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Organizational Information

About International Supply Chain Technology Journal

International Supply Chain Technology (ISCT) Journal is made up of two international, peer-reviewed, journals: a Print journal ***[ISSN:*** 2380-5730***],*** and an Online Journal ***[ISSN:*** 2380-1204***].*** ISCT Journal publishes original, high quality, supply chain technology empirical research that will have a significant impact on SCT Research and Practice. Manuscripts accepted for publication in ISCT must have clear implications for supply chain managers based on one or more of a variety of rigorous research methodologies. ISCT also accepts insightful meta-analyses of the SCM literature, conceptual/theoretical studies with clear implications for practice, comments on past articles, studies concerning the SCM field itself, and other such matters relevant to SCM for publication.

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Regular articles accepted for publication in ISCT must have clear implications for practitioners who manage product and process design, operations, and supply chains based on one or more of a variety of rigorous research methodologies. Manuscripts accepted for publication must meet the following criteria:

1. Research papers in the field of SCM in manufacturing and services.
2. Research rigor applied through the scientific theory-building approach.
3. Technological relevance.
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- Supply Chain Performance measurement and productivity
- Purchasing/sourcing Technology
- Materials and inventory Technology
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• Technology / Supply Chain Consultants
3-day RFIDSCM Workshop & Exam Session
Day-01
• Introduction.
• Overview of RFID Certification Topics & Pre-test Questionnaire Planning Topics.
• Implementation Topics.
Day-02
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• RFID ISCEA Certification Exam
• End of Exam
• Exam Grades & Certifications
• Adjourn/Exam Certification
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The Engineering Economics applied from the Security Perspective in Container Water ports

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ABSTRACT

The security in container ports is affecting the marine transport in close to 35% of the cases of container transportation, from damage, theft, and fraud. Because this sector is affected by security in several ways, this paper will present the economic analysis of the security in ports as sufficient justification to RFID (Radio Frequency Identification) implementation. This paper will attempt to justify against manually tracking and inspection. Furthermore, we will investigate how RFID is more economically viable and it is an accurate way to track the container to prevent and to track violations in security. Consequently, this paper will show a cost analysis to compare the manually tracking with the automatic tracking. A mathematical model will be presented as a result of this cost analysis. For the investment of RFID system this paper will present a ROI (Return of Investment) to find which alternative is better, to stay in status quo or improve the security system using RFID. Because there exist other benefits to implement RFID, it is sufficient to obtain at least equal NPV (Net Present Value) of both alternative, the manually tracking and security, and the automatic security and automatic tracking with RFID.

INTRODUCTION

The Ocean Container Industry (OCI) is certainly the shipping sector with the foremost growth in recent years. As an example, in 2008 the growing was 4.7% in marine transport commerce (Huang, et. al, 2012). Nearly most of the worldwide trade is carried out by marine sector. Hence, the safety of the transported containers is big issue. Many countries perform trade operations through various channels of transport. One of those means of transport is through ports. Ports are land facilities used to transfer goods and commodities between land and water. Some of the major features of ports include connections to land transportation such as highways, railways and pipelines, storage areas for cargos, equipment and people for the purpose of loading and unloading the vessels. Container transportation is mainly used for both national and international trade purposes. There are more than 50,000 merchant ships involved in international trade, which account for about 90 percent of the world's cargo transported by the international shipping industry. Without the shipping containers, the export and import activities necessary for the international community would not be feasible, which means, containers are a vital part of the global economy. Hence, the safety of the transported containers is a big issue.

Some of the challenges in container transport include theft of goods and vehicles, fraud and illegal immigration. Other challenges include the terrorist attack on the containers for the purpose of obtaining the dangerous goods shipments. These activities cause severe problems for the port authorities and will seriously affect the ability of the transport sector who are responsible for ensuring the flow of goods in an efficient manner. The efficient flow of goods should be maintained within the national and also international markets. The containers that are used for transportation in the shipping sector are susceptible for theft, loss of tracking and security issues. It is almost impossible to manually check all the containers that are used in the marine transportation to ensure its safety. So, the ports are using techniques involved in optical character recognition (OCR) have been proposed as a solution. However, this system needs capturing useful images which requires 16 cameras operating simultaneously, and the cost is extremely high. Furthermore, the accuracy of such identification systems ranges between 80 % and 90 %, due to outdoor environmental factors and damage to the codes on the containers, both of which affect the ability of cameras to identify information related to the containers (Huang, et. al. 2012).

Hence, the theory of Radio Frequency Identification (RFID) is widely used in the sector of marine transportation to ensure safety and security of the containers that are being shipped. Radio Frequency Identification is the use of radio waves to transfer data for locating and identifying any particular object. RFID uses tags, readers and antennas for this purpose. The tags contain electronically stored information. This information is read by the reader, which decodes them into useful data. This theory of RFID has been used for a wide variety of applications in recent years. This paper proposed the use of RFID technology in the marine transportation sector to ensure safety and traceability of the shipping containers. Huang, et. al., 2012 describes the use of low cost passive RFID e-seal system in order to improve the security of the transit containers. They also state that the passive RFID e-seal system can withstand harsh outdoor conditions like high temperature, high salinity, humidity and typhoons. RFID can also improve security at the port by identifying the trucks and truck drivers entering the port.

BACKGROUND

The theory of Radio Frequency Identification (RFID) is widely used in the sector of marine transportation to ensure safety and security of the containers that are being shipped. Radio Frequency Identification is the use of radio waves to transfer data for locating and identifying any particular object. RFID systems is comprised of tags, readers, antennas, and a host system for this purpose. The tags are made up of an antenna and an integrated circuit that contains electronically stored information. The tags may be active or passive in nature. The active tags have their own power source. The passive tags do not have their own power source and cannot initiate their interaction with the reader. This information is read by the decoder which decodes them into useful data. The RFID reader reliably reads the tags and communicates the results to the middleware. The benefits of using the RF technology in marine transportation includes reducing the port operation costs, improved flow of goods, getting access to real time information and finally achieving improvement in the overall security of the ports. RFID tags can be coupled with sensors or other hardware to extend the area of application. Middleware can also be used for the application of RFID in data processing. Sensors used in the RFID may be of radiation, gas and chemical sensor. Radiation sensors coupled RFID can be used in improving the security by identifying and preventing the illegal entry of radioactive material into the country. The gas and chemical sensors can also be used in the same method to improve the security by identifying improper substances (Louis, 2007).

HYPOTHESIS

One benefit of implementing RFID is that it can significantly reduce the theft and damage costs in the container ports operation. However, this is not the only benefit of RFID implementation. It can be said that the RFID implementation could be economically viable if the cost to maintain the operation in status quo is the same or more than the RFID cost. In contrast, if the RFID cost is greater than the status quo cost, which is to maintain the security without RFID tracking of containers, we can say that the economic benefit of security is insufficient to justify the RFID implementation into container water port operations. Consequently, the objective of this proposal is to know if the RFID technology can be justified using the security as a sufficient benefit to implement RFID systems into water ports. Thus, the null hypothesis and the alternative hypothesis can be presented as follows:

Ho: Economic benefit for security is sufficient to implement RFID into container water ports.

Hi: Economic benefit for security is insufficient to implement RFID into container water ports.

In other words, from engineering economic values the hypothesis can presented in this way:

Ho: Status Quo NPV >=Water ports with RFID NPV

Hi: Status Quo NPV < Water ports with RFID NPV

MEHTODOLOGY

The Methodology has two parts, the research methodology that we follow to develop this research, and the analysis methodology that presents the mathematical models.

RESEARCH METHODOLOGY

The theory of Six Sigma is used in this paper to analyse the feasibility of implementing the RFID technology for improving the security of the port systems. Six sigma is a set of techniques and tools for process improvement. Six sigma is applied on a manufacturing or business process to improve the quality of the output process by identifying and eliminating the causes of defects and minimizing the variability. A six sigma process is one in which the defects are as low as 3.4 defective opportunities / million opportunities.

DMAIC is the methodology used in the six sigma process which tries to improve the existing process. The steps in DMAIC are Define, Measure, Analyse, Improve and Control. The define step clearly explains the project, scope, goal and other main functions of the project. The measure step is basically a data collection step. The project team brainstorms and collectively measures the data needed for the project. These data are used to determine the gap between the required and current performance. The next step is to analyse and identify the root cause for elimination. It requires to list and prioritize potential causes of the problem. Prioritize the root causes to pursue the improvement step. The improvement step is to identify, to analyse and to implement a viable solution to the root cause problem. The function of this step is to create, focus the simple and viable steps of solution. The Plan, Do, Check and Act cycle is one of the important cycle which is used to implement and maintain a perfect solution for the process. The purpose of this step is to monitor the improvements to ensure continued and sustainable success. Figure 1 shows the three main steps of the research methodology: plan, predict, and perform. In addition, we made a previous comparison about the topic to define the objective and the hypothesis to prove. Then, we find the measures about cost and NPV to analyse, design the models and identify if this analysis could work. After that, we optimize and verify the results to present the conclusions.

