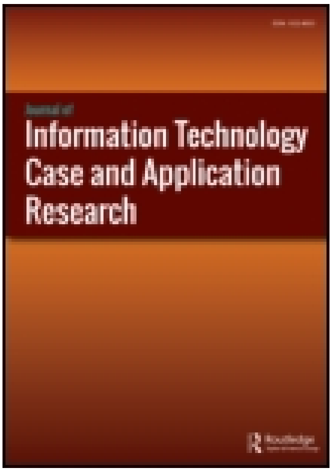

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Leveraging Information Technology for Disaster Recovery: A Case Study of Radio Frequency Identification (RFID) Implementation for Facility Retrieval

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Leveraging Information Technology for Disaster Recovery: A Case Study of Radio Frequency Identification (RFID) Implementation for Facility Retrieval

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Interest in utilizing radio frequency identification (RFID) methodology to facilitate disaster recovery management has risen substantially in recent years, especially in coastal regions that periodically suffer catastrophic losses due to natural disasters such as hurricanes. At this early stage of adoption, however, it is unclear how RFID technologies can best be integrated into the disaster recovery process and help individuals and organizations renew themselves after the crisis. This teaching case study evaluated the performance of three potential information technology solutions: (a) a global positioning system (GPS), (b) RFID and magnetic locators, and (c) a combined RFID/magnetic locator/GPS system. Experiments were conducted in order to assess the feasibility, reliability and cost of using RFID technologies in disaster recovery. A cost analysis showed that using RFID, magnetic locators, and GPS together reduces the cost of recovering utility facilities buried under storm debris by 26% compared to current methods. The results clearly demonstrate that RFID technology does indeed contribute to the efficient retrieval of utility facilities and help the community renew itself.

Coastal regions in the United States periodically suffer catastrophic losses due to natural disasters such as hurricanes and tropical storms. One of the worst hurricanes to hit the southeastern United States was Hurricane Katrina in 2005, which caused approximately $125 billion in damage and casualties numbered in the thousands, and 7 years later Hurricane Sandy caused an estimated $65 billion in the United States alone. The number of presidential disaster declarations is accelerating, doubling from that in the 1980s, and is accompanied with an increasingly negative economic impact (Burby, 2006), as well as social costs due to the impact on the physical and mental health of socially vulnerable populations (Emrich & Cutter, 2011). As a consequence, the government and relief organizations need to prepare for future natural disasters by strengthening their disaster response and recovery capabilities for both the pre- and post- disaster stages (Cumbie & Sankar, 2012). In addition, it will be helpful if information technologies can help individuals, organizations, and communities renew themselves after the crisis (Lally, 2008a).

A well-organized disaster recovery plan is an information-intensive effort, requiring the incorporation of advanced technologies into disaster relief operations (Cumbie & Sankar, 2012; Yates

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& Paquette, 2011). Information technology (IT) tools such as geographic information systems (GIS) and global positioning systems (GPS) can improve the way people communicate and share information, which is critical for good decision-making in real time in the aftermath of a natural disaster, as a report by the National Research Council (2007) pointed out. However, GIS, which is one of the most widely used technologies in disaster recovery operations, merely provides information on the static location of utility infrastructures and facilities (Chatfield, Wamba, & Tatano, 2010). This may not be very effective when the landscape has undergone major changes due to the high winds and storm surges typically associated with a hurricane. The resulting delay in identifying infrastructure elements and facilities inevitably impedes the cleanup operations, paralyzing local communities and businesses and delaying their return to normality for weeks or even months. Lally (2008a) suggests that information technologies may hold a key in rebuilding the infrastructure and might assist in the post-crisis renewal of the communities.

Radio frequency identification (RFID) may be one of the information technologies that could be used to resolve this issue. This technology is ideal for automatically identifying and dynamically surveying the movements and locations of public facilities, even those buried underground such as water and gas pipes, power lines, and telecommunication cables. Although RFID is not a new technology, its deployment in disaster management has tended to trail behind other industries and RFID implementation is still in its infancy. In addition, little is known about the performance of RFID in disaster recovery operations in coastal regions.

