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Technology Assessment for Nosocomial Infection Solutions

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Abstract

This study presents a technology assessment for reducing Nosocomial infections. Nosocomial infections (also known as hospital-acquired infection or HAI) present numerous problems for healthcare institutions including increased costs, increased use of hazardous cleaners, and patient reluctance towards treatment. Our goal is to incorporate more than the traditional economic point of view in evaluating alternatives for reducing infections. The Analytical Hierarchy Process is used to assess the feasibility of candidate technologies. Traditional criteria such as infection reduction and cost are used in addition compatibility with existing procedures and staff acceptance were used for evaluating technologies. Infection reduction and staff acceptance were determined to be the most important criterion through expert interviews. The analysis established that utilizing RFID for hand washing compliance was the superior technology given its superior reduction in HAI’s and good staff & patent acceptance.

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Abstract

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Introduction

The increase in nosocomial infections has drawn tremendous attention in the healthcare industry and from the public. The industry is concerned with the growing problem of multidrug resistant strains. Healthcare administrators are looking for ways to reduce nosocomial infection rates & costs while not contributing to increases in multidrug resistant strains. Any technology solution has to meet stringent regulations, with respect to quality and effectiveness in controlling nosocomial infections. It has to be cost effective but to be integrated into the existing system it must be easy to use and compatible with existing processes. The authors of this paper believe that the increasing trend in hospital-associated infections has provided the impetus to examine technology solutions for the problem.

This paper latches onto the momentum described above and hopes to further explore the assessment of four technology solutions towards infection rates in the United States, both in terms of capabilities as well as impediments to implementation. The Analytical Hierarchy Process (AHP) is used to evaluate a number of candidate technologies. Interviews with infection control professionals were used to validate the proposed methodology and establish the relative importance of the selection criteria.

Study Methodology

The reminder of this paper proceeds to establish the problem and evaluate alternative technological solutions.

A literature review examines the current problem of HAI's, existing solutions, methods for technology acquisition and assessment (TAA) in healthcare and the application of multi-criteria models to healthcare. The analysis of the literatures identifying key areas that play an important role in reducing hospital acquired infections.

The problem of HAI's was considered in detail and a gap analysis was used to evaluate the problem from multiple perspectives. From the gap analysis and previous health care studies an AHP model was developed. Selection of a technology for reducing hospital infections is a complex problem while making qualitative and quantitative decisions; we used a hierarchical decision model (HDM) to aid hospitals in determining the right technology to meet their objective. HDM is a tool to present a large decision problem as a hierarchy of smaller and less complex decisions (B. Wang, Kocaoglu, Daim, & Yang, 2010).

A list of proposed technologies applicable to solving the problem was developed through scanning the literature.

The model and solution set were validated with selected experts and an interview script was developed to interview experts in hospital infection control. Expert pairwise comparisons were used to compare criteria and sub-criteria two at a time in order to determine their value relative to each other.

The experts input were used to evaluate the relative importance of the model criteria and the solutions.

Using the AHP model the selected technologies were evaluated and the results analyzed.

Literature Review

To understand the problem of HAI's we examined the existing literature. We investigated the current problem of infections and current solutions. We reviewed methods for healthcare TAA, AHP and the use of AHP multi-criteria models in healthcare.

Hospital Infections

The Center for Disease Control (CDC) estimates that roughly 1.7 million hospital-associated infections, from all types of bacteria combined, contribute to 99,000 deaths each year (Pollack, 2010). The increase of antibiotic resistant bacteria is a worrisome trend, with few options to control the growth of these bacterial strains. The cost increase attributable to managing an episode of *Multidrug Resistant Staphylococcus Aureus (*MRSA) compared with managing non-resistant strain ranges between $2,500 and $17,422 (Brown, 2011). Litigation costs are also skyrocketing. Medicare announced that it will no longer pay for treatment of nosocomial infections effective October 2008, thereby making hospitals fiscally responsible for reducing the occurrence rate of these infections. Also there is an increasing awareness of the bacteria problem among consumers. Hospitals and other healthcare providers could gain a differential advantage by more effectively addressing this problem.

The US Department of Health and Human Services estimates the national health expenditures in the US to increase at an annual average growth rate of 6.3 percent between 2009 and 2019 (National Health Statistics Group, 2011). With an average cost per infection of $15,275, (Cosgrove & Carmeli, 2003) hospitals feel the incentive to put preventative controls in place.

Infection Prevention

Hospitals currently utilize a wide range of treatments and preventative measures to counter nosocomial infections. For certain procedures, prophylactic antibiotic treatment is used. This a preventative measure to prevent bacterial growth during or after the procedure. However, the overuse of prophylactic antibiotics can lead to the creation of drug-resistant organisms (McMillan, 2001). Patients are also given antibiotics post-treatment if signs of infection occur. This approach can also contribute to the creation of drug-resistant organisms.

Healthcare Technology Assessment and Acquisition

Much of the previous work in TAA in healthcare (Health Technology Assessment (HTA)) has focused on regulatory compliance and evaluating technologies using single criteria economic analysis of alternatives or expected mortality rate (P. K. Dey, Hariharan, & Clegg, 2006). In our study we wanted to consider a larger set of criteria so we have used an AHP model.

Analytical Hierarchy Process

AHP was developed to consider a devise set of criteria for selecting the best of a set of alternatives. It's been widely used in many areas. An overview can be found in (T.L. Saaty, 1977; Thomas Lorie Saaty, 1996). In a survey of TAA methodologies (Tran & Daim, 2008) it was one of the primary methods used for evaluating alternatives. As an example in (Daim, Yates, Peng, & Jimenez, 2009) it was applied to technology choices in the energy sector to select the best candidate fusing multidimensional criteria. A variant of AHP is HDM – very similar but uses a pair-wise raying scheme (Kocaoglu, 1983).

