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Role of Pilot Study in Assessing Viability of New Technology Projects: The Case of RFID in Parking Operations

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Abstract:

The use of pilot studies to evaluate the economic justification of technology projects is common in practice. The pilot studies play even greater role in the projects affecting customer interactions with the product/service offerings since perception and/or reaction of customers is captured and analyzed through such studies. Yet, many times the methodology used in these studies lacks rigor and comprehensiveness, and there are scopes for further improvement. The current literature provides limited information on how the pilot studies should be used to decide whether to go ahead with a proposed technology project or not. In this paper we present guidelines for effectively using pilot studies in making such decisions. With the help of a real-life pilot study on deployment of RFID technology in parking operations at a university, we discuss how the proposed guidelines may be implemented to evaluate the cost-effectiveness of the proposed project. In recent times RFID technology is getting increasing attention and many organizations are in the process of deploying this technology. The paper offers a timely and cost-effective evaluation study of a particular application of RFID technology. We found that users' benefits and costs played a crucial role in determining whether the proposed project should go forward or not. Also, we found that intangible benefits and costs to be important. These findings along with our discussions on the general methodology will provide practical guidelines for evaluating viability of technology projects using pilot studies.

Keywords: pilot study, customer input, economic justification, cost-effectiveness, RFID, parking, technology project

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I. INTRODUCTION

Many times adoption of new technology is a debatable and sensitive issue due to greater degrees of unpredictability, risk, and complexity associated with it. An organization must show substantial returns to justify implementation of new technology projects. The very nature of technology projects focusing on innovation and creativity makes them unique and it becomes quite difficult to assess the potential returns and benefits. Even the actual cost incurred in the project may turn out to be substantially different from the estimates. In order to address these issues, pilot studies are conducted which help the organization get a feel of the technology and perform an analysis of its cost-effectiveness prior to making decisions on whether to go forward with full scale implementation. Pilot studies may be defined as "small-scale versions of the planned study, trial runs of planned methods/measures, or a miniature version of the anticipated research" [Prescott and Soeken 1989]. The aim of such a study is "to avoid unforeseen difficulties that might arise from a research design" and "to discover possible problems while there is still time to remedy them" [Sanders and Pinhey 1983]. Pilot studies are even more important in customer-centric technology projects where the customers are significant beneficiaries of the project. For comprehensive evaluation of such a project, it is critical to analyze the users' feedback on the functionalities offered by the technology as well as the experience gathered in the pilot study by the organization that will eventually own the project (if implemented). Although pilot studies are used quite often to assess technology, the current literature provides limited information on a well-structured methodology for using these studies to justify new technology projects. We intend to reduce the gap in literature with a set of proposed guidelines and show how these guidelines can be used in real life with the help of a case study.

In recent years, RFID technology is receiving extensive attention due to its ability to track mobile items without manual scanning. While much of the current research has focused on RFID applications in various aspects of supply chain management (SCM), the technology has tremendous potential to enhance customer experience in retail stores, hospitals, parking lots, libraries, etc. In this paper we present a pilot study on the use of RFID technology in parking operations, where the RFID tags are used for opening access gates at a university parking lot to speed up the gate-opening process and provide added convenience by enabling hands-free entry. We undertook the pilot study to assess if a large scale deployment of RFID technology would be cost-effective for the university. We used a set of structured guidelines to accomplish the task and we present them in this paper.

The main objective of our research is to propose a set of well-structured guidelines for conducting pilot studies in a systematic fashion and subsequently analyzing the findings from the pilot to assess viability of technology projects. We also intend to present how the proposed methodologies can actually be applied in a real-life project so that the practitioners can have better idea of using them in their respective settings. With this objective in mind we have organized the paper as follows. In Section II, literature review on the use of pilot studies to justify technology deployment is presented. Subsequently, guidelines for successfully using a pilot study to evaluate new projects are introduced in Section III. Then a case of an actual pilot study for using RFID technology is presented and analyzed in Section IV. Finally, we conclude the paper with discussions of results and directions for future research.

II. LITERATURE REVIEW

The use of proof of concept pilot to assess viability of new technology deployment or business practice adoption is common in practice. For example, before global rollout of computer assisted selling process (CASP) system to enhance the buying experience at automobile dealerships, a detailed pilot study was undertaken to assess its usefulness [Reed et al. 2004]. Pilot study was successfully used to gather initial information about the use of groupware to support evaluation of software architecture in distributed arrangement and subsequently refine and assess larger-scale experimental programs [Babar et al. 2006]. With the help of pilot studies, Shiels et al. [2003] examined how information and communication technologies can be implemented and integrated with the business processes at small- and medium-size enterprises (SME). Gordon and Gordon [2002] used a pilot study to identify and investigate differences in IT service delivery among organizations based in different countries. A pilot study was conducted to investigate acceptability by patients and healthcare professionals of telegenetics, a new approach, for delivering cancer genetic services between the specialist center at Cardiff and remote clinical sites in North Wales [Iredale et al. 2002]. Liang et al. [2006] used a pilot study to assess the usefulness of a Web-based intervention support system to enhance health-related behavioral changes. Piplani and Fu [2005] proposed a framework based on multi-agent technologies, coordination theory, and optimization capabilities to align inventory decisions in decentralized supply chains. With the help of a pilot study they explored how the framework might be used to make the supply chain operations more efficient through appropriate cost sharing and service level agreement. A pilot study was carried out to test the usefulness of an ontology based methodology for knowledge sharing in the new product development process at a multinational organization [Bradfield and Gao 2007].

Use of pilot studies to understand and assess customer oriented processes or solutions is prevalent in practice. Since obtaining customer feedback for this type of system is essential for further justification, an initial pilot study has a crucial role to play. For example, IBM used a six-month pilot to assess the value of managing customer relationships [Massey et al. 2001]. The focus of the study was to investigate if the proposed CRM system would address the pain points of the customers and enhance satisfaction. The potential for additional revenue due to better relationships with customers was adjudged. Also, fast execution of prototypes rather than a time-consuming fully functional system provided additional leverage. Hill [2007] echoed similar views and mentioned that a big bang approach in implementing CRM might not be successful. The pilot study can be very useful in gradual rollout of new technology. Also, pilot study is widely used in market research. Grønholdt et al. [2000] used a pilot study to understand the relationship between customer satisfaction and loyalty. Bei and Chiao [2006] investigated how customers' perceptions about service quality, product quality, and price fairness influenced their loyalty to a service provider with the help of a pilot study. Gayathri et al. [2005] used a pilot study to investigate dimensions of quality of services provided by insurance companies and their relationship with customer satisfaction.