The primary goal of this paper is therefore to present a case study of applying an effective RFID-based solution to improve the retrieval of buried facilities as part of the disaster recovery effort and help in the post-crisis renewal of this community. The case study describes a series of experiments performed in Gulf Shores, Alabama, in collaboration with an RFID manufacturing company, a local utility company, city representatives and a university research center to evaluate the performance and effectiveness of three different RFID-based solutions for quickly retrieving buried utility facilities

INFORMATION COMMUNICATION TECHNOLOGY TOOLS FOR DISASTER MANAGEMENT

Effective disaster management relies on the information systems and technologies which could play a crucial role in making appropriate decisions at any stage of natural disasters and improving information dissemination and communication among of all stakeholders during response and recovery operations (Lally, 2008b). Many information communication technology (ICT) tools, such as geographical information system (GIS), remote sensing, RFID, GPS, building black box, radio communication media, and social media are available for use in disaster recovery (Adam, Shafiq, & Staffin, 2012; Peña-Mora et al., 2008; Reddick, 2011; Wang, Hubbard, & Hubbard, 2014). Table 1 lists each of these information technologies and its application in disaster recovery operations.

Most of these technologies rely on having the geospatial coordinates of each infrastructure facility. GIS refers to a computer-based system capable of capturing, storing, mapping, monitoring, analyzing and visualizing all types of spatial data and geographically referenced information. GIS is the foundation for supporting the preparedness, response, recovery, and mitigation efforts when disasters strike (Johnson, 2000). GIS provides a versatile platform that enables disaster managers to plan the evacuation routes in the preparedness phase. It supports search-and rescue

TABLE 1
Existing Information Communication Technology (ICT) Tools as Aid During Disaster Recovery

	Major applications
Geographic information systems (GIS)	• Support resource allocation and route determination • Provide geo-referenced information to response the disaster events • Support decision making during disasters
Remote sensing	• Use a recording instrument or device to measure or acquire information on a distant object or phenomenon during disaster recovery. • Map the variations in terrain properties • Locate the area of a natural disaster and monitor its growing proportions • Monitor the disaster event
Radio frequency identification (RFID)	• Capture on-site data and real-time data • Access to facility design documents and monitor facility condition • Track the movement of objects in real time and acquire required information automatically
Global positioning system (GPS)	• Pinpoint the location of damage sites and floodplains • Track the storm and flood by analyzing transmissions of GPS data • Help stranded persons find assistance or guide emergency vehicles
Building black box	• Support building assessment during disaster response operations • Store static building information (e.g., building model and drawings) • Provide dynamic building information through disaster resilient sensors
Radio communication media	• Receive and distribute alert messages and disseminate alert messages and advice to large sections of the public • Assist in organizing relief operations in areas • Exchange of information between individuals and/or groups of people involved in relief activities
Social media	• Map crowd sourced information in disaster response gained wide-scale media attention • Extract action items and location information from social media feeds

operations when it provides geo-referenced information such as hazard mapping and information on critical facilities at risk. GIS is also useful in providing needed post-disaster information and monitoring the progress for reconstruction of infrastructures during disaster recovery phase. During the mitigation phase, simulation models and cost analysis based on GIS can be executed providing valuable information to the community. However, the impediments limiting the effectiveness of GIS in disaster recovery are centered on the high data collection and maintenance costs and the issues of obsolescence, specifically, the inability to update outdated data in obsolete devices. Therefore, other information technologies need to complement GIS for improved disaster recovery efforts.

THE USE OF RFID FOR DISASTER RECOVERY

The use of radio frequency technology can be traced back to World War II. For example, the Germans used it to identify aircraft as friend or foe when a plane was close to their base. The first passive RFID tag came out in 1973, and was used to unlock a door without a key. In the 1970s, passive RFID tags (at a frequency of around 125 kHz) were attached to trucks to track nuclear materials transportation by U.S. government. Such kinds of system were applied to public toll payment and became commercialized in the mid-1980s. Later, high frequency RFID tags (13.56 MHz) with greater reading coverage and faster data transmission rate were developed for tracking assets, access control, and payment systems. Ultra-high frequency RFID systems with even better reading range and data transmission speed were developed by IBM in the early 1990s. However, the actual commercialization of such technology began in 1999 when two professors in Massachusetts Institute of Technology, David Brock and Sanjay Sarma, managed to develop low-cost RFID tags that can transfer data with an Internet accessible database (Roberti, 2015). This novel RFID system started the massive use of RFID tags in supply chain.

