off along with street clothes when changing to a gown. This would also decrease the chance of a patient covering the tag. Most patients who did not return their tag were contacted by phone at a later date. Many of these patients said that they left their tags on their bed when they left the ED. Since these tags were never recovered it is likely that housekeeping threw out the tags when cleaning the room. Better coordination with the EVS/ laundry staff is required to ensure tag retrieval.

Time from arrival to receiving of the tag could not be tracked with the tags. The raw timestamps file needed to be filtered to get the wait times and activity times needed for the simulation. This required the creation of several Access queries. For time being, manual data collection appears to be the only way to track time from arrival to receiving a tag.

Finally, results from the initial data collection had shown an insufficient amount of data for calculating process performance. The team calculated that an additional two weeks of full time data collection, based upon number of badges available and patient volumes, would provide sufficient confidence intervals for accurate conclusions.

5 CLINICAL IMPACT

As with any process investigation, the project team wanted to minimize the impact to an already busy ED staff (Rossetti, Trzcinski and Syverud 1999). Role definitions and training were important to ensure project members knew what to do. IR tag responsibilities included a coordinator, or leader, who plans and trains the staff, answers questions, monitors progress, and resolves issues. Also, physicians, nurses and registrars were issued tags and instructed to

keep them on during their entire shift. Finally, patients who were issued tags were instructed to keep the tags visibly with them. The coordinator, staff and patients completed these responsibilities with relative success. The staff were trained on their responsibilities prior to beginning IR data collection. Training included details of who needed to what and when.

The nurses issued IR tags to patients during the entire two week study. Tags were issued during triage. At the same time, Registration staff inputted tag information into the IR software program. Nurses also gathered tags from patients getting admitted to the hospital just prior to leaving the ED. Likewise, Registration staff gathered tags from patients being discharged just prior to departure. Overall, the staff was receptive to these additional responsibilities and the data collection was not very invasive.

5.1 Clinical Lessons Learned

During the two week data collection, there were concerns expressed by the staff. They occasionally felt they were being watched by "Big Brother" while wearing their IR tags. To address these concerns, tags were not uniquely labeled and staff could select any tag for their job type. However, some staff were still suspicious, even with these adjustments. Additional training should include more details about why the staff are wearing tags to lessen these concerns and increase cooperation.

Since not all the staff were aware of the study before it began, steps should be made so that everyone is briefed prior to starting. The project team could issue each staff member a memo outlining the project and their duties. Ideally this would happen before the system goes live. Most of the staff were receptive to our needs, but some saw the study as an interruption and unimportant. For this reason, better communication from their supervisor is required. Perhaps requesting the supervisor working with the project team to issue the memo would be helpful, as having the supervisor's name attached to it will have more political pull.

6 CONCLUSION

RFID is a powerful new technology that can validate or even replace activity duration estimates from traditional sources. However, a project team must implement a sound methodology which includes rigorous planning and testing of data collection hardware and processes.

IR tags used for this project cost about $50.00 each. The project team discovered that almost 30 tags were either lost or inadvertently removed. Since so many tags may be lost, project leadership must justify the increased accuracy of the simulation compared to the cost of lost tags and the man hours needed to issue and retrieve them. If passive data collection can be performed without placing patients and the public in possession of the tag the number of lost tags will dramatically decrease.

Project teams must also educate ED staff and patients about the purpose of RFID data collection. This will help avoid anxiety and proper usage of RFID tags. RFID technology will likely become a more popular data collection method that complements traditional sources of modeling data. It is easy to envision every ED someday using RFID to track their patients, staff and equipment. Our project team learned much from this first successful application.

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