As stated, pilot studies have been used extensively to understand, investigate, and assess adoption of new technology to improve business processes in a number of industry verticals. Yet the literature is somewhat limited in providing a well-defined structured methodology on how a pilot study should be used to justify new technology/ practice and estimate return on investment (ROI) particularly for customer-oriented solutions. If we closely look at various articles mentioned earlier, we can see that use of well-structured methodology in pilot studies is not reported much—rather they stress the results/findings. For example, Reed et al. [2004] discussed capturing the experience of users of a new computer-assisted selling process through personal interviews and closed circuit television and statistical analysis of the collected data. But the design of pilot study was not well documented. Massey et al. [2001], Piplani and Fu [2006], and Shiels et al. [2003] also discussed the results of pilot studies in details but did not mention much on pilot design. Some of the articles discussed about designing pilot studies in the context of assessing effectiveness or usefulness of a new method/technology, and dealt with experimental design, internal and external validity of survey instrument, and statistical analysis in great details. Babar et al. [2006], Gordon and Gordon [2002], Kasunic [2004], and Liang et al. [2006] belong to this category. While these papers dealt extensively with usefulness of a method/project from technical perspectives, they did not focus on return on investment or cost-benefit analysis which is important from a business viewpoint. Please note that we are not criticizing these articles for not having such analysis as their focus was different. We are simply reinforcing the fact that well-structured pilot study for economic justification of a project is not well documented in the literature.

Pilot studies are also often utilized in many other disciplines, but not much discussion is available on how to harness full potential of such studies in a systematic fashion. Sampson [2004] referred to this lack of information as the "under-reported and under-developed" aspect of qualitative research. Lancaster et al. [2004] mentioned misuse and misrepresentation of pilot studies in health research. van Teijlingen and Hundley [2001] pointed out under-reporting of pilot studies in social science literature and argued that sharing of detailed experience from both failed and successful pilot studies might be very useful for embarking on projects using similar methods or instruments. Despite our thorough search in multiple disciplines, we did not find any article presenting a well-structured methodology for using pilot study in economic justification of a new project. In the current paper we attempt to reduce the gap in the existing literature. We propose several guidelines for using a pilot study to justify a new technology project economically. Subsequently, we present a case study that uses the proposed guidelines to demonstrate the strong ROI potential of RFID technology in parking operations.

III. GUIDELINES FOR USING PILOT STUDY

Here we describe how pilot study can be used for justifying new technology deployment by an organization. Since adoption of new technology has many uncertainties careful consideration should be made before taking the final plunge. An analogy, as shown in Figure 1, can be drawn between crossing an uncharted river and taking an organization through the process of new technology deployment. While attempting to cross an uncharted river a seasoned explorer gets a bit inside the river but within a safe distance from the river bank to test the current before making the final crossing. If (s)he does not feel comfortable after testing the current, (s)he will reevaluate the situation and (s)he may even decide not to cross the river. Similarly, after initial planning and getting a positive feasibility report for a possible technology deployment, pilot study should be conducted and final decision for full scale deployment should be taken subsequently based on experiences gathered from the pilot. However, it should be noted that an encouraging experience in pilot does not automatically ensure a positive outcome in full-scale deployment. Similar viewpoints were expressed by Lancaster et al. [2004] and van Teijlingen and Hundley [2001]. Hence, skillful design of pilot, rigorous evaluation, and careful interpretation of results are absolutely critical for making the right decision on whether to move forward with the proposed deployment or abandon the project. In the subsequent sections we discuss these topics. A summary of this discussion is presented in the form of Figure 2.

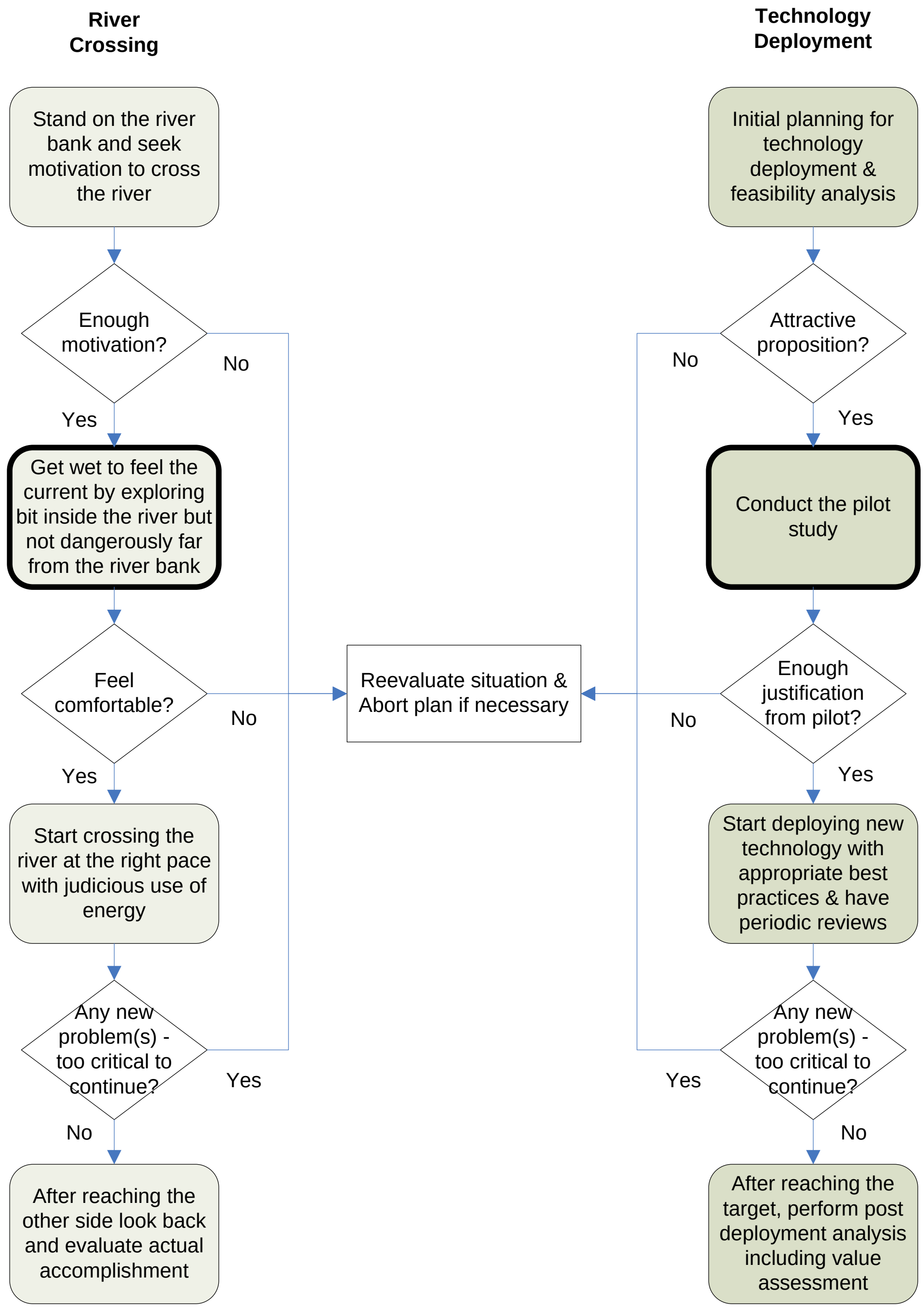

Figure 1. Comparison of River Crossing with Technology Deployment

DESIGN OF PILOT

There are several factors that should be considered in designing an effective pilot study for verifying the justification of new technology adoption endeavor. They are listed as follows.