The functionality of RFID is typically based on the design principles of event-driven IT architecture (i.e., publish/subscribe mechanism, asynchronous interaction, and loose coupling) (Wang, Kung, & Byrd, 2013). RFID-based system consists of a transponder (tag/smart label) with data memory and antenna, readers that allow users to store and process information and to receive and transmit radio-frequency (RF) signals, and a host computer with data processing software.

Currently, RFID tags are widely used in many organizations. For example, hospitals use RFID tags to track patients and facility assets to improve care and reduce costs and libraries and museums use RFID tags to management all inventories. RFID solutions can be used to simplify the processes such as production control, authenticity features/authenticity protection, and position identification in various industries. Retail, supply chain, and healthcare industries use RFID to track the movement of objects in real time and acquire required information automatically. From the standpoint of practitioners, the adoption of RFID helps reveal salient information that can be used to improve existing operational capabilities by reducing costs, and improving both productivity and customer satisfaction (Hardgrave et al., 2008).

Despite the growing use of RFID in companies' logistical operations, it has seldom been applied to disaster recovery processes. In the context of post-disaster recovery, utility firms could take advantage of RFID by utilizing it to reduce the effort involved in locating infrastructure facilities, as well as protecting them against the damage that is often incurred during the recovery process due to an imprecise knowledge of their exact locations (Lakshmi Narayanan & Ibe, 2012). Several pioneering studies have explored the use of RFID as a promising technology in the field of disaster recovery. For example, Chatfield et al. (2010) highlighted the potential role of RFID technology in establishing a robust disaster preparedness and response system and optimizing the disaster relief process. In the context of disaster reconstruction operations, Wang et al. (2014) pointed out that RFID technology can be used to track and locate the movement of resources such as people, material and equipment more effectively during recovery operations. Thus, the adoption of RFID technology has the potential to improve disaster management by speeding up post-disaster infrastructure facility retrieval procedures.

RESEARCH METHODOLOGY

Case Description

This case study was designed and conducted to compare the performance of three IT solutions for improving post-disaster facility retrieval operations in the city of Gulf Shores, Alabama in the United States. This coastal city is located in an area that is highly vulnerable to hurricanes and has suffered from a number of severe hurricanes in recent years (including Hurricanes Ivan in 2004, Dennis, Katrina, and Rita in 2005, Gustav in 2008, and Isaac in 2012), all of which caused extensive damage to the local utility infrastructure. The great majority of Gulf Shores' financial revenues come from the tourism industry, with total visitor expenditures estimated to reach more than $1 billion in 2013, a 33% increase over 2009. To maintain this growth trend, it is crucial to prepare for disaster recovery thoroughly and reduce the time needed to recover after a hurricane.

Problem Identification

The researchers set up face-to-face meetings with representatives from coastal municipalities and local utility companies to identity the major problems related to post-disaster recovery operations. Two of the major issues for disaster recovery identified were associated with facility retrieval operations.

The first issue is that the documents and maps used to store information on infrastructure facilities may be in paper form, which is difficult to preserve during a wind and water-related disaster, and to share with those who need the information during the recovery process. After a coastal natural disaster, most of the near-ground facilities are covered by huge quantities of debris and sand and utility companies must flag the areas where their facilities are located to ensure that cleanup teams avoid using heavy equipment in those areas. Paper maps are of only limited utility after a natural disaster, given that there may have been significant changes in the local topography, making it difficult to definitively identify specific landscape features. It can therefore take a considerable time to locate buried facilities based solely on information held on a paper map, which leads to the second problem, the additional damage inflicted on facilities during the cleanup process.