Analytical Hierarchy Process in Healthcare

AHP has been used in healthcare, although not for technology assessment. Liberatore and Nydick (Liberatore & Nydick, 2008) reviewed the use of AHP in the health field – finding many examples. Since 1988 the number of papers published has been increasing to about three per year. In their article they reviewed over 50 papers using AHP in the health field. They show examples for both patient care decisions (best type of treatment, diagnostic decisions) and for hospital management decisions (project evaluation, operational assessment). In an interesting series of papers by Dey (P. K. Dey, et al., 2006; P.K. Dey, Hariharan, & Despic, 2008; P.K. Dey, Hariharan, Kumar, & Moseley, 2004) it was used to develop a multifactor set of criteria to rate intensive care units. In an area related to technology assessment it has been used to evaluate alternative medical equipment selection. In (Abaza & Tawfik, 2008) AHP was used to select the most appropriate diagnostic equipment for the types of procedures the hospital performed and in (Sloane, Liberatore, Nydick, Luo, & Chung, 2003) it was used to evaluate alternative neonatal ventilators.

It was used in (Brent, Rogers, Ramabitsa-Siimane, & Rohwer, 2007) to select the most suitable medical waste disposal method for hospitals in developing countries. Meetings were held in multiple locations to brainstorm on the criteria and interactively determine the weighting criteria. Then the groups jointly evaluated the selected technologies. Although surveying the experts individually reduces the biases effect of influential contributors the joint development of the decision model improves buy-in to the solution selected.

Although there are papers on evaluating the best medical device to purchase or for assisting in defining what product development projects to pursue (J. Hummel, Wvan, Verkerke, & Rakhorst, 2000; J. M. Hummel, 2001) we did not find any prior uses of AHP for technology acquisition and assessment.

Problem

Gap Analysis

A gap analysis was conducted, arranging the problem into the following categories: Technical, Organizational, and Personal. Solution needs were first established through literary review. Once compiled, the needs were verified through expert interviews. With the needs established, additional research was conducted to match existing capabilities to the need. The capabilities were then evaluated to determine gaps in the current solutions. For example, the need to reduce infection rates has been stated by several sources (McMillan, 2001). The same sources listed prophylactic antiobiotic treatment as the primary existing solution. This information was then verified with several interviewed experts. Finally, the gap of increased drug resistance was given by both literature and expert sources.

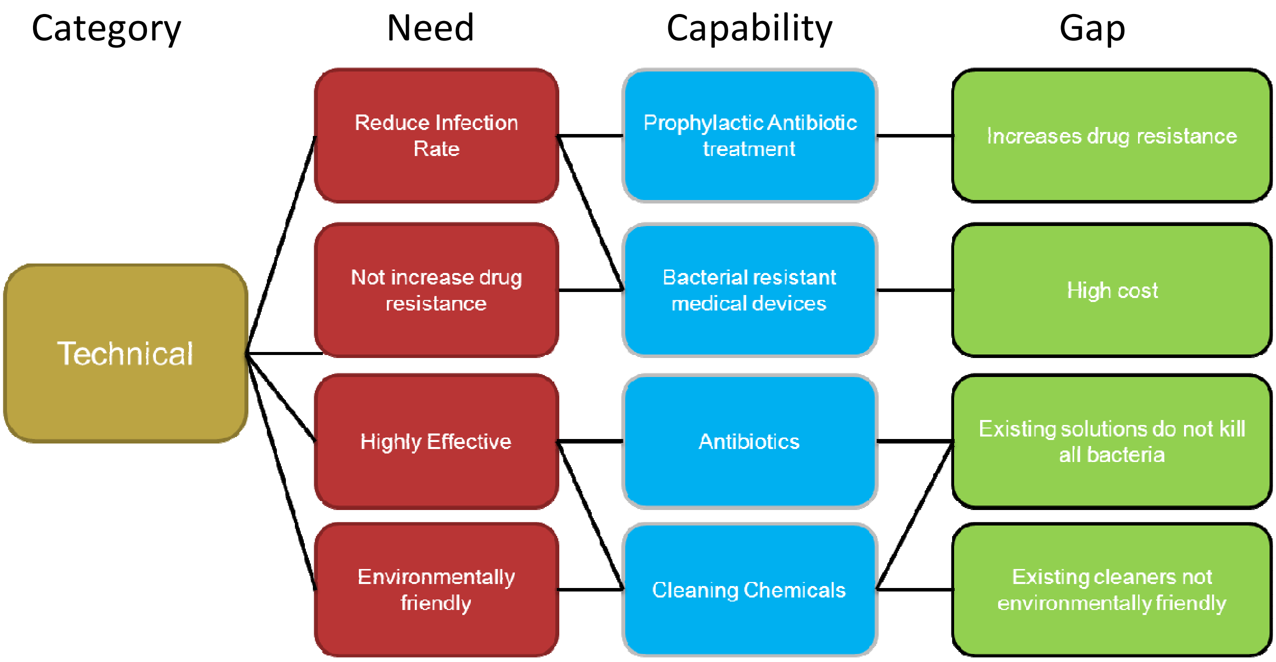

Figure I: Gap Analysis (Technical)