Unit of Analysis

A pilot study is usually conducted in a scaled down fashion, i.e., not all entities that fall within the scope of real implementation are involved in the pilot. Obviously, the question is which entities should get selected in the pilot study. While there are no exact guidelines, a judicious attempt should be made to include representative sample(s) from the population [Babar et al. 2006; Liang et al. 2006]. If the population is diverse it may be segmented based on its characteristics and samples from each segment can be chosen. If it is required to restrict sample size for economic and other reasons, adjustments should be made while extrapolating the results. For example, in the context of implementing RFID technology in parking lots, if we involve a disproportionate number of handicapped users in the pilot compared to their actual percentage in the user population, estimation of the benefit due to convenience of hands-free operation would need to be adjusted.

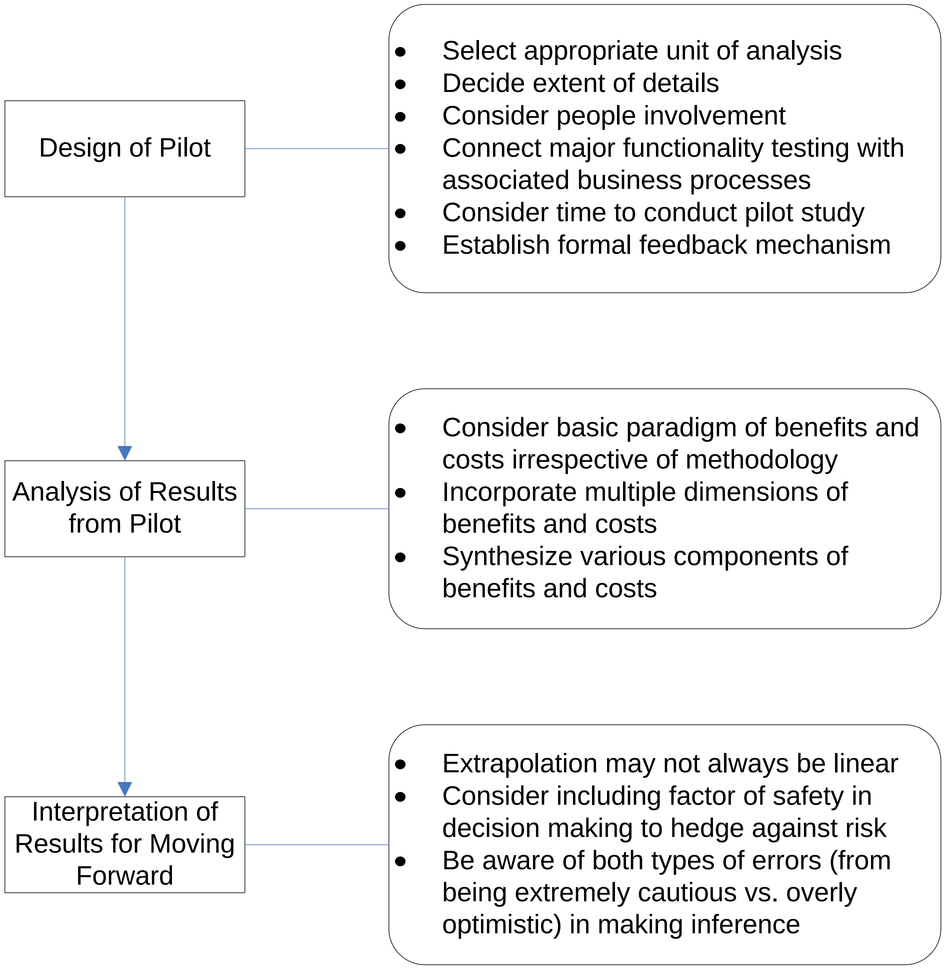

Figure 2. Summary of Proposed Guidelines for Pilot Study

Extent of Details

How much details should be incorporated in the pilot is an important issue to address. Usually the accuracy of decision on subsequent full-scale deployment increases with a more detailed pilot study (see Figure 3). However, inclusion of more details needs additional resources and causes delay in actual implementation. A well crafted balance is needed [Lancaster et al. 2004]. Efforts must be made to maximize accuracy of prediction while keeping tight control on extent of details although it is difficult to achieve.

Involvement of People Affected

Attempts should be made to involve a representative sample of the people in the pilot who will eventually have varying degree of interaction with the new technology, if deployed. The list not only includes the end users but also the people who will participate in installation and maintenance, and will be affected by the change.

Testing Functionalities and Associated Business Processes

Sometimes new functionalities are tested without considering the efforts needed to streamline associated business processes. Such practice should be avoided [Kasunic 2004]. While it may not be possible to test all functionalities and connected business processes, the major ones need to be evaluated. Assessment of functionalities should be made in unison with business processes.

Time to Conduct Pilot

Time needed to conduct a pilot study depends on complexity of the project. While sufficient time should be allocated to conduct the study, it should be noted that full-scale implementation awaits completion of pilot. Thus, extra time needed in pilot is like lost opportunity cost. Additional resources may be utilized to do some jobs concurrently in order to reduce the overall duration. The ability to rapidly show the existence of ROI is definitely a plus point of a pilot study [Havestein 2006].

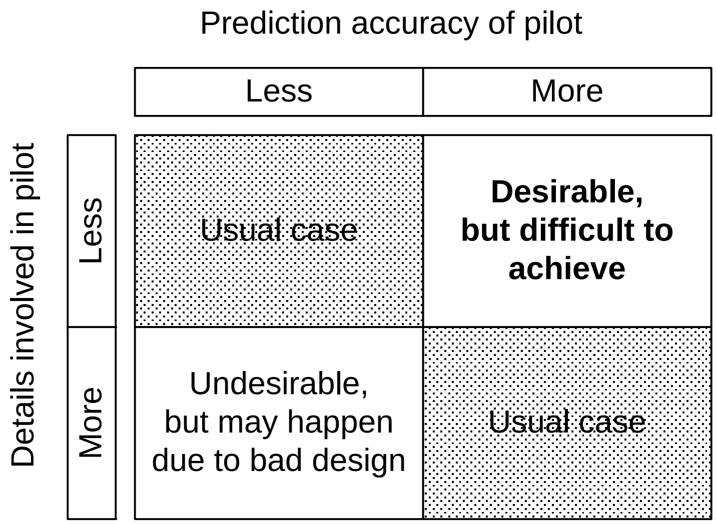

Figure 3. Tradeoff between Details Involved in a Pilot Study and Prediction Accuracy

Formal Feedback Mechanism

A formal mechanism should be put in place to capture the experience and lessons learned during the pilot [Kasunic 2004]. The recorded information may include difficulties, glitches, and shortcomings as well as positive experiences. The information should be used in the decision making process for subsequent full-scale deployment. A number of analyses including the ones on resource requirement, technology readiness, and risk assessment will need the information to update and validate some of the assumptions used. Also, the lessons learned during the pilot can be used in actual implementation to overcome similar difficulties encountered previously.