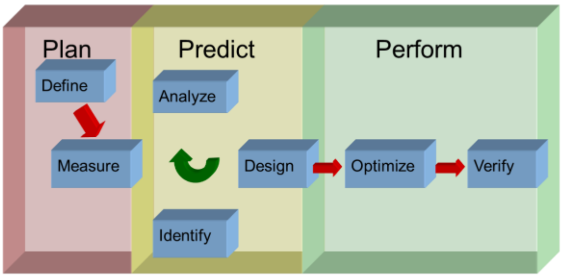

Figure 1. Dr. Erick Jones Six Sigma Research Methodology.

ANALYSIS METHODOLOGY

The implementation of RFID requires a cost analysis and compares the costs before RFID and the costs incurred after the implementation, which is presented in two scenarios. The first scenario is the do-nothing option or the company remains status quo. This scenario describes the baseline costs for the study. The second scenario demonstrates the costs and benefits of implementing the RFID system over a period. The economic analysis such as net present value analysis is performed on the data and the economic benefit of the RFID system to the company is justified. The null hypothesis is taken as “Security economic benefit is sufficient to implement RFID into container water ports” and the alternative hypothesis is taken as “Security economic benefit is insufficient to implement RFID into container water ports”. The analysis of hypothesis is done using a confidence level of α=10%. Therefore, according to the result from the hypothesis testing, either the null hypothesis or the alternate hypothesis is chosen. The analysis will require a mathematical model, so this paper is using the cost analysis, which is presented below.

$$E(Y) = A1B1C1 + A2B3C3 \quad (1)$$

The equation represented is the mathematical model of the theft and damage decision tree worldwide. A1 and A2 represents the containers tracked and non-tracked. B1 and B3 are the container with theft, and B2 and B4 represents the subsequent containers without lost due to theft. C1 through C4 represents the subsequent income involved, and when we multiply that we can calculate which the probability amount of cost of theft and damage. The dependent variable Y represents the total costs of theft and damage. This paper utilizes this mathematical model to solve for the total costs incurred in the operation of a port with all the theft, loss of tracking and errors included. Then the paper tries to find the same costs involved with all the constraints after the RFID technology is implemented. Then the economic analysis such as the net present value analysis is performed on the obtained results to verify whether the security economic benefit is sufficient to implement the RFID into container water ports. The hypothesis analysis is also performed on the obtained data to finally conclude our assumption.

In addition, the NPV equation is this:

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_o \quad (2)$$

Where:

Ct = net cash inflow during the period

Co= initial investment

r = discount rate, and

t = number of time periods

The model will be validated adding the cost of water ports with RFID and the implementation cost to calculate the NPV and comparing this value with the NPV of the status quo. In addition, we will calculate the Return of Investment as double check. For the ROI analysis we will use the following formula:

ROI = (Gain from investment – Cost of investment) / Cost of investment (3)

In this case, we will use the reduction of manual inspection cost as the gain from investment, because this paper is focusing in a reduction of cost and not in how the efficient can impact the operation to increase the incomes about the container movement.

From Huang, et al., 2012, described that the percent of worldwide trade for marine transport is around $620 billion, and 90% is for container transport. In other words, the worldwide trade of container transport is $558 billion in average. In addition, the theft and damage worldwide with indirect losses included is around $200 billion. From this data, it can be said that the cost for theft and damage is 35% of the worldwide trade of container transport. Therefore, Huang, et. al. 2012, said that just 60% of the containers are tracked for the security operation, so 40% of the containers are high susceptible to theft and damage. Thus, the figure 2 present the decision tree analysis.

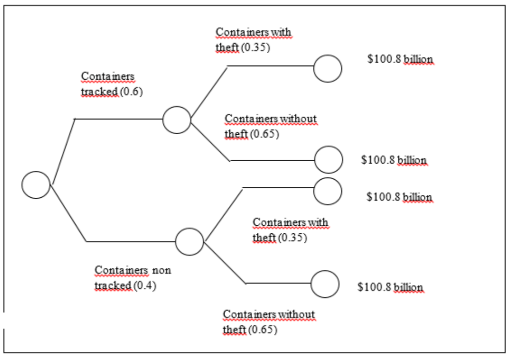

Figure 2. Theft and Damage decision tree in container transport for US ports

This decision tree about theft and damage is using the income of container port in US, which is $3.15 trillion (Jones & Okate, 2015), and using the 25 of the ports which is the 80% of the income (US DOT). Consequently, each port gain in average $100.8 billion, which is the number of the end of the decision tree.

ANALYSIS

COST ANALYSIS

In the cost analysis the calculation used the formula (1) and multiply in this way:

E(Y) = (0.6) (0.35)(100.8billion) + (0.4)(0.35)(100.8billion) = 35.28 billion.

This cost represents the cost in theft and damage. From Huang et. al., 2012, the RFID implementation is 75% in tracking the containers than the manual system. Consequently, the cost of thefts and damage when RFID is implemented should be 1-0.75 in probability multiplying by $35.28 billion, which is $8.28 billion.

NET PRESENT VALUE(NPV)

From the Net Present Value analysis, we will use the 2% rate which is the inflation rate presented by Jones & Okate, 2015 to analyze the investment and the cost to implement RFID in a water ports against the status quo.

From Jones & Okate, 2015, they show that an implementation in time 0 should be around $261,000 and the maintenance cost should be around $29,000. In addition, we will use a cash flow of 5 years to test the hypothesis. If the security cost is sufficient to justify an RFID implementation in terms of probability of theft and damage because absent of traceability. The cash flow diagram bellow illustrates the cost and return of the system without RFID implementation, which is around $68.5

billion.

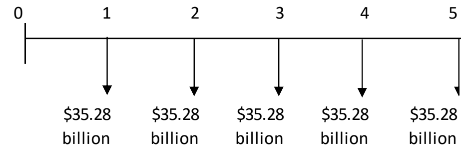

Figure 3. Cash Flow of a system without RFID implementation.

NPV (2%) = $0 + $35.28billion (P/A, 2%, 5)

NPV (2%) = $68.5 billion

The following cash flow bellow represent the RFID implementation and cost based in the efficiency in RFID tracking and maintenance cost.

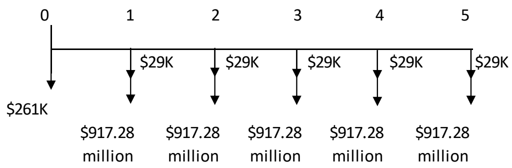

Figure 4. Cash Flow of a system with RFID implementation.

NPV (2%) = $261K + $8.28 billion (P/A, 2%, 5) + $29K (P/A, 2%, 5)

NPV (2%) = $17.1 billion

From the calculation above, the NPV of the status quo is far greater than the NPV of the RFID implementation.

RETURN ON INVESTMENT(ROI)

In the ROI analysis we will use the NPV of the cost to maintain the status quo as the gain of investment, because we are not considering the efficiency, we are just considering the cost of security. In addition, the NPV of the investment we are considering as the cost of investment. Using the formula (3) of the ROI we compute the following ROI:

ROI = ($68.5 billion – $17.1 billion)/ $17.1 billion

ROI = 300%

Thus, the ROI shows that the investment is far viable, because the return of investment is 300 percent in 5 years.

RESULTS

The probability of the mean cost of theft and damage in one port of US in average is $35.28 billion without RFID implementation and $8.28 billion with RFID implementation. This is using the 40% relationship of containers without tracking, and the 35% of theft and damage in containers because the absent of tracking. However, this result can be affected if the theft and damage impact was low.

The NPV for the status quo was $68.5 billion vs $17.1 billion of the RFID implementation using 2% MARR (minimum rate of return), and 5 years to analysis.

The ROI was 300%, so the cost of investment is far low than the gain.

CONCLUSION

We fail to reject Ho, and we can conclude that the RFID implementation can be justify using the security alone to present a strong argument.

This conclusion is based in the cost analysis with relationship of 75% efficient in reduction of actual cost, the NPV of the implementation is far low than the status quo, and the ROI is 300%.

FURTHER RESEARCH

As a further research we need more information to verify those percent about the efficiency in RFID implementation and the percent of cost by theft and damage to be more accurate in our analysis. Furthermore, another research can contemplate more in deep the details about the cost of manual security.