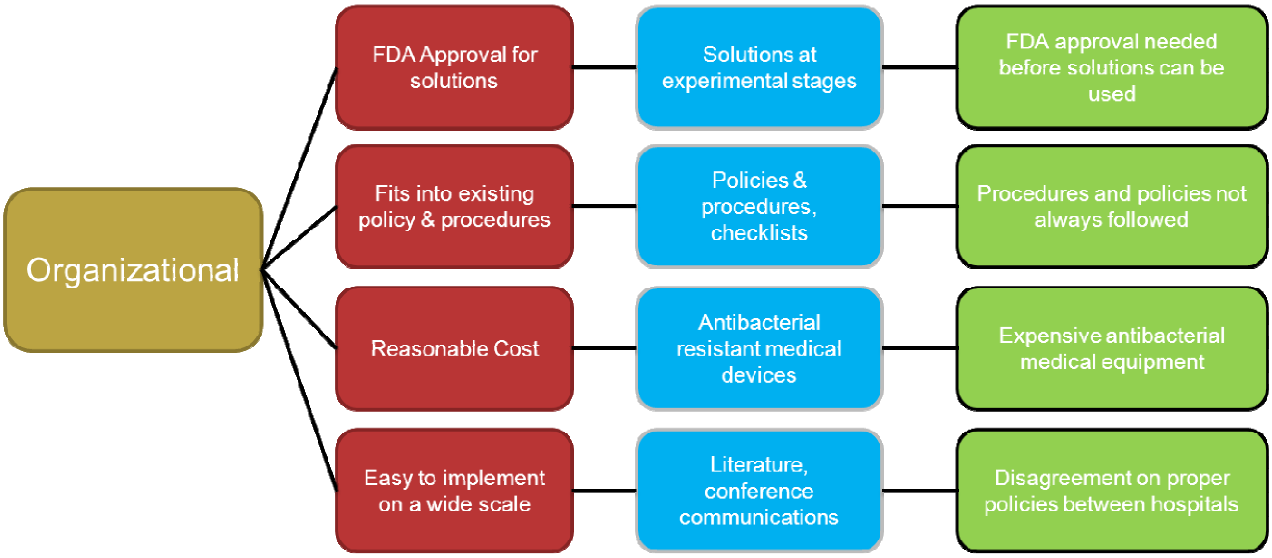

Figure II: Gap Analysis (Organizational)

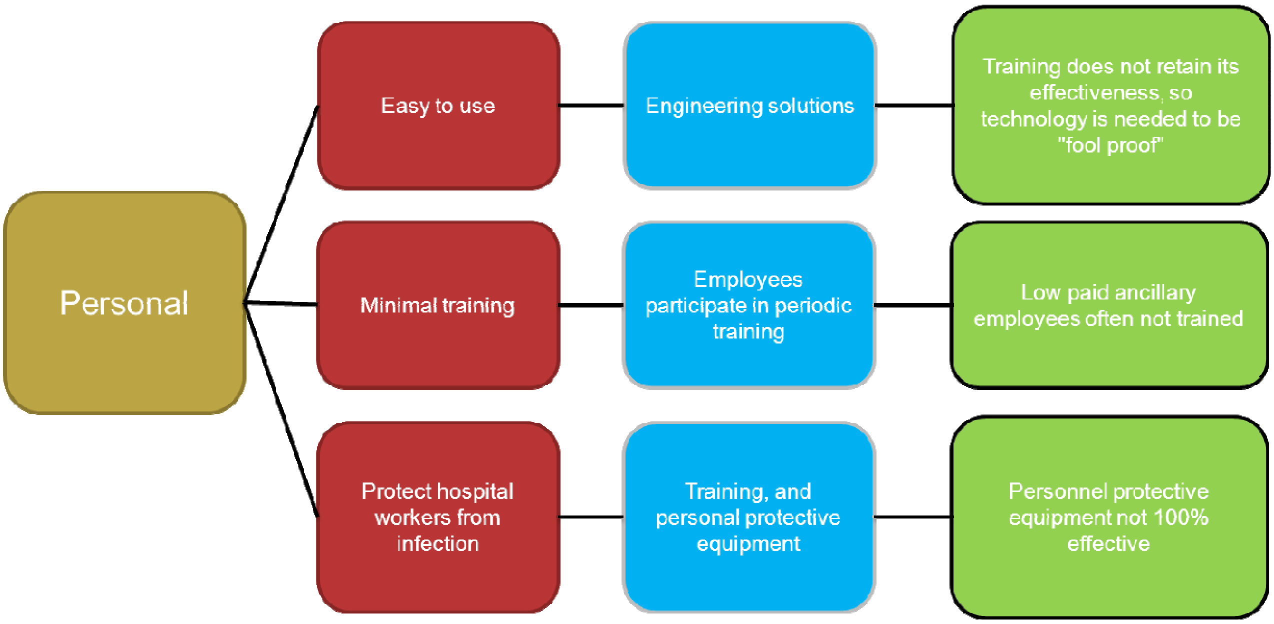

Figure III: Gap Analysis (Personal)

Criteria / Metrics

Through the literature review, a list of major criteria and sub-criteria were established for use in the model. These criteria were verified through initial expert interviews. Several items were added after the expert interviews. John Townes of OHSU, for example, state that one of significant problems they are facing is the excessive waste due to personal protective equipment. When travelling on rounds, students are less likely to enter the patient's room to observe the doctor's work because they need to put on a large amount of protective equipment. This equipment must then be taken off and thrown away by all students once the doctor leaves the room (John Townes, 2011). The complete list of criteria and sub-criteria can be found below:

- Infection Reduction
  - % reduction in infection rate of process
  - Ability to prevent creation of drug-resistant bacteria
- Cost
  - Initial cost
  - ROI
- Compatibility with existing policies and procedures
  - Hospital
  - FDA, OROSHA
- Level of training required
  - Hospital worker acceptance
  - Patient acceptability

- Environmental Impact
  - Minimal Environmental waste
  - Occupational safety: risk to workers

Technical Solutions

Biomimicry Solution

This emerging area of engineering thought and design principle could be described as: an innovation method that seeks to solve engineering problems by seeking sustainable solutions inspired by nature's processes and strategies (Benyus, 1997). By emulating natural models, using the principles of biomimicry will result in new product designs that coexist with the natural ecosystems around us and utilize the strategies that nature has developed over billions of years of evolution. By looking to nature to solve design problems, engineers engaged in biomimicry strive to follow nature's principles such as: building from the bottom up, optimizing rather than maximizing and utilizing ecologically friendly materials and processes (Hawken, 2008).