After a disaster, local governments usually clear the roads with excavators operated by temporary laborers who are generally not familiar with the territory and targets. As a result, when the workers use heavy equipment to remove sand and debris, they can easily damage or even destroy buried infrastructure facilities if the utility company cannot flag the area in time. One study has shown that 50% or more of the damage inflicted on critical facilities actually occurs during the cleanup process (Cumbie & Sankar, 2012). Broken infrastructure facilities such as water pipelines and power lines not only delay the community's recovery, but also cause major losses for the utility companies. Given this situation, local utility companies and coastal cities place a high priority on finding a better way to locate buried facilities quickly after a disaster and protect them from post-disaster damage, thus speeding up the recovery process (Appendix).

Experimental Design

The goal of this experiment was to test the effectiveness of RFID in retrieving utility facilities. To achieve this goal, we worked with a mid-western RIFD technology company who created the RFID solution. The company developed a tag that encloses the RFID chip in a strong metallic frame capped with a magnet nut that can be located by a magnetic locator. The RFID chips use the passive RFID technology and are programmable to incorporate useful information, such as the type of utility, utility depth, nearby utilities, intersections, hazards, and ID numbers. We buried the tags in different locations to simulate the location of utility facilities.

The effectiveness of RFID technology was measured by testing for the feasibility of use of the tags, their reliability, and cost-benefit analysis. First, we examined whether it was feasible to use RFID tags to retrieve information on utility facilities and compared their use versus using GPS coordinates alone. Then, we tested the reliability of the tags under different real-world situations (D'Mello et al., 2008). Finally, we performed a cost-benefit analysis using a potential use scenario.

CASE ANALYSIS

Phase I: Feasibility Analysis

In order to investigate the advantages of RFID enabled facility retrieval, we designed three different IT solutions, namely (a) GPS, (b) RFID and magnetic locators, and (c) a combined RFID/magnetic locator/GPS system, and compared their performance.

The first of these IT solutions used only a Topcon Handheld GPS unit (Figure 1) to locate the search area and a shovel to find the target.The second IT solution used a magnetic locator with an RFID reader (Figure 1). The magnetic locator was used to sweep the area to search for the specific RFID tags provided by the company (Figure 1). When an object was detected, the RFID reader was used to read the information on the tag, thereby avoiding the need to dig down to the target to identify it. The third IT solution consisted of an improved RFID-based solution that combined GPS and magnetic locators with RFID technology. Here, the handheld GPS device was used to narrow down the search area and then the magnetic locator was deployed to precisely locate the target and the RFID reader to identify it.

Time study and accuracy tests were used to determine the performance of the three IT solutions. Time study is a technique that quantifies the time spent on each activity that occurs in a workflow (Ker et al., 2014), while the accuracy test analyzes how many tags are actually retrieved by participants. To compare the performance of the three solutions, the recovery time and the accuracy of retrieval were recorded.

For this experiment, groups of three to four participants were assigned to use each of the IT solutions for 20 minutes and asked to find five targets located within 100 yards of the base point and buried at depths increasing in 6-inch increments from 0 to 24 inches on a "sugar sand" beach in Gulf Shores. The clock was started when the participants left the base starting point, and

			
Topcon Handheld GPS	Magnetic locator	Inframarker RFID reader	Inframarker RFID Tag

FIGURE 1 Technologies used for facility retrieval. GPS = global positioning system; RFID = radio frequency identification.

stopped when the targets had been located. A data recording sheet was developed to document the results of each test. The result was collected and collated at the end of the tests by an observer using a data sheet. Both accuracy of retrieval and recovery time were recorded and compared across the three IT solutions.

A total of 51 students from a large south-eastern university were divided into 17 groups to complete the tests for the three IT solutions. None of the participants had prior experience using the technologies. The average time taken to retrieve a target is shown in Figure 2. The shortest amount of time was for IT solution C (2:51 minutes), rising to 10:47 minutes for IT solution B and 14:11 minutes for IT solution A. The accuracy in locating the tags for the three tests is shown in Figure 2. Within the 15 minute period allowed, the participants located 91% of the tags using IT solution C and 39% of the tags using IT solution B, but only 19% of the tags using IT solution A (Figure 3).