ACKNOWLEDGEMENTS

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Saving the world with a gardening tool

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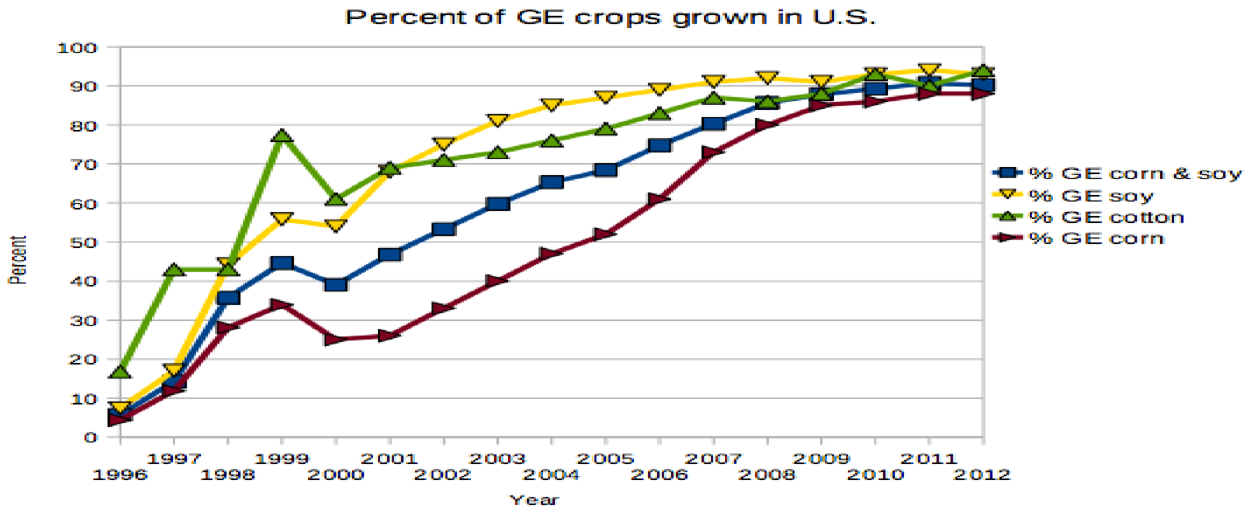
1. Introduction

Appreciating life is not as simple as it once was. An apple a day will no longer keep the doctor away because that very apple may have endured a scientific procedure known as genetic engineering. According to the Associated Press (AP) "[there is] a clear link between the use of pesticides sold by Monsanto and a growth in health problems in Argentina." During Dr. Damian Vernassi interview with the Associated Press, he underlined the potential health risks that are linked with genetically modified organisms. Dr. Vernassi who is a member of the Faculty of Medicine at the University of Rosario identified that. "glyphosate, a synthetic compound, which is marketed as a safe herbicide by manufacturers, actually poses serious health hazards confirmed by both laboratory and epidemiological studies." Some of the effects include endocrine disruption, DNA damage, cancer, birth defects and neurological disorders (Openearthsource). Not only is the chemical's residue found on GM (genetically modified) crops, it has also been detected in the air, rain and groundwater, the true toxicity of glyphosate—the active ingredient in Monsanto's broad-spectrum herbicide Roundup—is the leading reason behind a groundbreaking approach to research and discovery. If urban communities are allowed the opportunity to learn about the harms of the food industry, then they will avoid the detrimental side effects caused by genetically modified organisms and participate in the newfound culture of urban farming. In order to completely shield Americans from the troubles of a genetically altered organism, it is necessary that they are presented with the simplicity of organic gardening in urban scenery. The harms caused by GM (genetically modified) crops and the international approaches used to limit their exposure will be underlined. As well as an urban approach to farming, that if established could improve the lives of the 79% of Americans (KFF) that live in urban communities.

Genetically modified organisms have been an ongoing discussion in the international society since the 1990's when the regulatory framework was crafted in the European Union that created obligatory labeling for everything genetically modified organisms. Rendering to the World Health Organization: "Genetically modified organisms (GMOs) can be described as organisms in which the genetic material (DNA) has been altered in a way that does not take place naturally." The technology is often called "modern biotechnology" or "gene technology", sometimes also "recombinant DNA technology" or "genetic engineering".



1999 data: USDA Agricultural Economic Report No. (AER-810) 67 pp, May 2002
2012 data: USDA:NASS National Agricultural Statistics Service

Figure 1. *Percent of GE Crops Grown in U.S.* The World Health Organization stated that. “Biotechnology allows selected individual genes to be transferred from one organism into another, also between non-related species". Labeling in the EU is mandatory for products derived from modern biotechnology or products containing GM organisms (WHO). The legislation also addresses the problem of accidental contamination of conventional food by GM material.

In 2001, the European Commission adopted two new legislative proposals on GMOs concerning traceability, reinforcing current labeling rules and streamlining the authorization procedure for GMOs in food and feed and for their deliberate release into the environment. Genetically modified foods leave a crippling effect on the world's soil. Currently, the United States is undergoing a similar process regarding GMO labeling but unlike the European Union, GMO’s is deeply rooted in American society. The release of GMOs into the environment and the marketing of GM foods have resulted in a public debate in many parts of the world. Many

fear the loss of the organic seeds and feel that in time the use and distribution of genetically modified crops will be the faith of the world.

Activist groups like the “Non-GMO project” are fighting for the purity of our food sources. They are concerned about the undesirable level of control of the seed markets by chemical companies like the world-leading producer of GM Crops, Monsanto.

Sustainability groups that focus on the agriculture and biodiversity benefit of seeds depend solely on the use of valuable crops, both in terms of good crop protection practices as well as from the perspective of society at large and the values attached to food. Interest groups like “Organic Consumers Group” fear that as a result of the interest in the chemical industry has in seed markets, the range of varieties used by farmers may be reduced mainly to GM crops. This would

impact the world’s food supply as well as the long run of crop protection. For example, with the development of resistance against insects and the grown tolerance to certain herbicides the exclusive use of herbicide-tolerant GM crops would make the farmer dependent on these chemicals. Thus, leaving the ancient practices of farming in the hands of Monsanto. These groups fear a dominant position of the chemical industry in agricultural development, a trend that is far from sustainable.

In an article written by Bryan of Colorado State University he underlined how 60-70 percent of the food available to American consumers have at least one genetically modified organism encrypted in its ingredients. Which is an unsympathetic reality because of the health risks associated with genetically modified organisms. Genetically modified organisms have shown in lab studies their contribution to tumors, liver failure, cancer, obesity and diabetes. The use of genetically modified organism in time will destroy the earth ability to produce organic foods and human's ability to live. (WHO) Research done on genetically modified organisms has showed that in time, humans will build resistance to antibiotics and new allergies will surface- due to genetically modified organism's ability to alter genes. It so rich in science, yet lacking in nutrition. (SEEDS)

The only way to truly escape the harms placed on society by bio-engineered crops is to eat organic, local or learn how to plant your own fruits and vegetables. Urban farming is a futuristic approach to the benefit of safe and healthy eating. Eating fast-food is an easy way to drown under the tides of genetically engineered ingredients. However, gardening is a natural approach that is not only affordable but it also carries the same beneficial factors as buying organics. In some communities, gardening is seemed unrealistic. Yet, that is when the use of community gardens in an urban setting can shelter the needs of a community and bring forth the idea of sustainable living to an entire area.

Farmer and author Michael Ableman once lived on a commune in California during his teenage years. From there, he learned about the importance of farming. Ableman co-founded an urban farm in the heart of Vancouver. He also founded California's Center for Urban Agriculture; he composed three best-selling books and created the Centre for Arts, Ecology and Agriculture, which he runs from his home in Vancouver. Saltspring Island's Foxglove farm is the farm Ableman and is family spends the majority of their time at. (Vancouver, B.C) in an article written by the Vancouver Sun, he emphasized the importance of organic farming and its beneficial effects on society. Ableman used his hands on attitude in creating a 120-acre organic farm that he runs with his wife where they educate the community on sustainable forestry, agriculture and culinary arts. Ableman created an environment where members of his community can participate in organic farming. He not only created an opportunity for people to better their nutritional intake of fruits and vegetables. But he also made way for once convicted felons who do not seem suitable for a job to earn an income. Not only does Ableman contribute to Vancouver but he also conducts an organic 10-acre farm in California. Ableman's organic farm in California follows the same practices of his Foxglove farm except it includes the help of California high school students that live in housing projects across the troubling neighbourhood of Los Angles.