Sharklet Technologies (SLT) markets surface technologies that inhibit microorganism growth without the use of chemicals. The company's core product, called Sharklet SafeTouch, emulates the functionality of Galapagos shark skin denticles which enable the animal's surface to remain bacteria free despite the fact that it is slow moving under water. SafeTouch, a breakthrough cost-saving surface technology, provides an incremental, non-chemical, passive and persistent defense against the spread of bacteria and nosocomial infections including antibiotic resistant strains, by inhibiting bacterial growth. SafeTouch is a no-kill, non-toxic surface designed to inhibit bacterial growth including *Methicillin Resistant Staphylococcus Aureus (MRSA), E. coli*, *Staph a., Pseudomonas aeruginosa, vancomycin-resistant enterococci (VRE)* and a host of other bacteria. The SafeTouch durable skin surface is topography of billions of tiny raised, microscopic diamond shaped patterns called Sharklet. This unique micro topography is inhospitable for bacterial growth and *inhibits bacterial bio-film development.* The Sharklet pattern has been shown to reduce bacterial growth by 86 percent versus an untreated surface (Sharklet Technologies, 2011).

Though using the SafeTouch product is easy, it requires time and energy to apply, inspect, maintain and replace the product when necessary. This surface has proven effective at inhibiting bacterial colonization for up to 21 days. Primary users of the product include anyone who comes in contact with the SafeTouch product, such as patients and families, physicians, nurses, janitors and equipment technicians. Administrators are not only the primary decision makers, but also approvers and buyers. In addition, Government health agencies, like the FDA, will enforce product regulations for using these in healthcare facilities.

Costs and pricing

For hospitals, the opportunity to reduce hospital-related nosocomial infections helps control costs associated with treating these infections. The product guidelines suggest replacing SLT SafeTouch skins on average every three months. There is no upfront capital cost required for this solution. The price per square foot for SafeTouch is $12.36 (see the Appendix: Tables 1 and 2 for price, cost saving calculations). According to Ken Chung, the product director at SLT, five square feet of SLT skin is sufficient to cover the high traffic area of a single patient room.

RFID Solution

One of the new technologies being applied to reduce hospital infections is RFID. There have been numerous papers on the use of RFID in healthcare (Lahtela, 2009; S. W. Wang, Chen, Ong, Liu, & Chuang, 2006; Yao, Chu, & Li, 2010). They have suggested using RFID for tracking patents, equipment and staff to improve workflow, efficacy and patient safety. They have even suggested tracking surgical sponges so they are not inadvertently left in the patent during surgery (Rogers, Jones, & Oleynikov, 2007).

To reduce infection RFID can be used to monitor hand-washing compliance, collect data for post-infection analysis and to prevent infections by tracking if equipment has been properly sanitized before being used on the next patient. Papers by Do (Do, 2009) and (Jain et al., 2009) have proposed the idea of using RFID to monitor hand washing.

One limited trial found a significant increase in hand washing compliance resulting in a 22% reduction in HAI's (Brazzell, Yarbrough, Davenport, Dietz, & Tucker, 2011). While the $1500 to $2000 capital per room to install the systems (Rosemberg, 2011) is relatively expensive a typical infection can cost $15,000 to $20,000.

Silver Catheter Technology Solution

Urinary Tract Infections compose 35 to 45% of all nosocomial infections. Nearly all of these infections are caused by catheter-related infections (McMillan, 2001). Another solution that is showing promise in the fight to reduce hospital infections is the application of nano-silver coatings on medical devices. Samuel notes that contaminated catheters are responsible for over 40% of nosocomial sepsis in acute care hospitals. Sepsis is a severe bacterial infection of the bloodstream, resulting in blood pressure drops and patient shock.

He proposes a solution to the problem: nano-silver coated catheters.

> *This technology describes an even distribution of billions of nanoparticles (3–8 nm) of silver (0.8–1.5 wt.%) in the catheter matrix (polyurethane, silicone) on a carrier, preferably barium sulphate (Fig. 2). Free silver ions are liberated on the surface exhibiting a strong antimicrobial activity against a variety of organisms irrespective of their resistance to antibiotics. Various prototypes have been manufactured with an increasing surface of silver0. Presently, a catheter with a surface of silver0 nanoparticlesof 2500 cm2/g polyurethane or silicone is manufactured (Samuel & Guggenbichler, 2004).*

The stated benefits of silver catheters vary greatly. Table 3 and Table 4 in the appendix outline several studies and list their impact. While catheters cost roughly 25% more on a per-unit basis, they yield a 7% median reduction in infection rate (Johnson, Kuskowski, & Wilt, 2006). Another stated benefit of the silver catheter technology is that it is effective against existing drug resistant bacteria. This is important for any solution, as drug resistant bacteria are increasing in prevalence. The selected solutions must address this problem in some way.

Costs and pricing

As stated, catheter costs increase with silver technologies. In one case, a per-unit cost of $16.78 for traditional catheters increases to $20.87 for silver alloy urethral catheters (Saint, Veenstra, Sullivan, Chenoweth, & Fendrick, 2000). While this increases the costs for hospitals, the 7% reduction in procedure infection rate more than makes up for the increased costs (Johnson, et al., 2006).

Silver catheters show promise as a potential technology to reduce nosocomial infections. They have shown to be effective against bacterial growth, and do not contribute to the creation of drug-resistant bacteria. However, the catheters have a much higher cost when compared to their traditional counterparts. This problem must be resolved if they are to see more mainstream use.

Targeted Cleaning Solution

Environmental contamination with pathogens commonly occurs during routine medical care. Many studies have described transmission of pathogenic organisms through contact with contaminated room surfaces (Carling, Parry, Von Beheren, & Healthcare Environm Hyg Study, 2008). Of particular concern is the potential for transmission of multidrug-resistant organisms, such as methicillin-resistant Staphylococcus aureus (MRSA) and vancomycin-resistant enterococci (VRE), which are associated with healthcare-associated infections, increased lengths of stay in hospitals, increased healthcare costs, and increased mortality (Carling & Bartley, 2010; Wilson et al., 2011).