EVALUATION USING PILOT

Technology project evaluation is often complex and so are the associated pilot studies [Keen 2003]. A number of metrics such as revenue gains, cost savings, time to market, on-time delivery, market share gains, etc. can be used to measure value generated by technology projects [Foley 2002]. According to a study based on interviews with executives involved in IT project decisions, companies should look beyond ROI and total cost of ownership [Rogow 2004]. Some organizations have formalized the process measurement and process improvement as part of evaluation of technology-based projects [Segars et al. 2001]. According to Irani et al. [1997] evaluation of technology based projects can be classified into four major approaches: economic, strategic, analytical, and integrated. Economic approaches generally use financial measurements such as ROI, internal rate of return, net present value, and payback approaches and usually ignore intangible factors. A project's strategic alliances with corporate objectives are dealt with by using strategic approaches and both tangible and intangible factors are considered. Analytical approaches such as analytic hierarchy process [Saaty 1990], risk analysis [Remenyi and Heafield 1996] and scoring models [Nelson 1986] are structured but subjective and involve the use of tangible and intangible factors. Integrated approaches such as balanced scorecard [Kaplan and Norton 1996] and multi-attribute utility theory [Sloggy 1984] incorporate subjectivity within formal structure, and consider both financial and nonfinancial dimensions of decision making. Which methodology is most suitable for evaluating a pilot is beyond the scope of this article. In fact each approach has its pros and cons and selection of appropriate methodology varies with the situation. The purpose of the above discussion is to show that irrespective of rigor and relevance, each of the methodologies work within the basic paradigm of estimating benefits and costs although their scope may extend beyond pure financial terms.

Benefits and costs can be broadly classified into two categories: tangible and intangible. While tangible benefits are usually direct monetary savings, intangible benefits may be increase in competitiveness, enhancement of customer satisfaction etc. Tangible costs are investments for new technology, consultant fees etc. On the other hand, intangible costs may be value of lost opportunity, lack of sale due to slow response, etc. While costs and benefits to the organization deploying the new technology may be of primary focus, costs and benefits of other entities in the supply chain should not be ignored (see Figure 4). Tangible and intangible benefits/costs of the suppliers and customers affected by the deployment of the new technology should be considered in the process of evaluation. The consideration is even more important if the implementation requires collaboration with suppliers/customers. Also, involvement of customers may vary depending on whether they are business customers or consumer customers. In short, tangible and intangible benefits/costs of three broad entities in the supply chain, i.e., organization, suppliers, and customers need to be considered for a comprehensive evaluation. It should be noted that not all projects will involve suppliers or customers, and degree of inclusion of intangible benefits and costs will depend on the decision maker. In the subsequent sections we describe various dimensions of benefits and costs, and show how to synthesize these components to make a final decision.

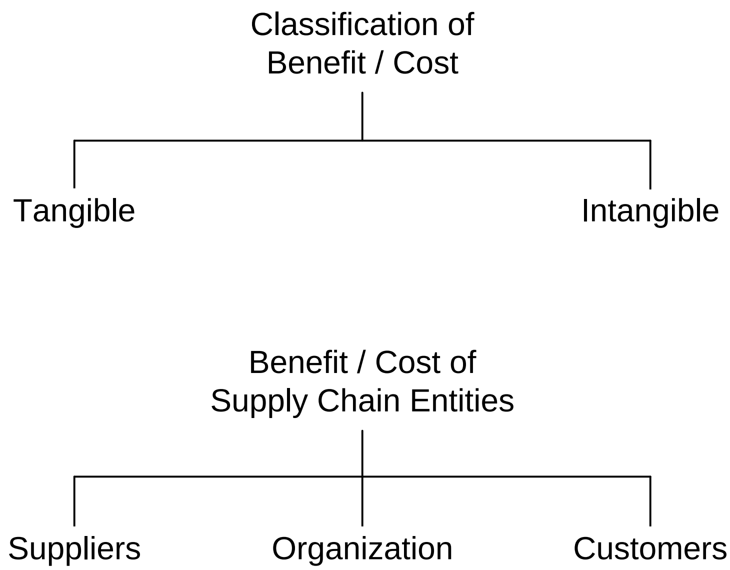

Figure 4. Different Dimensions of Benefit/Cost

Various Dimensions of Benefits and Costs

The organization as well as its suppliers and customers may benefit from new technology deployment. Benefits may be realized in various forms as presented in Table 1. The basic equation of calculating profit is as follows:

Profit = Unit selling price x Demand – Cost

Table 1. Multiple Dimensions of Benefit

Supply Chain Entity	Potential Benefits
Organization	Efficiency in business processes Enhancement of competitiveness potential Improvement in product/service quality
Supplier	Improvement in fulfillment efficiency Entering into strategic partnership
Customer	Higher satisfaction Time savings Easy access or convenience

Table 2. Multiple Dimensions of Cost

Supply Chain Entity	Potential Costs
Organization	Expenditure for new technology Cost of resources (implementation cost) Cost of organizational and business process changes Cost of difficulty faced during implementation
Supplier	Cost of adopting new technology if mandated by driving organization Cost of difficulties/glitches faced during rollout when suppliers' business processes are affected
Customer*	Cost of malfunctioning Cost of technology compliance

* Cost components may vary depending on consumer and business customers.

Anything that influences these three parameters and enhances profit potential may be treated as benefit. For example, increased customer satisfaction due to technology deployment is likely to increase demand and a satisfied customer may also be willing to pay slightly higher price. The resulting increase in profit may be treated as a benefit of the new technology responsible for enhanced customer satisfaction. Similarly, increase in competitiveness may positively affect both demand and selling price, and enhanced business process efficiency may cut cost resulting in higher profit. The list given in Table 1 provides some guidelines about tangible and intangible benefits. Similarly, various dimensions of tangible and intangible costs are presented in Table 2.

Synthesis of Various Components of Benefits and Costs

The various components of benefits and costs estimated in the pilot study may not be equally important. There are various multi-criteria decision making approaches available in the literature that can be used to combine various components based on their relative importance.