Urban farming is a widespread approach to sustainability in cities across the world. It offers multiple benefits: Food security, an easy admission that in turn lessens costs and produce that is delivered at its freshest state. Not only do urban farms contribute to the environment but it also enhances to the greenery of a city, operating as drainage basins and reducing harmful run-off. It increases shade, and also acting as a buffer against climate change as they reduce the bearing of the heat. According to the International Federation of Organic Agriculture Movement, organic agriculture is a "production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects." (KARACHI)

The World Health Organization (WHO) would like to recommend eliminating trans fat from the global food supply. Even though many countries have already successfully eliminated the fats from their food-supply. There are still the low- and middle-income countries we must look at such as India as this country faces additional challenges on the removal process from their food supply collected at the manufacturer, retailer and consumer levels. The researchers did qualitative interviews where they had conducted with the manufacturers (n = 13) and local food vendors (n = 44). The final results were that the fat content of sampled oils from street vendors contained high levels of saturated fat (24.7-69.3 % of total fat) and trans fat (0.1-29.9 % of total fat). Households in India were consuming snacks high in trans fat as part of daily diets (31 % village and 84.3 % of slum households) and 4 % of rural and 13 % of urban households which exceeded WHO recommendations for trans fat intakes (Downs SM *et. al* 2015.)

Another study demonstrated concerns about food security and its effect on persistent undernutrition that has increased interest in how agriculture could be used to improve nutritional outcomes in developing countries. This study was conducted from the months April to August of 2012. It also involved developing a conceptual framework linking agriculture and nutrition, identifying relevant research projects and programs, devising and populating a "template" with details of the research projects in relation to the conceptual framework, and so much more. (Turner R *et. al* 2013)

Finally, microbial hazards are associated with certain environmental matrices, livelihood strategies, and food handling practices. All of these are constrained by time-consuming conventional microbiological techniques. Which can eventually lead up to health risk assessments of narrow geographic or time scope. The health risk usually only targets very few pathogens. Health risk assessment are also based on one or few indicator organisms with true disease burden due a number of coexisting causative pathogens. Researchers estimated annual gastroenteritis burden of the individual pathogens from sampling points that were -10.6log(10) to -2.2log(10) DALYs. The aggregated annual gastroenteritis burden due all the target pathogens per sampling point was -3.1log(10) to -1.9log(10) DALYs. These results had exceeded WHO acceptable limit of -6.0log(10) DALYs. This current approach will facilitate the comprehensive collection of surface water microbiological baseline data. This approach will also aimed to reducing microbial hazards in similar landscapes worldwide (Tserendorj A *et. al* 2011).

2. Discussion

By introducing the use of urban farming to the citizens of America its beneficiary outcomes will change the lives of the 79 percent of Americans who live in urban surroundings. Which will lead to a healthier America that is also educated in sustainable practices. It is in the best interest of all to know the foods that are severed everywhere are being processed. The companies are not concerned they are looking at the end goal which is filling up their bank account. There should be further investigations on the genetically modified products.

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New approach for minimizing human errors in hospital operating rooms by using RFID lerting systems

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Abstract: Patient safety is an increasing concern in health care due to the fact the increasing number of medical errors. Most fatal medical errors happen in hospital operating rooms. This research proposes a unique approach that decreases medical errors in hospital operating rooms using an RFID-based technology to alert doctors and nurses when the wrong tool enters to the operating area, via text message. This research focuses on healthcare

systems, specifically operation rooms at the hospitals and provides an approach to increase the reliability of patients by using an RFID alerting system. By applying Design For Six Sigma (DFSSR) methodology this research proposes a unique approach that decreases medical errors in hospital operating rooms using an RFID-based technology to alert doctors and nurses when the wrong tool enters to the operating area.

1. Introduction

According to institute of medicine (Kohn L. T., 2000) statistics about 44,000 to 98,000 people lost their lives from medical errors each year in United States. These medical errors charge United States to spend up to 17 to 29 billion dollars. Each year the number of deaths caused by medical errors makes it fall among the top ten reasons of death, which is higher than traffic accident, Human immunodeficiency virus (HIV), breast cancer or traffic accidents. Among all of these medical errors, surgery errors after drug related errors, is one of the most common errors that causes deaths. By enhancing the operating room (OR) environment through improved management, employee communication, medical process check and data transmission can raise the patient care (Po-Jen Chen, 2009).

This research proposes a new approach to decrease medical errors in order to prevent mistakes and build a reliable environment for patients in hospital operating rooms. The innovation of this research is using automatic technology that could directly communicate with the charge nurse who is responsible for all equipment that is needed for surgery to alert him/her about the wrong tools that enter the operating room. Design For Six Sigma Research (DFSS-R) methodology is used for this research. This paper follows the given format: Section 1 presents the introduction, Section 2 provides background and literature review with respect to the research, Section 3 presents the approach and data collection technique, Section 4 presents data and results concerning the functionality of the approach and Section 5 discusses the conclusions.

The research question for this study is: Can text messaging be automated for hospital operations reliably and effectively? The overall objective of this research is: Can Radio Frequency Identification (RFID) and alerting technologies reduce the amount of fatal errors in the operating room? The goal is to evaluate a methodology that measures parameters, which determine reliability and effectiveness of automated texting technologies.

2. Background

2.1 RFID and Patient Safety in Healthcare

This subsection develops background literature of using RFID in hospitals and also describes some existing alert systems that inform doctors and nurses in critical situations.

The first step in literature review is to look for pros and cons of implementing RFID-based technology in hospitals. Chiara Borea, Giovanni Miragliotta, Pala, Perego and Tumino (2011) propose a generic model that intends to increase the overall information regarding the possible profits that RFID technologies produce if implemented in a healthcare setting. Then they deliver managers working in healthcare services with effective equipment for the analysis and evaluation of investments in RFID technologies.

While most of the existing studies focus on demonstrating how RFID can benefit the healthcare industry, S. L. Ting, S. K. Kwok, Albert, Tsang and Lee (2009) focus on management problems associated with building an RFID scheme in medical associations. They propose 11-step development methodology for adopting an RFID system in a medical association, which are: information gathering, hardware selection, new system introduction, system design, system demo testing, security and permission setup, implementation, document policies and procedure setting, staff training, system monitoring and finally celebration.

After implementing RFID-based technology in hospitals, it is necessary to employ a reliable alert system both for equipment and patients. Min Chen, Sergio Gonzalez, Leung, Zhang and Li (2010) propose a second-generation RFID-Sys-based e-healthcare system that could alert the hospital in critical situations about the patient physiological signals. In this system the medical situations of a patient can be checked as recognized by the corresponding healthcare system, and afterward updated in the database by a Wi-Fi connection, a cellular phone, or something alike depending on the patient's position.

While the previous example was about alerting hospital for critical situation of patient, Paul Nagy, Ivan George, Bernstein, Caban (2006) propose an RFID-based system that more focuses on assets and equipment in hospitals. They develop five categories of equipment that should be tagged in operating rooms. They also classify patient safety concerns in the preoperative settings into three parts, which are: right patient wrong treatment, right patient no treatment and unknown patient undetermined resource. In first classification they point to the system that could look for dangerous co-location problems and make appropriate alerts.

Since our research is based on RFID technology we focused more on researches that employed RFID but there are some other alerting systems that are not based on RFID, for example David Alan Heck, Kathryn Rapala and Canada (2006) invented an alerting system for hospitals in order to enhance the patients' safety. This patent includes an output device, which incudes a computer monitor and bunch of indicators. This patent acts more like an active checklist that could partially avoid human errors.

One of the practical studies that considers most aspects of implementing RFID-based technology in operating rooms is proposed by Po-Jen Chen, Yung-Fu Chai and Huang (2009). This system will scan its environment to identify if any non-allowed staffs have entered or if any prohibited medical supplies and drugs have been located in the OR. This system has five steps to be completed and two steps plays a key role regarding to the alerting systems, which are step three and four. Step three: in this step, as soon as the patient arrives at the operating room the system will detect the patient and at the specific amount of time if the surgeon has not yet arrived the OR, the system will notice him/her by sending a text message to his/her cellular phone. Step four: The anesthesiologists have to confirm whether the surgical agreement has been signed before anesthesia. If the surgeons have not yet arrived into the operating room, a text message will be sent to notify that the anesthesia has been completed.

While most studies focus on one type of RFID technology either passive or active, Michael Kranzfelder, Dorit Zywitza, Jell and Schneider (2012) propose a model that applied both technologies. They employed passive tags to track surgical sponges and active tags to monitor surgeons. Their main objective was to develop a model to avoid retaining surgical sponges inside of the patients' body. There is an alerting interface that monitors the passive tags and shows the number of missing sponges.

2.2 Texting in Healthcare Environment

The next subject that needs to be described in the background review is about using cellphones in operating rooms by doctors. Many people think that doctors do not use their cellphones during the operation or even in a hospital environment but a questionnaire based survey of doctors from all specialties (A G Kidd, 2004) shows that 66% of doctors admitted to using it in the hospital and 64% admitted to leaving their cellphones on in 'high risk' areas such as operating rooms.