Although the goal of environmental cleaning and disinfection is not sterilization, adequate cleaning requires sufficient removal of pathogens to minimize patients' risk of acquiring infections from hospital environments. This is particularly true in areas serving high-risk patients, such as intensive care units (ICUs). Although the Centers for Disease Control and Prevention recommends that "close attention be paid to cleaning and disinfecting high touch surfaces in patient care areas" and that hospitals "ensure compliance by housekeeping staff with cleaning and disinfecting procedures," (CDC, 2003) the literature findings identified that there are areas of substantial improvement to achieve thoroughness of cleaning in the hospitals.

Given the need to achieve this increased thoroughness of cleaning in the hospitals without having to go too far from the regular norm of cleaning process, we identified Target Cleaning Technology as the best fit. The targeting solution consists with an environmentally stable, nontoxic base to which a chemical marker is added so that it fluoresces brightly when exposed to ultraviolet light. Also, it is developed so that it would be inconspicuous, dries rapidly on surfaces, remain environmentally stable for several weeks, and be easily removed with water-based disinfectants. Although the dried marking solution resists abrasion, once it is moistened, it can be completely removed by wiping with a damp cloth for less than 5 seconds using light, finger-tip pressure.

The target solution is applied on "high touch objects" (HTO), which includes, toilet handles, horizontal surface of toilet bowls, bedpan flushing devices, horizontal surface of sinks adjacent to a faucet, doorknobs (or push/grab plates), toilet area hand holds immediately adjacent to the toilet, bedside tables, telephone receivers, call buttons, over bed tables, seats of patient chairs, and frequently contacted areas on bedrails (Siegel, Rhinehart, Jackson, & Chiarello, 2006).

Studies have indicated that, in general, hospitals maintain consistently high cleaning rates (between 80% to 90%) for sinks; toilet seats, bed pans and tray tables, but rest of the HTOs have a very low cleaning rate. The results of clinical trials in 10 hospitals which used target solution to clean showed that at least 2 types of HTOs had a cleaning rate of more than 90% (Carling, et al., 2008).

Criteria	Sub-Criteria	RFID	Spot Cleaning	Silver Catheter	Biomimicry
Infection	Reduce Infection rate	22%	10%	3%	12%
	Drug Resistance	No	No	No	No
Cost	Initial Cost	$1,300	No	No	No
	ROI	< 3 Months	Positive	Positive	< 2 Months
Compatibility	Fit Existing Procedures	Very	Somewhat	Very	Somewhat
	Regulations (OROSHA/FDA)	Yes	Yes	Yes	Yes
Acceptance	Staff	Yes	Yes	Very	Maybe
	Patients	Very	Yes	Yes	Maybe
Environment	Toxicity	No	No	Some	Some
	Minimal Waste	Yes	Yes	Yes	Some

Table I: Summary of Solutions

Model

Hierarchical Decision Model

The design of the Hierarchical Decision Model (HDM) must satisfy the goal of developing a model that will allow hospitals/health care institutions to choose a technology that will help reduce the Hospital Acquired Infection (HAI) rate. The model developed in this paper consists of four levels as shown in Fig. IV.

There are many technological solutions available for the hospitals which addresses the issue of reducing hospital acquired infections. Each technology have their unique advantages and functionalities on addressing the infection growth, most often accessing these functionalities in accordance to a hospital requirements can be a complex, time consuming and mostly subjective decision. HDM can be used to quantify a subjective decision process and by doing so, it reduces the complexity of accessing various technologies. HDM is very commonly used tool and model for ranking alternatives with complex criteria.

The criteria for the model was determined through literature studies and also, from the expert interviews. The survey questionnaire can be found in **Appendix II**. The top level represents the goal of reducing HAI. The last level is represented by the four alternative technologies available to achieve the goal. The criteria of selecting the technology should meet the requirements of hospital/health care institutions by five major categories, reduction in infection rate, cost, compatible with existing policies and procedures, level of training required and environmental impact. Thus, these criteria were assigned to the level just below the top level.

The third level constitutes the sub criteria of these major criteria. Under reduction in infection rate the sub criteria included are the percentage in reduction rate and prevention of furthering drug-resistant bacteria. The cost includes capital cost and return of investment (ROI). The compatibility with existing policies, and procedures might vary between institutions and states and may include hospital, Federal Drug Administrative (FDA) and Oregon Safety and Health Administration (OROSHA) regulations. Under acceptance, the new technology must be acceptable to both hospital workers as well as to patients. The environmental impact might also vary between institutions and states, but they mainly include environmental waste and occupational safety of workers.