These results show that IT solution C achieved the highest accuracy in the shortest time, demonstrating that combining GPS, magnetic locators, and RFID technology should dramatically speed up the disaster recovery process and maximize the accuracy of the facility retrieval process.

Phase II: Reliability Test for the RFID Technology

The reliability test was designed to measure the read reliability of the RFID tags to understand how well the tags perform under different conditions. Four different soil conditions (soil, moist soil, sand, and concrete, each 6 inches deep) and 3 different reading heights (fire hydrant, 10-ft tree, and 20-ft tree) were tested. Each RFID tag was programmed with different facility information so that an RFID reader could identify it. Based on the results of the first phase, a new device that incorporates both GPS and an RFID reader was developed by the company and this was used in this experiment.

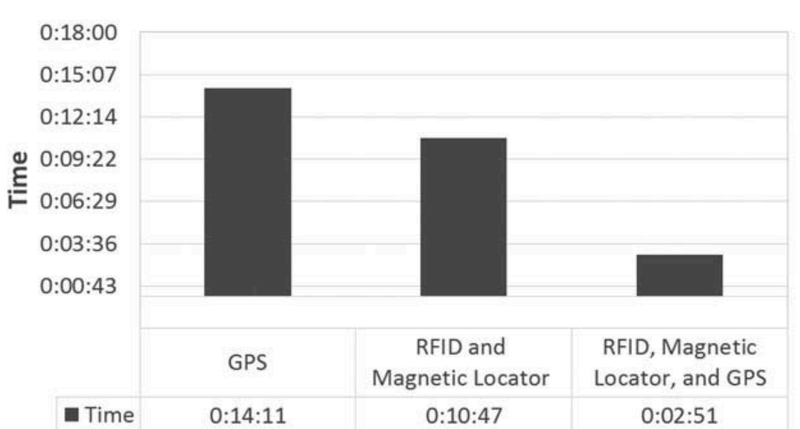

FIGURE 2 Average time taken to retrieve each target in minutes. GPS = global positioning system; RFID = radio frequency identification.

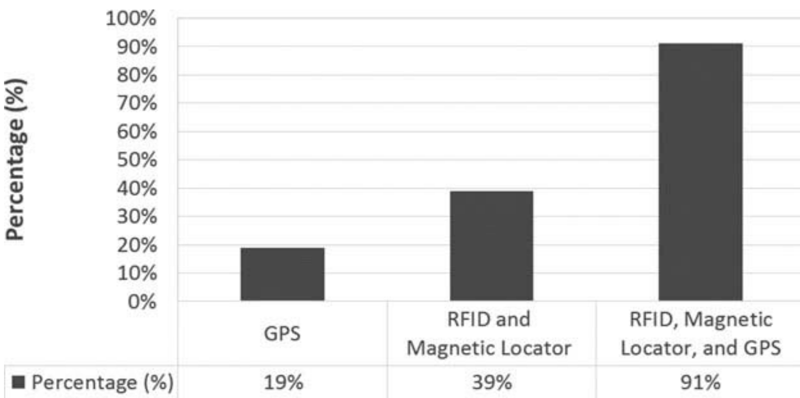

FIGURE 3 Accuracy of the three information technology solutions. GPS = global positioning system; RFI = radio frequency identification.

Participants were divided into groups of two to three and asked to retrieve the buried RFID tags under the different experimental conditions using an RFID reader. Only the effectiveness of the RFID reader in reading these tags was examined, since neither the GPS nor the magnetic locator would be affected by these conditions. As with the first phase, time and accuracy were used as the parameters to measure the performance.

A total of 42 undergraduate students participated in this experiment and were divided into 11 groups to complete the tests. The read reliability percentage of the RFID tags under four different soil conditions (Figure 4), and three different heights (Figure 5) were recorded. The results show that the read percentage for tags buried under 6 inches of soil or sand was 100% and all the groups were able to read the tag information successfully. However, only 89% of the RFID tags buried under 6 inches of moist soil or concrete could be read. When testing reading height level, the results yielded valuable information regarding the ability to read tags from a