One other research about using text message in healthcare system evaluates the effect of a short messaging system for following up between surgeons and patients after surgery. This study considers the following factors for the research: telephone calls, number of clinic visits and days to surgical drain removal. Retrospective review identified 102 procedure-matched patients who underwent breast reconstruction for an oncologic diagnosis. They compare two groups of patient with the same conditions as follow: age group, gender, procedure, weight and complication of the procedure. Results show that clinic follow up for the clinic that used texting was one third less than the other clinic. The perspective of this study was not on cost analysis but it is necessary to mention that clinic follow up visits patients are free for three month. The clinic visits were limited to wound issues or complications, which was 20% for both groups (Rao R, 2012).

In another study researchers implemented a system to improve completing the clinical documentation and evaluate the results over time. They used custom software to constantly look for missing clinical documentation during anesthesia. They used patient allergies as a test case, regarding to a distinctive requirement in their system that allergies must be manually input into the electronic record. If no allergy data was input within 15 min of the "start of anesthesia care" event, a one-time prompt was sent via text to the individual, who is performing the anesthetic. Results indicate that before activating the alert system, the fraction of charts without an allergy comment was slightly more than 30%. This reduced to about 8% after beginning the alerts, and was significantly changed from baseline within 5 days (Warren S. Sandberg, 2008).

The last but not the least literature review about using text messages in healthcare systems is a research that proposed a methodology to measure the distance of the anesthesiologists' home from the hospital via sending a text message. Two unannounced simulated emergency recall maneuvers were conducted, with text messages sent requesting for the estimated time to return to the hospital. Replies to the simulated emergency alert were received from about 50% of staff, with 16 projecting that they would have been able to return to the hospital within 30 minutes on both dates. Of the non-responders to the alert, 48% declared that their cellphone was turned off or not with them, while 22% missed the message (Richard H. Epstein, 2010).

2.3 Previous Relevant Funded Researches

A research that is provided by Agency for Healthcare Research and Quality (1 U18 HS015846) develops, implements and evaluates a widespread team communication systems resulting in a toolkit that can be generalized to other settings of care. Regarding to the literature review of this study, analysis of 421 communication events in the operating room indicate communication failures in about 30 percent of team interactions; one-third of these risked patient safety by increasing pressure, disturbing routine, and increasing cognitive load in the OR setting (Catherine Dingley, 2008).

In another research that is funded by AHRQ (1 U18 HS016680) authors highly emphasize on the critical role of the team communication in operating room. Today, team communications in the OR are considered more by disruptive manners than by the smooth delivery of care. The noticeable differences in the background of the several disciplines lead to misinterpretations and misunderstandings. The consequence of the lack of role clarity and poor communication can prevent having effective teamwork (John T. Paige, 2008).

Another related research that is funded by U.S. Army Medical Research & Materiel Command (under contract DAMD-17-3-2-001) discusses the four pillars of a smart and safe operating room. One of these pillars are the informatics section, they believe that a manager of a well-run operating room should know the presence of physicians, nurses, anesthetists, patients and major pieces of equipment. Redundancy, communication problems, Inefficiency, system failures and usage problems are among the concerns driving annual healthcare expenses to over a half-trillion dollars, or equivalent of 30 to 40 cents of each healthcare dollar. (F. Jacob Seagull, 2008).

3. Methodology

The proposed methodology and approach to minimize human errors in hospital operating rooms includes a framework that can be used by hospital managers, which would allow them to alert doctors when they are using a wrong tool. In this research we used DFSS-R methodology to minimize errors. Erick Jones has developed DFSS-R methodology (Erick C. Jones V. V., 2007).

We use a population of UTA students to test existing equipment of traditional fixed and handheld readers with existing software located in the Radio Frequency and Auto Identificaiton (RAID) Labs to collect data. The equipment that is used for this experiment are ATID Handheld RFID Reader, ALIEN RFID Reader, Motorola Andrew RFID-900-SC Antenna and Mannequins and Beds.

After an interview with one of the surgeons of University of Texas Southwestern about the average number of tools that are using in operating room for each operation, he declares that for 2 hours operations they use approximately 25 to 30 instruments. Regarding to this interview, 30 items are tagged plus 3 extra tools, in other words 30 items are placed on the table that are supposed to be on the table which are necessary for the operation but 3 extra tools are also placed on the table, which are the wrong tools that experimenters should recognize and write the tag IDs down.

Different tag brands are used for this experiment because in the real world equipment is not tagged with the same tag brands. Different objects with different shapes and materials are used to make the environment more similar to the actual operating room. Multiple data analysis tools such as ANOVA, F-Test, Tukey's Multiple Comparison Procedure, Modified-Levene test and Residual analysis are used for this research.

3.1 Specific Aims

3.1.1 Specific Aim #1

The first Specific Aim for this research is to evaluate the reliability and effectiveness of manual texting in hospital operations. 33 items are tagged and placed on a table, 24 identifiers with a list of equipment that is supposed to be on the table are asked to manually check all of the equipment via a handheld RFID reader and also check if there is any wrong tool on the table. If they detect any wrong tool they write it down and then send a text message containing the extra tag IDs to another experimenter who is playing the role of charge nurse and alert him/her about the wrong tool.

It is assumed that in different times there are different numbers of human error, so the experiment is run in different time slots, which are: time slot A form 8am to 10am, time slot B form 10am to 12pm, time slot C form 1pm to 3pm, time slot D form 3pm to 5pm.

In order to avoid correlation, each identifier runs the experiment just once. The start time is the time that the experimenter begins the experiment, which is reading the tags with the handheld and the end time is the time that the text message is delivered to the person who is playing the role of the charge nurse.

Figure 3.7: An experimenter is reading the tags by RFID handheld

The expected outcomes for this aim were to simulate performance of operating room personnel who were using texting as a means to track and identify inventory. We hypothesize there would be a large amount of human error based on the operating time periods.

3.1.2 Specific Aim #2

The second Specific Aim is to evaluate the performance of the automated texting with RFID based technology. 33 items are tagged and placed on a table. Then, this table is placed between portal antennas and the RFID reader starts reading the tags and if it detects any wrong tool, it highlights it on a computer and the operator gets alerted about the wrong tool and texts the charge nurse. Because we do not have a reader that can generate a text message we have to make some assumptions to complete the experiment. Since the existing equipment cannot generate text messages, we assume that the RFID reader sends all of the text messages that it is supposed to send.

This experiment is run for six times in 4 different time slots. We assumed that after long hours of working, electrical devices make errors, so we turned on the RFID reader for time slot A and we do not turn it off until the end of the time slot D.

The expected outcomes were to benchmark the performance of simulated enhanced RFID system with texting capabilities. We hypothesize that this system can be described that can incorporate the texting and RFID into a system that can automate alerts.

3.1.3 Specific Aim #3

The third Specific Aim is to evaluate the manual texting versus auto texting technology. To address this aim, all of the data that is gathered in previous aims are going to be compared. This aim is also has two parts, the first part is to compare the means of errors between two systems and the second part is to compare the time that it takes for each experiment to be completed for each system.

The expected outcomes were to identify key differences between the manual texting process and the simulated automated texting system with RFID tagged inventory. We hypothesize though texting is a semi-automated process the automated system would perform better based on time of day.

3.2 Hypothesis Tests

We chose $P - Value = 0.1$ for all hypothesis for two main reasons, first of all: knowing an error could cause a huge disaster in hospital operations, it is not realistic to choose an α more that 0.1 and secondly: in order to get some significance levels for results for this research we did not select the small α.

3.2.1 Hypothesis for Specific Aim #1

3.2.1.1 Hypothesis Test for the Number of Errors in Manual System

We hypothesized that there is a significant difference between the means of human error for each time slot. We reject the null hypothesis if the mean number of errors for all time slots is equal.

$$H_0: \mu_{ME1} = \mu_{ME2} = \mu_{ME3} = \mu_{ME4} \ , \quad H_a: not\ all\ \mu_{MEi}\ are\ equal$$

3.2.1.2 Hypothesis Test for the Times of Completion in Manual System

We hypothesized that there is a significant difference between the means of mean times of completion for each time slot. We reject the null hypothesis if the mean times of completion for all time slots are equal.

$$H_0: \mu_{MS1} = \mu_{MS2} = \mu_{MS3} = \mu_{MS4} \ , \quad H_a: not\ all\ \mu_{MSi}\ are\ equal$$

3.2.2 Hypothesis for Specific Aim #2

3.2.2.1 Hypothesis Test for the Number of Errors in Auto System

We hypothesized that there is a significant difference between the means of the auto system error for each time slot. We reject the null hypothesis if the mean numbers of errors for all time slots are equal.

$$H_0: \mu_{AE1} = \mu_{AE2} = \mu_{AE3} = \mu_{AE4} \ , \quad H_a: not\ all\ \mu_{AEi}\ are\ equal$$

3.2.2.2 Hypothesis Test for the Times of Completion in Auto System

We hypothesized that there is a significant difference between the mean times of completion for each time slot. We reject the null hypothesis if the mean times of completion for all time slots are equal.

$$H_0: \mu_{AS1} = \mu_{AS2} = \mu_{AS3} = \mu_{AS4} \ , \quad H_a: not\ all\ \mu_{ASi}\ are\ equal$$

3.2.3 Hypothesis for Specific Aim #3

3.2.3.1 Hypothesis Test for the Number of Errors in Manual and Auto System

We hypothesized that there is a significant difference between the means of errors from manual texting and auto-texting. We reject the null hypothesis if the mean number of errors for manual and automatic system are equal.

$$H_0: \mu_{ME} = \mu_{AE} \ , \quad H_a: not\ all\ \mu\ are\ equal$$

3.2.3.2 Hypothesis Test for the Times of Completion in Manual and Auto System

We hypothesized that there is a significant difference between the mean times of completion for each system. We reject the null hypothesis if the mean times of completion for both systems are equal.