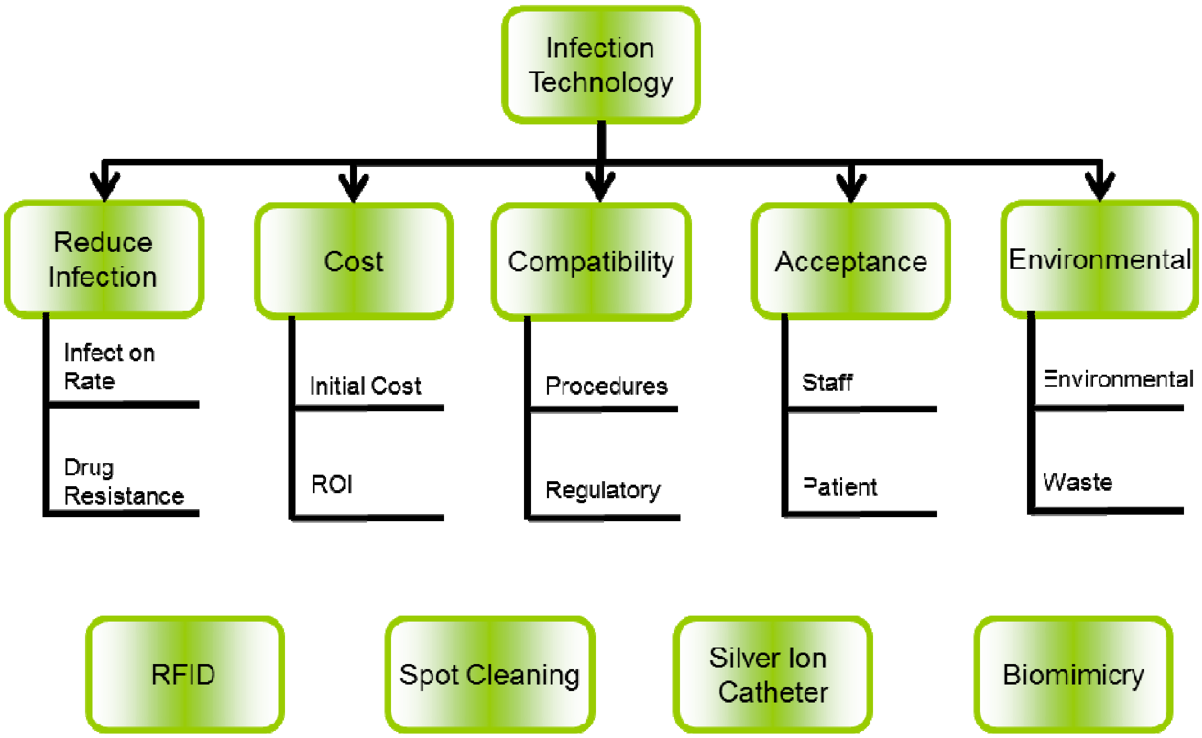

Figure IV: Hierarchical Decision Model (HDM) for reducing hospital acquired infection

Weights for Criteria from experts

We conducted the survey by administering them to various hospital heads for infectious disease control. These surveyed hospitals are mostly located in Portland metro area. The survey was designed as a judgment quantification instrument in the collection of information in the relative importance of the different criteria and sub-criteria that can impact the decision of choosing the right technology.

The respondents were asked to compare different sub-criteria for each major criterion with respect to their relative importance, and to compare the major criteria to each other. In each comparison, a total of 100 points should be allocated between two elements in pair to indicate a judgment of how much one element is more important than the other element.

PCM software was used to calculate the relative weights of each major criterion and the weights of each sub-criterion under each major criterion. The summary of the calculated weights for the model is shown in **Table II.**

Criteria	Weight	Relative	Final
Reduce Infection	0.27		
Infection Rate		0.57	0.1539
Not Increase Drug Resistance		0.43	0.1161
Cost	0.12		
Capital Cost		0.44	0.0528
ROI		0.56	0.0672
Compatibility	0.16		
Fits Existing Procedures		0.202	0.0323
Regulatory Approved (OROSHA/FDA)		0.798	0.1277
Acceptance	0.26		
Staff		0.482	0.1253
Patients		0.518	0.1347
Environment	0.19		
Not Environmentally Toxic		0.58	0.1102
Minimal Waste		0.42	0.0798

Table II: Summary of final weights for the model

Solutions and weights

In order to more precisely define the preferences for our decision criteria and sub-criteria, we surveyed our experts again and calculated utility scores. The survey questionnaire can be found in **Appendix II**.

Each alternative was compared against each other to find their preferred score. The preference for each sub-criterion was measured based on expert's preference for each of the different sub-criterion types. The preference for cost was measured based on expert's preference between capital cost and return of investment. To determine the infection reduction attribute, we used percentage in reduction of the infection rate in a hospital and at the same time not to increase the creation of drug resistant bacteria. For the compatibility attribute, the preference was measured based on the hospital policies and the Oregon State Occupational Safety and Health Association (OROSHA) and US Food and Drug Administration (FDA). The preferences for acceptance of the new technology should have both employee and patient. To determine the preference for environment, the new technology should produce minimal waste and also should not be environmentally toxic to both the personal that is using it and for the environment itself.

Results

In order to determine the best technology to reduce hospital infections based on our model, each of the alternatives was compared against one another, and the alternative with the highest preference score is recommended below. The final preference scores for each alternative were calculated by multiplying the relative weight of each criteria and sub-criteria with the utility values of each attribute for the alternative and adding up all the values – resulting in one final score for each alternative based on their attributes. The total possible preference score is 1.0, indicating that the alternative perfectly matched all desired criteria. Table III below shows the scoring for all alternatives.

Criteria	RFID	Spot Cleaning	Silver Ion	Biomimicry
Infection	0.084429	0.058266	0.061344	0.065961
Reduce Infection rate	0.055404	0.029241	0.032319	0.036936
Not Increase Drug Resistance	0.029025	0.029025	0.029025	0.029025
Cost	0.019344	0.032016	0.026592	0.041376
Minimal Initial Cost	0.000528	0.020592	0.01584	0.01584
ROI	0.018816	0.011424	0.010752	0.025536
Compatibility	0.040646	0.040646	0.042584	0.036124
Existing Procedures	0.008721	0.008721	0.010659	0.004199
Regulations (OSHA/FDA)	0.031925	0.031925	0.031925	0.031925
Acceptance	0.07327	0.063935	0.083983	0.037559
Staff	0.028819	0.027566	0.047614	0.020048
Patients	0.044451	0.036369	0.036369	0.017511
Environmental Impact	0.059394	0.057798	0.05339	0.02052
Minimal Toxic	0.03306	0.03306	0.028652	0.01653
Less Waste	0.026334	0.024738	0.024738	0.00399
Total	0.277083	0.252661	0.267893	0.20154

Table III: Alternative scoring

It can be seen from the table III, that all the alternatives scored very closely. Even though RFID obtained the highest score, Silver-Ion and Spot Cleaning were not too far behind. RFID obtained best infection reduction score even though it had worst cost of all the alternatives. Silver-Ion managed to get highest acceptance score and managed to maintain a good scoring for the rest of the criteria. Spot-Cleaning had a worst infection reduction but managed to get good score in all the other criteria. Biomimicry was the least expensive in terms of capital cost but had poor scores in acceptance and environmental criteria.

Analysis

The results of our analysis using the AHP model show that RFID was a somewhat superior technical solution to reducing hospital infections but that silver-ion catheters and spot cleaning are also viable solutions.