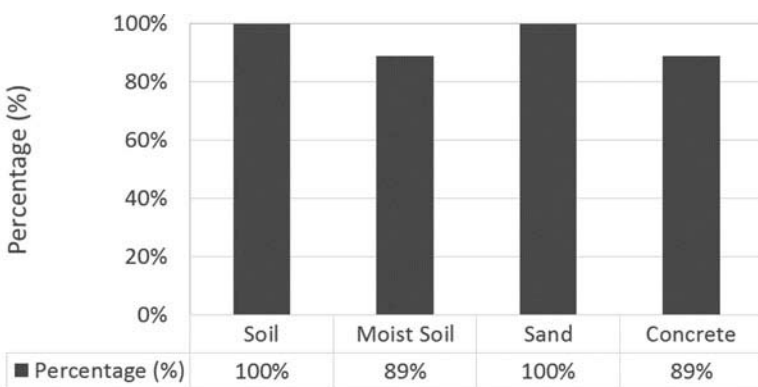

FIGURE 4 Read reliability under different soil conditions.

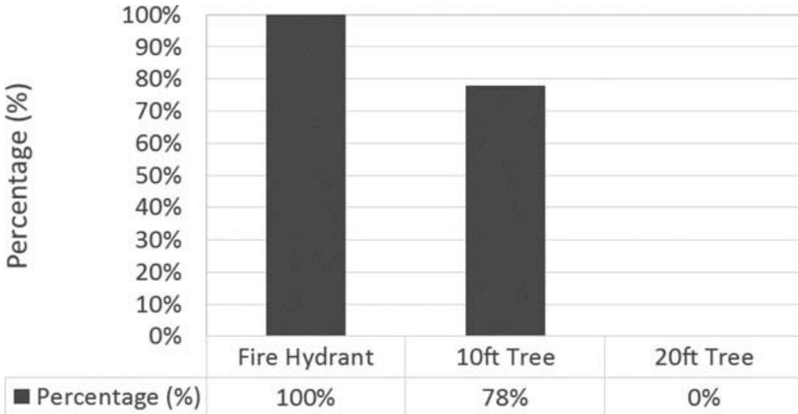

FIGURE 5 Read reliability at different reading heights.

distance. At the fire hydrant level (4 ft high) all of the tags could be read, for a 100% success rate, but this dropped to 78% at a height of 10 ft and none of the RFID tags could be read at a height of 20 ft. These results indicate that RFID tags function fairly reliably in regular conditions, including moist environments and through concrete covers, but can only be read easily at heights below 10 ft.

Phase III: Cost Analysis

The Midwest and East Coast are heavily dependent on the delivery of natural gas, crude oil and refined products that are delivered via major pipelines that come ashore along the Gulf region. Hurricanes Katrina (in August 2005) and Rita (in September 2005) revealed that the simultaneous loss of a handful of pipeline operation support systems in the Gulf completely disrupt the supply of gas, crude oil, and refined products to these regions (Hibbard, 2006). We therefore performed a cost analysis to compare the performance of the best of the IT solutions tested here with the current average performance of utility companies in locating a 10-mile long gas pipeline that had been buried and was not identifiable after a hurricane.

As the results reported above demonstrate, IT solution C (the GPS and RFID combination) provides the best solution for facility retrieval operation and RFID tags are reliable under most conditions. We interviewed two superintendents who work for a southeastern utility company to understand the method they currently use for facility retrieval. The most common approach is to locate utility facilities (e.g. power, water, wastewater, natural gas, and cable television) using Auto CAD map, copper wire, Pipehorn pipe and cable locators, and ground-penetrating radar (GPR). According to the 2013 annual Damage Information Reporting Tool (DIRT) report, the average success of underground facility retrieval is only 80.32% due to the loss of landmarks and the accuracy of the retrieval methods (Common Ground Alliance, 2013). When a gas pipeline is accidentally damaged, this will interrupt excavator operations for approximately for 1.84 hours and the average cost for one hour of downtime is around $500.