$H_0: \mu_{AS} = \mu_{MS}$, $H_a: not\ all\ \mu\ are\ equal$

4. RESULTS

The result chapter follows the same steps from the approach section of the methodology chapter and the results for each step are shown in the same order. This chapter includes raw data that is gained by the experiments, analysis of the raw data and the results of the hypothesis tests. All statistical calculations are calculated by SAS software.

4.1. Results for Specific Aim #1

4.1.1 Number of Errors for Manual System

The results of human errors are shown in table 4.1. Each cell of this table represents the number of errors of each individual experimenter.

Table 4.1 24 Observations from 24 different identifiers

Time Slots	Observations					
A	3	1	2	1	2	1
B	2	1	1	2	1	1
C	0	0	0	1	1	0
D	1	0	1	1	1	3

4.1.1.1. ANOVA Table and F-Test

The ANOVA table for the errors of manual system is calculated by SAS and shown in Table 4.2. The P-Value that is calculated in this table is much smaller than the p-value that is considered for the F-Test. Because The P-Value is smaller than 0.1, we reject the null hypothesis.

Table 4.2: ANOVA table for number of errors in manual texting system

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	5.79	1.93	3.56	0.0325
Error	20	10.83	0.54		
Corrected Total	23	16.625			

4.1.1.4. Tukey's Test

The results of Tukey's test are shown in table 4.3. Tukey's is a comparison test to recognize if there is any difference between the means of each category for a specified significant level. Comparisons significant at the 0.1 levels are indicated by *. This test controls the Type I experiment wise error rate.

Table 4.3 Tukey's Test for the number of errors for manual system

Minimum Significant Difference	1.0401			
Category Comparison	Difference Between Means	Simultaneous 90% Confidence Limits		
1-2	0.3333	-0.7067	1.3734	
1-4	0.5000	-0.5401	1.5401	
1-3	1.3333	0.2933	2.3734	*
2-1	-0.3333	-1.3734	0.7067	
2-4	0.1667	-0.8734	1.2067	
2-3	1.0000	-0.0401	2.0401	
4-1	-0.5000	-1.5401	0.5401	
4-2	-0.1667	-1.2067	0.8734	
4-3	0.8333	-0.2067	1.8734	
3-1	-1.3333	-2.3734	-0.2933	*
3-2	-1.0000	-2.0401	0.0401	
3-4	-0.8333	-1.8734	0.2067	

From the analysis of this table, it can be inferred that the minimum significance difference for these categories is 1.0401; if a difference between the means of each category fall beyond this number, it shows that two categories have significant difference between their means. Table 4.2 shows that at 0.1 significant level, category 1 and category 3 have significant a difference between their means.

4.1.1.5. Residual Plot

The other important plot that should be considered is the residual plot to be sure that we have a constant variance for the data. The residual plot for the number of errors in the manual system is shown in figure 4.3.

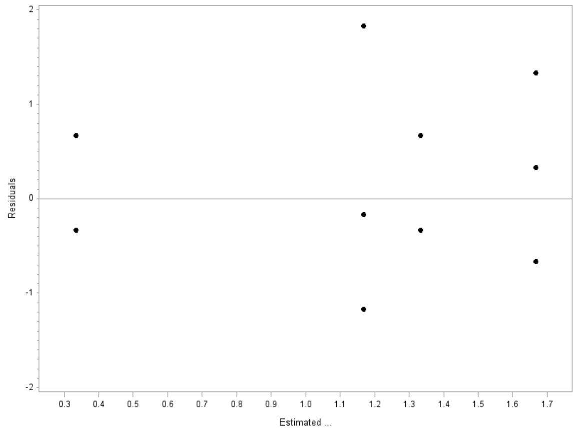

Figure 4.3 Residual Plot for the number of errors in manual system

As it appears in figure 4.3, there is no funnel shape for the data and there is no curvature to be considered, therefore by the analysis of this plot it could be inferred that constant variance is satisfied and no need for transformation.

4.1.2. Times of Completion For Manual System

The time that it takes for each observation to be completed is measured and includes reading time, checking the tags and sending an appropriate message. Table 4.4 shows these times in the minute unit.

Table 4.4: Time that it takes for each observation for manual system to be completed (minutes)

Row	Categories	Observations (Minutes)					
1	Time Slot A	8	22	18	22	13	18
2	Time Slot B	18	21	10	27	11	17
3	Time Slot C	21	14	26	25	30	22
4	Time Slot D	17	13	17	8	18	13

4.1.2.1. ANOVA Table and F-Test

The ANOVA table for the mean times of completion for the manual system is shown in Table 4.5. The P-Value that is calculated in this table is much smaller than the p-value that is considered for F-Test. Because the P-Value is smaller than 0.1, we reject the null hypothesis

Table 4.5: ANOVA table for the mean times of completion for manual texting system

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	868050	289350	2.82	0.065
Error	20	2050200	102510		
Corrected Total	23	2918250			

4.1.2.4. Tukey's Test

The results of Tukey's test are shown in table 4.6. It can be inferred that the minimum significance difference for these categories is 452.46. Table 4.6 shows that at a 0.1 significant level, category 1 and category 3 have a significant difference between their means.

Table 4.6: Tukey's Test for the mean times of completion for manual texting system

Minimum Significant Difference		452.46		
Category Comparison	Difference Between Means	Simultaneous 90% Confidence Limits		
1-2	340.0	-112.5	792.5	
1-4	370.0	-82.5	822.5	
1-3	520.0	67.5	972.5	*
2-1	-340.0	-792.5	112.5	
2-4	30.0	-422.5	482.5	
2-3	180.0	-272.5	632.5	
4-1	-370.0	-822.5	82.5	
4-2	-30.0	-482.5	422.5	
4-3	150.0	-302.5	602.5	
3-1	-520.0	-972.5	-67.5	*
3-2	-180.0	-632.5	272.5	
3-4	-150.0	-602.5	302.5	

4.1.2.5. Residual Plot

As it appears in figure 4.7 there is no funnel shape for the data and also there is no curvature to be considered, therefore by the analysis of this plot, it could be inferred that constant variance is satisfied and no need for transformation.

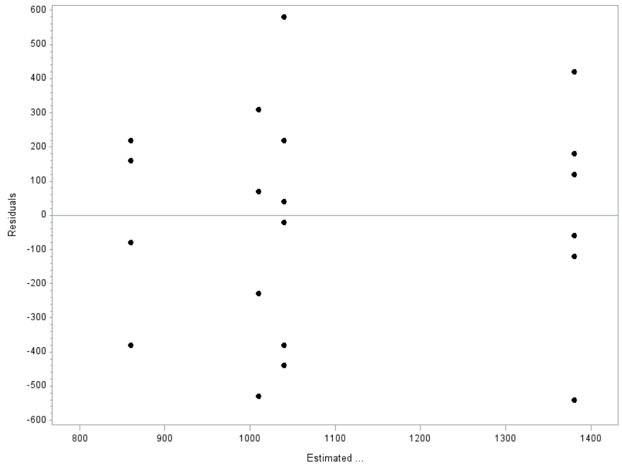

Figure 4.7: Residual Plot for the mean times of completion for manual texting system

4.2. Results for Specific Aim #2

4.2.1 Number of Errors for Auto System

The results of 24 observations from auto texting are shown in table 4.3. The errors of each time slot are shown in each individual cell.