The RFID enabled hand washing system was the highest rated technology. RFID systems with 28% reduction in patent infections had the greatest infection reduction which was the most heavily weighted criteria. For the second highest criteria, acceptance it was in the middle of the solutions with it having the highest patent acceptance. Although it was the only solution that had a capital cost, cost was not an important criterion.

Silver-Ion catheters were the second highest rated solution. It had the highest acceptance, especially among hospital staff. For all the rest of the areas it showed moderate results.

The spot cleaning technology had the worst infection reduction of all the solution but was moderately good in all over categories.

Of all our data for the model are ROI data was the least accurate due to the difficulty in estimating costs for future solutions. But the cost was also the least important criteria so it's likely that the results would show little difference with more accurate cost information.

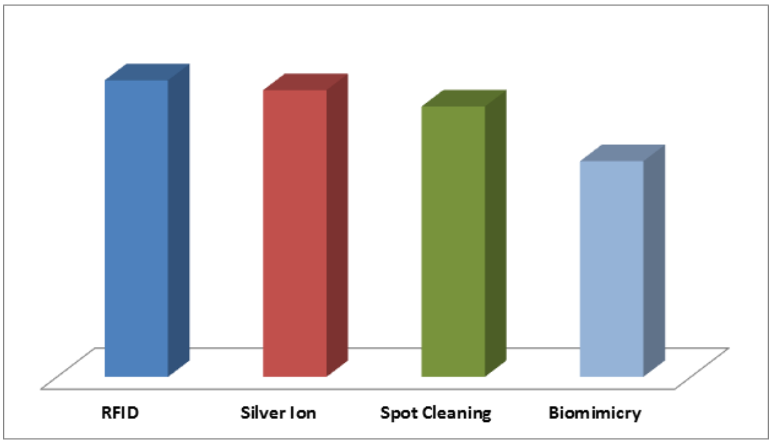

Figure V Technical Solutions

Conclusion

This paper presented results for technology assessment of four solutions alternatives. Healthcare administrator opinions were used to rank the criteria to the AHP model. The best option among the solutions was the RFID solution. The interesting part is this was the solution with the most upfront cost for installation. This solution scored best in terms of reducing MRSA levels while not further contributing to aggravating the problem and also in terms of acceptance by hospital personnel.

Based on our analyses, we should continue identifying more solutions towards resolving this problem. For future work we identified some more solutions that could be considered:

- UV Room Cleaning: In this solution an empty hospital room could be decontaminated with UV rays for a timed exposure to minimize MRSA levels of bacterial colonization.
- Data Mining: This was recommended by several experts. Data mining systems keep stringent records on all patients before and after procedures. If a patient develops an infection after they have left the hospital, the system will link that infection to the associated procedure. This allows hospitals to keep more effective records on infection rates for procedures.
- Education & Training: This happens to be the most traditional and deep rooted solution that most experts believe would solve the problem. The experts believe that the solution is all about embedded culture and mind-set towards clean practices.

Future Work

For future improvements, we would consider revising our model by removing and refining some criteria.

An Improved economic analysis by collecting additional cost data from local hospitals and existing infections rates would help refine the methodology. Extending experts used for expert input via online surveys and additional contact with Portland APIC chapter would provide more accurate datasets for analysis.

The economic analysis assumes no interaction among solutions and the same starting point for all hospitals. The analysis does not use time-value of money calculations. Net Present Value calculations for each of the solutions would be more effective for capital costs and return on investment. By incorporating these changes, one can easily make adjustments to the model, and it will provide more accurate financial estimate

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Appendix

Appendix I: Tables

SafeTouch Reduces MRSA by 86 %
% of hospital infections caused by surfaces/environment = 13%
Overall infection reduction = 86% x 13% = 12%
1% in infection reduction saves 250$/year/room
Safetouch solution Total cost savings = 12% x 250 =3000$/year

Table 1: Biomimicry Infection reduction

Price per kit: $12.36 x 5 sq.ft = $61.78
Price of materials per year =$61.78 x 4(quarters)= ~ $ 247
Price of labor for applying per year =~ $ 247 (assumed equal to price of materials)
Total cost per year = $ 494
Payback period < than 2 months

Table 2: Biomimicry SafeTouch Ongoing Costs

Research Paper	Catheter Type	Method of Entry	Control Infection Rate	Experiment Infection Rate	Control Cost	Experiment Catheter Cost
Gentry, Scope: Using silver to reduce catheterassociated urinary tract infections	silver alloy hydrogel-coated Foley Catheter	Urethral Catheter	7.70%	5.10%		2,654 GBP savings, which offsets the increased cost
Moretti, et al: Impact of central venous catheter type and methods on catheter-related colonization and bacteraemia	Silver, platinum, carbon black CVC	Intra-venous	0.40%	0%	NA	NA
Rupp et all: Effect of a Second-Generation Venous Catheter Impregnated withChlorhexidine and Silver Sulfadiazine on Central Catheter–Related Infections	Chlorhexidine and Silver Sulfadiazine Catheter	Central Venous	24.10%	13.30%	NA	NA
Dikon: Silver Coated Foley Catheters – Initial Cost Is Not the Only Thing To Consider	Silver-coated Foley Catheter	Urethral Catheter	Nearly 40% of nosocomial infections are UTI. 90% of these are catheter-related		$37,023 per year	$65,725 per year
Saint: The Potential Clinical and Economic Benefits of Silver Alloy Urinary Catheters in PreventingUrinary Tract Infection	Silvery Alloy	Urethral Catheter	0.03	0.016	$16.78 per unit	$20.87
Research Paper	**Catheter Impact**					
Blot, et all: Clinical and Economic Outcomes in Critically Ill Patients with Nosocomial Catheter-Related Bloodstream Infections	Catheter-related Bloodstream infection: 1.8% attributable to nosocomial infection from catheters. 27.8% vs. 26%					
Leone, et all: Risk factors of nosocomial catheter-associated urinary tract infection in a polyvalent intensive care unit	(9.6%) who received an indwelling urinary catheter acquired a urinary tract infection on day 12±7.					
Samuel, Guggenbichler: Prevention of catheter-related infections: the potential of a new nano-silver impregnated catheter	Contaminated catheters responsible for over 40% of all nosocomial sepsis in acute-care hospitals					