Also, they may not be estimated using the same unit. This may create additional difficulties in the process of evaluation. One standard approach to deal with such situation is to convert everything into dollar value, then estimate overall benefit and cost, and finally calculate benefit-cost ratio. We call this monetary value based benefit-cost ratio (MVBBCR) approach. The other approach is to keep the benefit and cost components in original units, i.e., use the units that are easier to follow or comprehend, and synthesize them using the analytic hierarchy process [Saaty 1990] to unit-less scores for benefit and cost and finally evaluate each of the alternatives in terms of unit-less scores. We call this analytic hierarchy process based scoring (AHPBS) approach. In the RFID case study we present in details how these two approaches can be used for evaluation of a project with the help of a pilot. We do not claim that these two methods are the best available evaluation approaches but the primary reasons for selecting them are their robustness, ability to capture details, ease of use, and popularity among practitioners.

Another important consideration is at what point of time benefits due to technology deployment are realized and costs are incurred. Implementation of new technologies may not provide rapid return. Brynjolfsson and Hitt [1998] discussed the importance of complementary investments in business process redesign, organizational realignment, and strategic planning to attain the full benefit potential of investment in new technology. These steps are painstaking and time consuming, and hence the realization of the full benefit from a new technology may be delayed and time phased. Brynjolfsson and Hitt [1998] suggested that if an organization executed these steps properly over time they would surge ahead of competition. Thus, for benefit and cost flow analysis, similar to cash flow analysis, capturing the time value of money may be needed to assess the impact of full-scale technology deployment based on the information gathered from the pilot study.

INTERPRETATION OF RESULTS

Analyzing the information gathered from a pilot and interpreting the evaluation results may be tricky. Careful judgments should be made regarding the next step of actual deployment based on the case study.

Extrapolation of Results

Sometimes benefits and costs estimates from pilot are linearly extrapolated for the case of actual implementation. For example, in an actual project that is tenfold the size of the pilot, one may expect the benefit to be ten times the estimate of benefit obtained from the pilot. However, such a linear assumption does not hold true all the time. It is possible that the benefit may taper off or cost may increase exponentially as the scope of the project increases. Also, the reverse phenomena may occur. Hence, such linear extrapolation should be treated with caution and if used the linear assumption should be validated. Since potential return from a technology adoption project depends on a complex interaction of a number of factors it is extremely difficult, if not impossible, to predict benefit and cost trajectories accurately. Pilots provide some sort of idea about the real thing, but not the whole truth. The decision makers need to be aware of this fact.

Factor of Safety

Cost-effectiveness analysis of the findings from the pilot study may be used to take a decision on whether to move forward with full-scale implementation. At the same time we all know that actual implementation is more complicated and riskier than the pilot. Hence, a factor of safety which is often used in engineering design may be used. For example, assume a benefit-cost ratio of 2:1 is the minimum corporate hurdle rate or standard at an organization for deploying new technology. Suppose a factor of safety of 1.5 is used. In this case we should expect the pilot to yield a benefit-cost ratio of at least 3:1 in order to move forward. A balance is needed to choose the safety factor—if a high value is chosen many useful projects may not meet the requirement, on the other hand a low value will increase the risk.

Comparison with Testing Hypothesis

A decision to go ahead with actual implementation based on a pilot study can be viewed as testing hypothesis in statistics although the setup is not as structured for the pilot based decision making. With the help of pilot study decision makers gather evidence to accept or not to accept the null hypothesis of the deployment of new technology being useful for the organization. Like statistical hypothesis testing, a decision based on the pilot study has type-I and type-II errors although these terms are not used in technology and project management literature. In the context of project justification using pilot study, type-I error would be not to go ahead with full-scale deployment based on the results of pilot study when deployment would have been actually useful. On the other hand type-II error would be to go ahead with full-scale deployment based on the results of pilot study when deployment would not have been of much value to the organization. While type-I errors, as stated above, would have lost opportunity cost, typically type-II errors would possibly have more detrimental effect to the organization. It is important to explore how these two types of errors can be controlled in making inferences. Unfortunately, at this time no formal methodology in the context of pilot study exists to the best of our knowledge. Nonetheless, the decision makers should be aware of the risk associated with the inference from pilot studies.

IV. CASE STUDY

Radio Frequency Identification (RFID) technology is poised to enhance the customer-centric offerings in the corporate world [Top 2006]. Big retailers like Wal-Mart, Target, and Tesco are using RFID tags to improve supply chain efficiency and customer service. Companies in other sectors such as apparel, chemical, defense, healthcare, manufacturing, packaging, and transportation are adopting RFID technology to improve operational efficiency. A number of articles [Bose and Pal 2005; Lapide 2004; Wong and McFarlane 2003] discuss the role of RFID in the context of supply chain management (SCM). Also, non-SCM applications of RFID technology have strong potential. We present such an application in this section. The value proposition of use of RFID technology in parking operations at a U.S. university is analyzed with a help of a pilot study.

The parking officials at a U.S. university are considering various options to make the parking experience more user-friendly and the associated operational processes more efficient. In order to protect the identity of the university we will refer to this institution as “ABC University.” One of the major considerations is to replace the magnetic swipe cards with RFID tags to open the gates at parking lots. The adoption of RFID tags will make it easier for the users of the parking lot to enter it as they would not need to roll down the window of the vehicle to access the swipe card reader and the time taken to open the gate after the user arrives at the gate will be reduced. Also, the parking administration may save money in the renewal of parking permits and enhance reputation by providing better service. However, new technology deployment means additional spending as well. The parking administration needs to find out if the adoption of RFID technology would be economically justified. A pilot study is conducted and the information gathered is subsequently analyzed to assess the viability of the rollout of the RFID-based system at the university parking lots. In the following sections we describe how the pilot study was conducted and attractiveness of the proposed RFID technology adoption was evaluated.

SETUP OF THE PILOT STUDY AT ABC UNIVERSITY

The university has 20 gated parking lots where RFID technology may be deployed. Since the parking administration had limited resources they decided to conduct the pilot study only at one parking lot. The lot was selected as infrastructure was readily available to conduct the pilot study. However, it was also ensured that the selected lot was a representative sample. One of the authors looked at technical details, coordinated the pilot experiment, and recorded various details related to the project. The other authors were responsible for designing the study and played the role of devil’s advocate. Having one author as a participating member provided easier access to various information needed for analysis. He also recorded technical difficulties faced during extensive testing of the technology and passed the information to the parking administration.

While most of the users of this lot would open the entry gate by swiping their ID cards, users with special needs would use remote control units for opening the gate without swiping cards. The extent of modifications of the existing hardware circuitry at the gate was kept at a minimum level to avoid warranty issues with the current system and one of the remote control units was altered for controlling the gate using the RFID reader during the pilot study. At the same time additional care was taken to make sure the pilot setup offered the same functionality and perception to the users as a full-scale RFID deployment.