Table 4.7: Number of errors for auto system in each time slot

Row	Categories	Observations					
1	Time Slot A	1	0	0	1	1	0
2	Time Slot B	0	0	0	1	0	1
3	Time Slot C	0	0	0	1	0	0
4	Time Slot D	1	0	0	1	1	2

4.2.1.1. ANOVA Table and F-Test:

The ANOVA table for the errors of the auto system is shown in Table 4.8. because the P-Value is greater than 0.1, we fail to reject the null hypothesis and we conclude H_0.

Table 4.8: ANOVA table for the number of error in auto texting system

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1.458	0.486	1.5	0.2461
Error	20	6.5	0.325		
Corrected Total	23	7.958			

4.2.1.4. Tukey's Test

The results of Tukey's test are shown in table 4.9. From the analysis of this table, it can be inferred that the minimum significance difference for these categories is 0.8056. Table 4.9 shows that at a 0.1 significant level, there is no category that have a major difference in means.

Table 4.9: Tukey's Test for the number of errors for auto texting system

Minimum Significant Difference		0.8056	
Category Comparison	Difference Between Means	Simultaneous 90% Confidence Limits	
4-1	0.3333	-0.4723	1.1390
4-2	0.5000	-0.3056	1.3056
4-3	0.6667	-0.1390	1.4723
1-4	-0.3333	-1.1390	0.4723
1-2	0.1667	-0.6390	0.9723
1-3	0.3333	-0.4723	1.1390
2-4	-0.5000	-1.3056	0.3056
2-1	-0.1667	-0.9723	0.6390
2-3	0.1667	-0.6390	0.9723
3-4	-0.6667	-1.4723	0.1390
3-1	-0.3333	-1.1390	0.4723
3-2	-0.1667	-0.9723	0.6390

4.2.1.5. Residual Plot

As it appears in figure 4.11, there is no funnel shape for the data and also there is no curvature to be considered, therefore by the analysis of this plot, it could be inferred that constant variance is satisfied and no need for transformation.

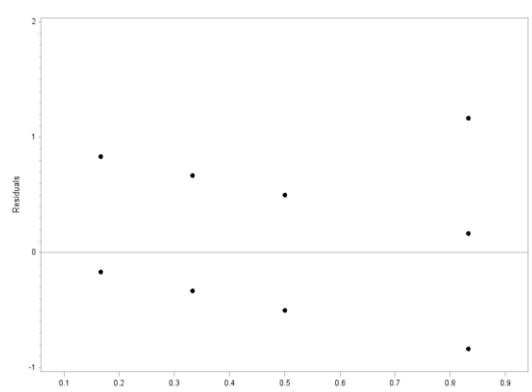

Figure 4.11: Dot Plot for the number of errors in auto texting system

4.2.2. Times of Completion For Auto System

The time that it takes for each observation to be completed by the auto-texting system is measured and includes reading time, checking the tags and sending an appropriate message. Table 4.10 shows these times in second unit.

Table 4.10: Time that it takes for each observation for auto-system to be completed (second)

Row	Categories	Observations (Seconds)					
1	Time Slot A	36	38	29	30	32	28
2	Time Slot B	37	27	28	31	32	27
3	Time Slot C	33	36	35	37	33	28
4	Time Slot D	28	30	34	38	32	27

4.2.2.1. ANOVA Table and F-Test:

The ANOVA table for the mean times of completion for auto system is shown in Table 4.11. Because The P-Value is greater than 0.1, we fail to reject the null hypothesis and we conclude H_0.

Table 4.11: ANOVA table for the mean times of completion for the manual texting system

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	34.833	11.6111	0.8	0.5094
Error	20	291	14.55		
Corrected Total	23	325.833			

4.2.2.4.Tukey's Test

The results of Tukey's test are shown in table 4.12. From the analysis of this table, it can be inferred that the minimum significance difference for these categories is 5.3905. Table 4.12 shows that at 0.1 significant level, there is no category that has a major difference in means.

Table 4.12: Tukey's Test for the mean times of completion for auto texting system

Minimum Significant Difference	5.3905

Category Comparison	Difference Between Means	Simultaneous 90% Confidence Limits	
3-1	1.500	-3.890	6.890
3-4	2.167	-3.224	7.557
3-2	3.333	-2.057	8.724
1-3	-1.500	-6.890	3.890
1-4	0.667	-4.724	6.057
1-2	1.833	-3.557	7.224
4-3	-2.167	-7.557	3.224
4-1	-0.667	-6.057	4.724
4-2	1.167	-4.224	6.557
2-3	-3.333	-8.724	2.057
2-1	-1.833	-7.224	3.557
2-4	-1.167	-6.557	4.224

4.2.2.5. Residual Plot

As it appears in figure 4.15, there is no funnel shape for the data and also there is no curvature can be considered, therefore by the analysis of this plot, it could be inferred that constant variance is satisfied and no need for transformation.

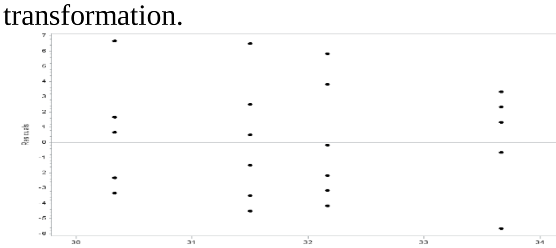

Figure 4.15: Residual Plot for the mean times of completion for auto texting system

4.3 Results for Specific Aim #3

4.3.1 Number of Errors for Manual and Auto System

The data for this aim is exactly the same as the one that is collected for previous aims. It is combined in a single table in order to analyze together and compare two technologies, which are manual texting and auto-texting.

4.3.1.1. ANOVA Table and F-Test:

The ANOVA table for Errors of Manual and Auto system is shown in Table 4.14. Because the P-Value is less than 0.1, we reject the null hypothesis.

Table 4.14: ANOVA table for Errors of Manual and Auto system

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	12.583	1.797	4.15	0.0016
Error	40	17.333	0.433		
Corrected Total	47	29.917			

4.3.1.4. Tukey's Test

The results of Tukey's test are shown in table 4.15. From the analysis of this table, it can be inferred that the minimum significance difference for these categories is 1.1014. Table 4.15 shows that at 0.1 significant level, there are multiple categories that have a major difference between their means. The majority of these differences are between two systems, which are manual and auto texting. From these results it can be inferred that there is a significant difference between the means of errors in the manual and auto systems.

Table 4.15: Tukey's Test for the number of errors of manual and auto system

Minimum Significant Difference		1.1014		
Category Comparison	Difference Between Means	Simultaneous 90% Confidence Limits		
1-5	1.1667	0.0652	2.2681	*
1-3	1.3333	0.2319	2.4348	*
1-6	1.3333	0.2319	2.4348	*
1-7	1.5	0.3986	2.6014	*
2-7	1.1667	0.0652	2.2681	*
5-1	-1.1667	-2.2681	-0.0652	*
3-1	-1.3333	-2.4348	-0.2319	*
6-1	-1.3333	-2.4348	-0.2319	*
7-1	-1.5	-2.6014	-0.3986	*
7-2	-1.1667	-2.2681	-0.0652	*

4.3.1.5. Residual Plot

According to figure 4.19, it seems that we have a funnel shape for the residual plot, in order to test the constant variance we use Modified-Levene test and the results are shown in table 4.16

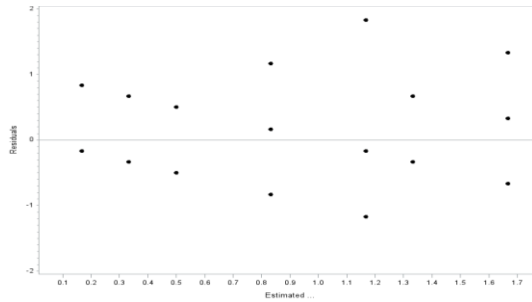

Figure 4.19: Residual Plot for the mean times of completion for manual and auto texting system

4.3.1.6. Modified-Levene test

Modified-Levene test is used to check whether the variances of the samples increase or decrease. For conducting the "Modified-Levene" test, we should first divide the data in to groups of same population. In this research, the data are divided in two groups of 24, which are manual versus auto. The results are shown in table 4.16. Since $\alpha = 0.1$ and the p-value is 0.4771, which is greater than α Hence, it can be concluded that we are in an equal variance situation and should use equal variance t-test. The computed P-value for T-test is presented in Table 4.16, in which for equal t-test is p=0.6442. Since we fail to reject H_0. It means that we can say that our constant variance assumption is not violated.

Table 4.16: F-Test and T-Test for Modified-Levene test for the number of errors of manual and auto system

Method	Num DF	Den DF	F Value	Pr > F
Folded F	23	23	1.35	0.4771

group	N	Mean	Std Dev	Std Err	Min	Max
1	24	0.5784	0.5678	0.1159	0.0734	2.2202
2	24	0.5073	0.4887	0.0997	0.0734	2.0734
Diff (1-2)		0.0711	0.5297	0.1529		

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	46	0.46	0.6442
Satterthwaite	Unequal	45	0.46	0.6442

As it appears in figure 4.19, there is no curvature and also regarding to the Modified-Levene test constant variance is satisfied therefore it could be inferred that constant variance is satisfied and no need for transformation.