Based on this scenario, we compared the cost efficiency (set-up cost and operational costs) for IT solution C and the method currently used to locate and identify this gas pipeline. Labor cost was not included because compared with the set-up and operational costs, the cost of labor is negligible in this scenario. According to the RFID tag placement recommendations developed by 3M (2010), a straight gas pipeline requires one tag for every 328 ft (100 m) to clearly identify its location; extra tags are required at corners when the pipeline bends. This should give workers sufficient information to place flags to warn excavator operators conducting clearance operation in the vicinity of gas stubs (Figure 6). Therefore, for the 10-mile (16-km) long gas pipeline, it was computed that approximately 160 RFID tags would be needed. If the tags were not present, utility workers would have to physically locate the pipe every 328 ft using traditional tools and place flags accordingly.

The set-up cost for the current retrieval methods would be U.S. $0 since the company already has all the necessary equipment and trucks in place. The set-up cost for IT solution C would be U.S. $8,200 since it has to purchase 160 RFID tags (each at $20), a GPS integrated RFID reader, and a magnetic locator.

The operational cost of using the current method to locate the 10-mile long gas pipeline would be approximately U.S. $29,000. This was computed by multiplying the interrupt time (1.84 hours/interrupt) by the number of segments (160) in the 10-mile pipeline, by the average cost for locating each segment ($500), and by the efficiency of the retrieval process (80.32% for the current process). The operational cost would reduce to $13,200 for the IT solution C since the efficiency of the retrieval process will be 91% as per our reliability test (Figure 3). Adding the setup and operational costs (Table 2), the current method will cost $29,000 whereas the IT

FIGURE 6. Map of the model gas pipeline used for the cost comparison.

TABLE 2
Results of the Cost Analysis

Cost Items	*Current Solution (Accuracy Rate: 80.32%)*	*Information Technology (IT) Solution C (Accuracy Rate: 91%)*	*Cost Reduction (%)*
Set-up costs	U.S $0 (no new devices)	Devices U.S $ 5,000 per unit	−100%
	U.S $0 (no new devices)	Radio frequency identification (RFID) tags: 160 x U.S. $20 = U.S. $3,200	−100%
Operational costs	Interrupt time x number of segments x interrupt cost x probability of interruption = 1.84 hr x 160 x U.S, $500 x (1-0.8032) = U.S. $29,000	Interrupt time x number of segments x interrupt cost x probability of interruption = 1.84 x160 x U.S. $500 x (1-0.91) = U.S. $13,200	54.48%
Total cost	U.S. $29,000	U.S. $21,400	26.21%

Note. This comparison between two solutions was based on the one-time retrieval of 10 miles of gas pipeline, categorized into 160 segments.

solution C will cost $21,400 leading to a potential cost reduction of $7,600 (26.2%) for the 10 mile long gas pipeline.

Hibbard (2006) states that at the close of 2004, the natural gas network in the Gulf Region included more than 200 mainline inter- and intra-state systems, totaling almost 300,000 miles of pipeline, with a capacity of approximately 178 billion cubic feet per day (Bcf/d). If we assume that 0.1% of these miles of pipelines might be damaged during a future disaster, the cost savings using the RFID solution (IT solution C) would be $228,000. In addition to the cost savings, such a technology will lead to quicker recovery from the disaster for the community leading to post-crisis renewal and will add to the comfort and well-being of the community members.

IMPLICATIONS

This case study provides the following insights for local governments and communities in the coastal regions, as well as practitioners and researchers in the area of disaster recovery. First, the results of the various analyses carried out for this study highlight an important message: The use of RFID is a practical solution to increase the speed and reliability of disaster response and recovery. It is especially advantageous in reducing the recovery time needed to search for vital facilities, increasing the accuracy of retrieving facilities that are buried by debris and sand, and minimizing the damage caused to utility facilities by excavators during the disaster recovery process. These findings provide convincing evidence that should encourage disaster recover practitioners to invest in RFID technologies to help in post-crisis renewal.

Second, RFID suffers from environmental limits that may hinder the companies' intention to use it. These limitations have also raised concerns among local governments in the nation's coastal regions who are considering adopting RFID-based solutions for disaster recovery. In general, RFID technology is very reliable, but it must be used appropriately. This implies that more extensive reliability tests of RFID technology need to be performed under a wider range of conditions. Our results address some of these issues by demonstrating that the reading of the

RFID tags is quite stable under many of the conditions typically encountered in post-coastal disaster environments. Therefore, this case study should encourage companies to develop appropriate RFID technology for these specific applications.