Table 3: Silver Catheters (Impacts and Infection Reduction) (Blot et al., 2005; Dikon, 2006; Gentry H, 2005; Leone et al., 2003; Morettia, Ofsteadb, Kristyc, & Wetzlerd, 2005; Rupp et al., 2005; Saint, et al., 2000; Samuel & Guggenbichler, 2004)

Study, Year (Reference)	Test Group, n/n	Control Group, n/n	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Absolute Risk Reduction, %
Nitrofurazone					
Maki et al., 1997 (30)	8/170	14/174		0.58 (0.25-1.36)	3
Al-Habdan et al., 2003 (27)	0/50	18415		0.08 (0.00-1.33)	12
Lee et al., 2004 (32)	14/92	19/85		0.68 (0.36-1.27)	7
Silver (pre-1995)					
Lundeberg, 1986 (28)	9/51	24/51		0.38 (0.19-0.73)	29
Liedberg et al., 1990 (23)	3/30	25/60		0.24 (0.08-0.73)	32
Liedberg and Lundeberg, 1990 (24)	6/60	22/60		0.27 (0.12-0.62)	27
Liedberg and Lundeberg, 1993 (29)	8/75	23/96		0.45 (0.21-0.94)	13
Silver (post-1995)					
Maki et al., 1998 (31)	64/407	94/443		0.74 (0.56-0.99)	5
Verleyen et al., 1999A (25)	6/12	8/15		0.94 (0.45-1.96)	3
Verleyen et al., 1999B (25)	5/79	12/101		0.53 (0.20-1.45)	6
Karchmer et al., 2000 (14)	154/5398	189/5634		0.85 (0.69-1.05)	2
Thibon et al., 2000 (26)	9/90	13/109		0.84 (0.32-1.87)	0.5

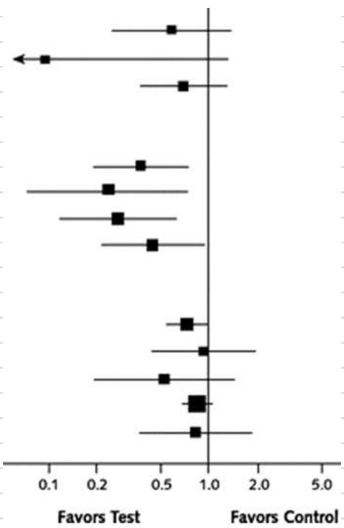

Table 4: Silver Catheters (Infection Reduction) (Johnson, et al., 2006)

Appendix II: Expert Pairwise Questionnaire

	Sum to 100		
Infection Reduction Criteria	A	B	
Reduce Infection			Cost
Reduce Infection			Compatibility
Reduce Infection			Acceptance
Reduce Infection			Environment
Cost			Compatibility
Cost			Acceptance
Cost			Environment
Compatibility			Acceptance
Compatibility			Environment
Acceptance			Environment
Reduce Infection	A	B	
Reduce Infection			Not Increase Drug Resistance
Cost	A	B	
Initial Cost			ROI (Return On Investment)
Compatibility	A	B	
Fits Existing Procedures			Regulatory Approved (OHSA / FDA)
Acceptance	A	B	
Staff			Patients
Environment	A	B	
Not Environmentaly Toxicity			Generate Little Waste

Appendix III: Expert Solutions Preference Questionnaire

Reduce Infection Rate	A	B	
RFID			Spot Cleaning
RFID			Silver Ion
RFID			Biomimicry
Spot Cleaning			Silver Ion
Spot Cleaning			Biomimicry
Silver Ion			Biomimicry

Not Increase Drug Resistance	A	B	
RFID			Spot Cleaning
RFID			Silver Ion
RFID			Biomimicry
Spot Cleaning			Silver Ion
Spot Cleaning			Biomimicry
Silver Ion			Biomimicry

Initial Cost (Capital)	A	B	
RFID			Spot Cleaning
RFID			Silver Ion
RFID			Biomimicry
Spot Cleaning			Silver Ion
Spot Cleaning			Biomimicry
Silver Ion			Biomimicry

ROI	A	B	
RFID			Spot Cleaning

RFID			Silver Ion
RFID			Biomimicry
Spot Cleaning			Silver Ion
Spot Cleaning			Biomimicry
Silver Ion			Biomimicry

Existing Procedures	A	B	
RFID			Spot Cleaning
RFID			Silver Ion
RFID			Biomimicry
Spot Cleaning			Silver Ion
Spot Cleaning			Biomimicry
Silver Ion			Biomimicry

Regulations (OHSU & FDA)	A	B	
RFID			Spot Cleaning
RFID			Silver Ion
RFID			Biomimicry
Spot Cleaning			Silver Ion
Spot Cleaning			Biomimicry
Silver Ion			Biomimicry

Staff	A	B	
RFID			Spot Cleaning
RFID			Silver Ion
RFID			Biomimicry
Spot Cleaning			Silver Ion
Spot Cleaning			Biomimicry
Silver Ion			Biomimicry

Patients	A	B	
RFID			Spot Cleaning
RFID			Silver Ion
RFID			Biomimicry
Spot Cleaning			Silver Ion
Spot Cleaning			Biomimicry
Silver Ion			Biomimicry

Environmental Toxicity	A	B	
RFID			Spot Cleaning
RFID			Silver Ion
RFID			Biomimicry
Spot Cleaning			Silver Ion
Spot Cleaning			Biomimicry
Silver Ion			Biomimicry

Waste	A	B	
RFID			Spot Cleaning
RFID			Silver Ion
RFID			Biomimicry
Spot Cleaning			Silver Ion
Spot Cleaning			Biomimicry
Silver Ion			Biomimicry