4.3.2. Times of Completion for Manual and Auto System

The time that it takes for each experiment to be completed for both manual and auto-texting is combined in a single and unified by converting all units to seconds.

4.3.2.1. ANOVA Table and F-Test:

The ANOVA table for the mean times of completion for the manual and auto systems is shown in Table 4.18. Because the P-Value is less than 0.1, we reject the null hypothesis, and the explanation of this hypothesis will be explained in hypothesis section.

Table 4.18: ANOVA table for the mean times of completion for manual and auto system

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	13861848.92	1980264.13	38.63	<.0001
Error	40	2050491	51262.28		
Corrected Total	47	15912339.92			

4.3.2.4. Tukey's Test

The results of Tukey's test are shown in table 4.19. From the analysis of this table, it can be inferred that the minimum significance difference for these categories is 378.84. Table 4.19 shows that at 0.1 significant level, there are multiple categories that have a major difference between their means. The majority of these differences are between two systems, which are manual and auto texting. From these results it can be inferred that there is a significant difference between the means of errors in the manual and auto systems.

Table 4.19: Tukey's Test for the mean times of completion of manual and auto system

Minimum Significant Difference				378.84
Category Comparison	Difference Between Means	Simultaneous 90% Confidence Limits		
3-4	520	141.2	898.8	*
3-7	1346.3	967.5	1725.2	*
3-5	1347.8	969	1726.7	*
3-8	1348.5	969.7	1727.3	*
3-6	1349.7	970.8	1728.5	*
2-7	1006.3	627.5	1385.2	*
2-5	1007.8	629	1386.7	*
2-8	1008.5	629.7	1387.3	*
2-6	1009.7	630.8	1388.5	*
1-7	976.3	597.5	1355.2	*
1-5	977.8	599	1356.7	*
1-8	978.5	599.7	1357.3	*
1-6	979.7	600.8	1358.5	*
4-3	-520	-898.8	-141.2	*
4-7	826.3	447.5	1205.2	*
4-5	827.8	449	1206.7	*
4-8	828.5	449.7	1207.3	*
4-6	829.7	450.8	1208.5	*

4.3.2.5. Residual Plot

According to figure 4.20, It seems that we have non-constant variance, in order to test the constant variance we use Modified-Levene test and the results are shown in table 4.20

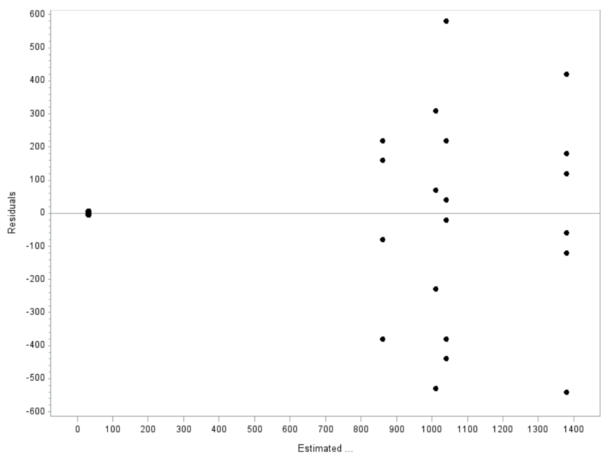

Figure 4.23: Residual Plot for the mean times of completion of manual and auto system

4.3.2.6. Modified-Levene test

The results are shown in table 4.20. Since $\alpha = 0.1$ and the p-value is less than 0.0001, which is obviously less than α Hence, it can be concluded that we are in an unequal variance situation and should use unequal variance t-test. The computed P-value for T-test is presented in Table 4.20, in which for unequal t-test is p=0.0251. Since we reject H_0. It means that we can say that our constant variance assumption is violated.

Table 4.20: F-Test and T-Test for Modified-Levene test for the mean times of completions for manual and auto system

Method	Num DF	Den DF	F Value	Pr > F
Folded F	23	23	6.08	<.0001

Group	N	Mean	Std Dev	Std Err	Min	Max
1	24	327.1	248.9	50.7994	29.25	869.3
2	24	200.2	100.9	20.604	95.25	304.8
Diff (1-2)		127	189.9	54.8188		

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	46	2.32	0.0251
Satterthwaite	Unequal	30.368	2.32	0.0275

4.4 Hypothesis results

Based on the results of each Specific Aim, hypothesis tests now have all the requirements to be tested. The explanation for each individual aim is provided in the following.

4.4.1. Specific Aim #1

4.4.1.1. Hypothesis Result for the Number of Errors in Manual System

We reject the null hypothesis because the P-Value that is calculated is 0.0325 in table 4.2 is less than the P-Value that is considered for this study, which is 0.1. Results show that not all means of errors are equal in each time slot.

4.1.1.2 Hypothesis Result for the Times of Completion in Manual System

We reject the null hypothesis because the P-Value that is calculated 0.065 in table 4.5 is less than the P-Value that is considered for this study, which is 0.1. Results show that not all of means of times to complete the experiments are equal in each time slot.

4.4.2. Specific Aim #2

4.4.2.1. Hypothesis Result for the Number of

Errors in Auto System

We fail to reject the null hypothesis because the P-Value that is calculated 0.2461 in table 4.8 is greater than the P-Value that is considered for this study, which is 0.1. Results show that the means of errors have no difference in each time slot for the auto system.

4.4.2.2. Hypothesis Result for the Times of Completion in Auto System

We fail to reject the null hypothesis because the P-Value that is calculated in table 4.11 0.5094 is greater than the P-Value that is considered for this study, which is 0.1. Results show that the means of times to complete each experiment have no difference in each time slot for the auto system.

4.4.3 Specific Aim #3

4.4.3.1. Hypothesis Result for the Number of Errors in Manual and Auto System

We reject the null hypothesis because the P-Value that is calculated is 0.0016 in table 4.14 and is less than the P-Value that is considered for this study, which is 0.1. It can be concluded that not all of means of errors are equal in each category. By analyzing the results from Tukey's test, we conclude that except for one category, all other categories that have a different mean for errors are dedicated to different systems, therefore it can be concluded that auto-texting using RFID technology can reduce human errors for hospital operations.

4.4.3.2. Hypothesis Result for the Times of Completion in Manual and Auto System

We reject the null hypothesis because we have very small P-Value in table 4.17, which is less than 0.0001, and it is obviously smaller than the P-Value that is considered for this study, which is 0.1.

It can be concluded that not all of the means of times that it takes for the experiments to be completed are equal in each category. By analyzing the results from Tukey's test, we conclude that except for one category, all other categories that have a different means for completion are dedicated to different systems, therefore it can be concluded that auto-texting improves the process of texting in hospital operations effectively.

CONCLUSIONS

Patient safety is a growing anxiety in health care due to the fact there is an increasing number of medical errors. This research proposes a unique approach that decreases medical errors in hospital operating rooms using an RFID-based technology to alert doctors and nurses when the wrong tool enters to the operating area, via text message. The goal is to develop a methodology that measures parameters, which determine reliability and effectiveness of automated texting technologies. Results show that the reliability and effectiveness of auto-texting is higher than manual texting for hospital operations.

5.1 Limitations

Although the research has reached its aims, there were some limitations for this research. First of all, the reader that was used for auto texting is not equipped with software that could generate a text message; therefore it is assumed that the reader sends text messages by 100 percent accuracy. In this research, we tried to simulate the actual environment, but it was not completely the same setting. Accordingly, the other limitation was running the experiment with actual tools and an operating room environment.

5.2 Contribution to the body of knowledge

There is a very limited research on the impact of texting in comparison to other automation technologies. People are looking at texting as a social means but not necessarily a means for efficiency. We are contributing as an alternate inventory control process. We are enhancing RFID automation with texting and our contribution is modernizing RFID by combining it with additional technology, which is text messaging.

5.3 Future Work

The work performed in this research provides basis for future research in several areas. One of the important areas for future work is to employ a method other than text messaging to alert nurses because this method highly depends on the service provider. In some situations, because of the high network traffic, the text message will not deliver and it could cause a problem. One solution for this problem is to design an application for smart phones to notify the nurses by a push notification center that is designed for these devices. This method works as long as the user accesses to the Internet.

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PWD Groups has been around since 2000 providing service in logistics consulting, system integration, and real estate sales and financing. We specialize in providing the right personnel for the customers need. We expect that the customer experience will be a good one and they will come back to us for other products and services.

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