The utilities of different users may vary and they may view the new system differently. A faculty/staff may be willing to spend more money than a student for the convenience offered by the hands-free system. Similarly, a handicapped driver may perceive the utility differently. In order to capture feedback from diverse groups of users, volunteers with different parking permit types were chosen. The time and location of the pilot was advertized in the campus and potential participants were asked to contact the pilot study coordinator with parking permit information before a deadline. Subsequently, volunteers from each group were randomly chosen. A total of 30 volunteers were given RFID tags to enter the parking lot. The number was consistent with the common statistical practice of having a sample size of 30. Also, personnel from parking administration who would potentially operate and maintain the system were present during the pilot study to get a first-hand experience of the operation.

Efforts were made in the pilot to simulate the operations of the actual system as closely as possible by choosing appropriate hardware and software so that all key functions remained the same. In this case there was no need for streamlining any existing business processes. However, the parking administration personnel and director were interviewed and consulted a number of times to assess the effort needed to implement the RFID based system. The time for conducting the pilot study was kept to a minimum due to the constraints on the volunteer users' time commitment. All volunteers used the RFID system on the same day. However, data were collected separately for several days to capture arrival patterns on different days of the week. In order to avoid any potential glitches, extensive tests of the system were conducted in a laboratory environment before deploying it in the field for the pilot study involving volunteer users. The entire pilot was video taped and the processing time or the time to open a gate after a vehicle arriving at the gate was estimated by replaying the video.

After the volunteers experienced the RFID-based system, they were asked to fill up a short questionnaire. They were asked to compare the RFID system with the existing system in terms of convenience and time savings. Also, they were asked how much extra money they would be willing to pay for the additional convenience and time savings provided by the RFID system. In addition, they were asked how they would accept inconvenience caused by any potential malfunctioning of the new system. Also, they were requested to provide overall comments about the system after experiencing it. The questionnaire is provided in the appendix.

The personnel and director of parking administrators were interviewed to assess operating cost savings, additional potential for more revenue, and reputation enhancement due to the new system. Also, they were questioned about resource requirements for full-scale implementation, training, business process change, and potential change in operating and maintenance cost. Also, the parking director was requested to provide an estimate of the relative importance of various components of benefits and costs. A number of iterations were required to make adjustments to these ratings so that they were consistent with the AHP methodology.

TECHNICAL DESIGN OF THE PILOT

The pilot portal (as shown in Figure 5) was constructed by mounting an ALR-9800 reader from Alien Technologies inside a NEMA-12 enclosure to protect the hardware from harsh environmental conditions. The system was installed at an automated parking lot, currently operated by swipe cards. In order to avoid connecting the RFID hardware directly to the existing hardware which would have caused issues with current warranty, an alternative approach was used. A remote radio-controller unit, which was part of the existing system and used specifically for providing swipe-free access to disabled and handicapped persons, was used to operate the gate. The circuit of the remote controller was slightly altered so that it could be driven by the RFID reader. The key components used in the pilot are shown in Figure 6. For the pilot experiment, we used an Allen-Bradley Ultrasonic Sensor and a pseudo-reflective photo-eye to trigger the reading process and an Edwards-Signaling five-color light-stack to provide participants with visual feedback of their progress. Also, audio notification was provided using a buzzer when the gate opened.

Figure 5. (a) Installation of the Parking Controller Portal at the Lot; (b) An Inside View of the Portal

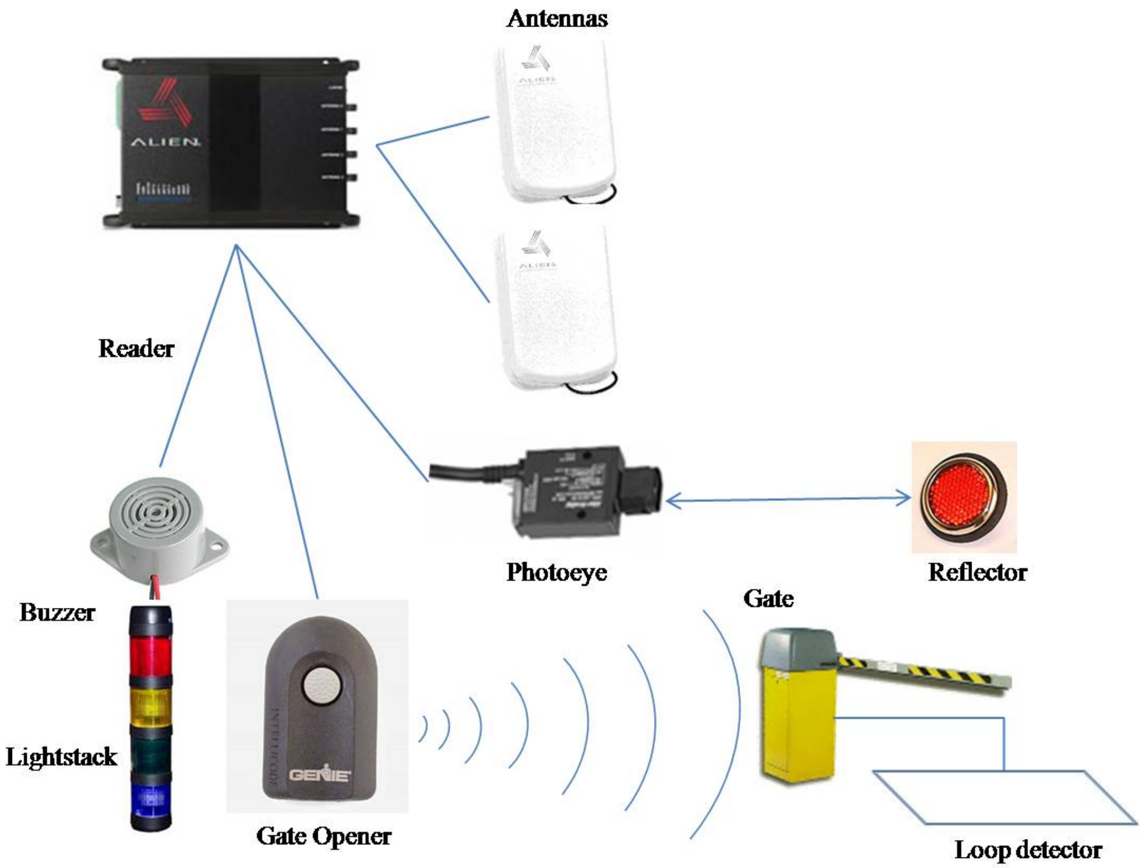

Figure 6. Key Components used in the Pilot Study

The participants were provided with a retro-fitted hangtag with an embedded ALR-9440 Gen2 "Squiggle" inlay. This hangtag was used just like the current tag, hanging vertically from the rearview mirror of the vehicle. In case a rearview mirror was not available the hangtag was taped to the windshield while keeping its orientation approximately vertical to the ground. The RFID read process was triggered via the ultrasonic sensor used for detecting objects in its path.