Finally, cost is another major issue for any adoption decision, including those related to new RFID technologies. The case study examined the cost of RFID installation in the context of the potential reduction in cost of the damage incurred during facility retrieval operations. Although adopting RFID technologies requires set-up costs as shown in Table 2, compared to the current average retrieval performance, the installation of RFID tags on facilities could almost halve the potential operational costs (reducing them by 54.48%) and achieve an overall saving of approximately 26.21% for a 10-mile long gas pipeline. The length of the total utility network in the United States is estimated to be about 11 million miles, nearly three times the reported length of the nation's highways, and potential savings could be substantial (Sterling et al., 2009). Therefore, we suggest that utility companies should seriously consider the use of RFID to improve their disaster recovery capabilities and reduce their total costs. Manufacturers of pipeline and utility facilities might also want to investigate the possibility of incorporating RFID and other sensor technologies in their products to help develop a *smart infrastructure*.

CONCLUSIONS

This case study evaluated the effectiveness of RFID to aid the disaster recovery process in coastal regions using feasibility, reliability and cost analyses. Our results clearly demonstrate the value of combining RFID technologies, magnetic locators, and GPS to facilitate the post-disaster retrieval of buried utility facilities. The estimated 26.21% reduction in the cost of recovering a 10-mile gas pipeline makes a compelling financial case for the use of RFID. Future research needs to incorporate and extend the RFID solutions available for disaster management. Finally, we hope our results will provide useful insights for companies and governments seeking better IT solutions to boost their disaster recovery capabilities.

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Lin Lu is a graduate student in the Department of Aviation and Supply Chain Management at Auburn University. Her research interests include information risk analysis and GIS applications. She earned her B.B.A. in Information Management and Information Systems from Communication University of China and a MMIS from Auburn University.

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APPENDIX: RESEARCH NOTE

In this teaching case, students analyze the case using the conceptual lenses of post-crisis renewal and boundary objects and use multiple criteria to evaluate an information technology use. The first lens, *post-crisis renewal*, considers how a knowledge management system could be built in the face of a devastating loss to provide qualified first responders information on electricity, gas, and water infrastructures (Lally, 2008a). The information on the infrastructure objects discussed in the case study could be stored and made available to first responders using laptops, smart phones, and other digital devices. A potential exists to develop a knowledge management system so that public can enter information about the damaged infrastructure objects with photos thereby enhancing the post-disaster recovery process. Use of RFID technologies by the first responders and utility personnel can lead to quick and accurate retrieval of the infrastructure facilities thereby decreasing the recovery time and reducing the associated costs.

The second lens, *boundary objects*, consider how information about disaster recovery is often shared among multiple agencies (e.g., utilities, cities, emergency management agencies) via IT-based RFID tags (Cumbie & Sankar, 2012). Given this preeminence of IT acting as boundary and boundary-spanning objects, we want to study, as Maldonado, Maitland, and Tapia (2010) do, the links between these objects, their impact on disaster recovery, and the criteria used to choose them. The degree by which the RFID tags become embedded in information infrastructures can shape organizational identity (Gal, Lyytinen, & Yoo, 2008) and impact the effectiveness of recovery from disasters.

As a fundamental platform to all community stakeholders, the infrastructure represents both a physical object and a boundary object. Whereas water or electricity flows through physical infrastructure objects during normal operation, the information about the physical infrastructure (using the RFID tags) is needed to flow and be shared among the community of disaster response and recovery stakeholders. Traditional metrics associated with choosing the technology in disaster recovery (such as profits or asset utilization) may need to be reformulated to address the twin lenses of post-crisis renewal and boundary objects (Lally, 2008a; Cumbie & Sankar, 2012). This case study uses three criteria, feasibility, reliability, and cost to show how the RFID technology can contribute to the efficient retrieval of utility facilities. This case study presents and reinforces how IT is valuable in unusual situations (such as disaster recovery), the difficulties in sharing information about the facilities, need for knowledge management systems on infrastructure facilities, and the criteria to make IT decisions.