Figure 7 presents a simplified version of the logic of the FlexRFID Finite State Machine which was used to control the operations of the system [Sengupta 2006]. The default state of the system was State 0, in which state the light-stack showed a red light and the gate was locked. When an automobile triggered the system by blocking the ultrasonic sensor or the photo-eye, the system went to State 1, when the light-stack displayed an amber light, and the reader was turned on for 1 second. If no tag was read in 1 second, the system returned to State 0. If a valid tag was detected, the system went to State 2, the gate was unlocked, the light-stack displayed green, and the read cycle was cancelled. Once the loop detector sensed that the vehicle crossed the gate, the system returned to State 0 when the gate was locked and the red light was displayed again. While the pilot experiment was going on, other parking users who did not participate in the study, were able to enter the parking lot using the swipe cards. We made such a provision so that usual operation was not disrupted.

EVALUATION USING THE PILOT STUDY AT ABC UNIVERSITY

After conducting the pilot study and gathering all necessary information, the cost-effectiveness of the proposed university-wide RFID-based parking system was evaluated using the framework presented in Figure 8. The framework focused on estimating costs and benefits of both parties—the parking administration and the users. In estimation of benefits and costs, average or expected values were used. Individual observations/data points were plotted to check for outliers and outliers were discarded to remove bias in estimation of expected values. Both tangible and intangible dimensions of benefits and costs were captured. For example, with RFID-based systems parking administration could save operating costs which was tangible. Also, greater customer satisfaction might enhance their reputation as a service organization and this aspect of the potential benefit was intangible. The time value of money was taken into consideration by converting investments into annual equivalent monetary amounts using interest rate and capital recovery factor. The past history of parking permit issuance was used to estimate the growing trend in the number of parking users. The number of users did not change significantly for the last few years. Since the cost of deployment would not be the same for all lots due to different size and varying degrees to readiness, these factors were considered in extrapolation of cost and benefits. For the same reason, heterogeneity of users with different parking permit types was also taken into account. In the following paragraphs the procedures for estimating the benefits and costs for a potential full-scale deployment of RFID are narrated briefly.

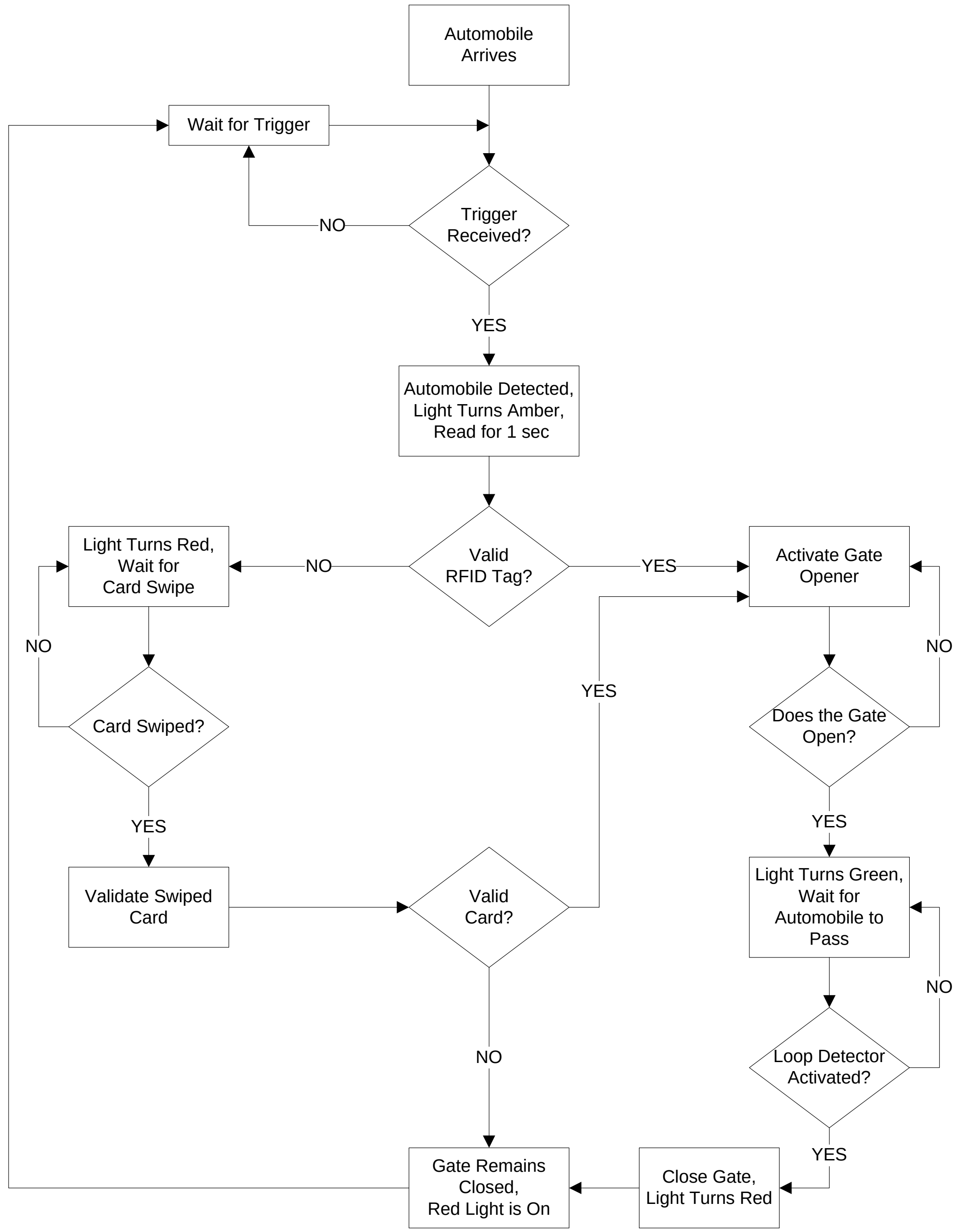

Figure 7. Logic Used in the Pilot Study to Control the Gate of the Parking Lot

Benefits

The parking administration's benefit included: 1) operational cost savings; 2) potential for more revenue; and 3) better reputation. The operational cost can be saved because during parking permit renewal old RFID tags can be used. Also, signal from the RFID reader can be monitored by security personnel, thereby reducing the chance of vandalism. Also, the technology deployment may help future projects undertaken by the parking administration. These benefits were estimated using dollar amount as well as unit-less scores. The parking officials compared the current swipe card system and the proposed RFID system and rated them on various aspects of operating cost savings, i.e., 1) easy renewal; 2) easy maintenance; and 3) future benefit. On the other hand, in order to compare these two systems in terms of dollar amount, savings were estimated using various information such as costs of current tags and RFID tags, service life of tags, number of parking users, growth rate in demand, interest rate, and past history of vandalism and associated costs. In order to estimate the potential for generating higher revenue, the following aspects were considered: 1) extra revenue due to slightly higher parking fee; 2) extra revenue due to better enforcement; and 3) slight increase in membership due to enhanced convenience offered by the new system. In order to quantify better reputation due to deployment of the RFID system, parking administration officials were asked after participating in the pilot how much they would be willing to spend for enhancing reputation by deploying such a user-friendly system as the proposed one. Also, they rated both current and proposed systems from the perspective of customer service using unit-less scores.

The parking users' benefit included: 1) time savings and 2) convenience due to ease of access. Time savings had two components: 1) less time to pass through the gate and 2) less waiting time in queue. The processing times for both systems were captured through field studies. Subsequently, the corresponding dollar savings were estimated using the parking lot usage data and data on willingness of the users to pay additional money that was captured through the survey. The savings due to less waiting time in queue was estimated using a set of queuing models capturing arrival patterns varying with the time of the day. The parameters used in the queuing models were estimated from vehicle arrivals and entry data recorded at different locations. Since the inter-arrival times at different times of the day fitted nicely with exponential distributions, we used the M/G/1 queuing model instead of simulating the scenarios. The convenience due to ease of access was estimated both in monetary amounts and unit-less scores using the responses provided by the users who volunteered to participate in the pilot study. Since time savings would vary depending on traffic patterns that changed with the hours of the day, data were collected for several days at multiple parking lots. Subsequently, this cross-sectional data that captured the location and temporal effects on traffic were utilized to extrapolate the potential time savings from full-scale RFID deployment. On the other hand, ease of access due to RFID would vary with user's utility. For the sake of simplicity we assumed that a user's utility is tied to his/her type of parking permit. In the pilot we collected information on convenience score/willingness to pay from users with each permit type. We also determined the total number of parking lot users on campus for each type of permit and subsequently calculated the total savings due to added convenience of RFID tags.

Costs

The cost of parking administration included 1) investment in the new system and 2) additional maintenance and operating cost. The cost of new system included 1) cost of technology; 2) cost of implementation; 3) cost associated with organizational and business process changes; and 4) cost of difficulty faced during implementation. The cost of technology was determined from costs of various gadgets used. The estimate of man-hours needed for implementation provided cost of implementation. The parking administration did not foresee any major change in organization or business process causing additional expenditure. The cost of difficulty faced during implementation was difficult to estimate as this required forecasting the extent of difficulty faced in future. As a rough estimate, experience of the parking administration officials in a past automation project was used as a surrogate. While these four components of costs are one-time investment cost, the benefits were calculated on an annual basis. In order to be consistent the investment costs were distributed over the five year service life of the proposed system by converting it into annual equivalent costs. In order to estimate the cost of technology and cost of implementation in a full-scale deployment, technology readiness in terms of hardware and software was evaluated and categorized by the parking administration. For each category the cost was estimated by the pilot coordinator who was an RFID expert. For projecting the cost of difficulty faced during full-scale implementation, the estimated number of man-hours for fixing difficulties was based on information from previous technology projects implemented at the university. The parking administration did not think the new system would cause additional maintenance and operating expenses.

The parking users' cost included: 1) increase in parking fee and 2) potential inconvenience that might occur due to malfunctioning of the new system. The parking administration suggested a 5 percent hike in parking fee. From the current fee structure of each type of permit and the total number of users in each category the total cost due to increase in parking fee was estimated. In order to estimate potential inconvenience caused by malfunctioning, the volunteer users were asked how much they would expect to be reimbursed per occurrence. This information was collected for users with each type of parking permit. For an estimate of the number of occurrences of malfunctioning, similar incidents in a past automation project was used as a surrogate. Since this was not an actual representation, we used conservative numbers so that the cost would be slightly overestimated, thereby reducing the attractiveness of the proposed system to some extent. However, since the contribution of this component of cost was minimal the approximation was not likely to affect the results of the analysis to a great extent.

Results

The benefits and costs, estimated in dollar amount, are presented in Table 3. They were used to calculate the benefit-cost ratio. The benefit-cost ratio of the proposed RFID system is 4.17. This means the estimated benefit from the new system would be more than four times the cost. This justifies the deployment of the proposed RFID-based system economically. If we consider the parking administration's benefits and costs only, the benefit-cost ratio is reduced but it is still significantly above one (2.72). Even if we use a factor of safety of 2, parking administration's benefits still outweigh the costs by 36 percent. The higher value of the overall benefit-cost ratio, compared to the one specific to the parking administration, indicates the RFID system would generate significantly more benefit for the parking users compared to the costs they would have to pay. Also, we conducted a separate break-even analysis solely based on parking administration's costs and returns, and found the breakeven point would be reached in little more than two years.

Table 3. Estimated Benefits and Costs (in Dollars) on an Annual Basis

Benefit			Cost		
Parking Administration	Parking Users	Total	Parking Administration	Parking Users	Total
$102,169	$364,908	$467,077	$37,953	$74,380	$111,973
Benefit-Cost Ratio: **4.17**					

Table 4 summarizes the overall ratings of the current system and the newly proposed RFID system using unit-less scores. Both systems were evaluated using various criteria presented in Figure 8. The relative importance of these criteria was obtained by asking the parking officials to rate the criteria on a 1 to 9 scale [Saaty 1990]. Some iterations were needed to obtain a consistent rating and subsequently normalized weights were obtained. The ratings of both systems were multiplied by normalized weights to get normalized scores for both alternatives. Higher the score better is the alternative. It can been seen in Table 4, the RFID system would do overwhelmingly better than the current system in generating benefits for both parking administration and users. On the other hand, the current system would be slightly better than the RFID system in keeping the cost low for both parking administration and users. However, after relative weights of benefits and costs were accounted for the overall rating significantly favored the proposed RFID system over the current system. Thus, using various analyses we established the cost-effectiveness of the RFID system.

Table 4. Estimated Benefits and Costs Using Analytical Hierarchy Process (AHP)

	Benefit of Parking Administration	Benefit of Parking Users	Cost of Parking Administration	Cost of Parking Users	Final Score
Relative Weights	0.1538	0.6122	0.0429	0.1911	
Score of Current System	0.2850	0.3258	0.5293	0.5144	**0.3643**
Score of RFID System	0.7150	0.6742	0.4707	0.4856	**0.6357**

Note: The parking administration and users provided responses in different easily comprehensible scales. The relative weights and scores presented here were normalized. The consistency ratio of relative weights was 0.0912 (i.e., less than 0.10) indicating stable ratings.

Sensitivity Analysis

While the results obtained above provided evidence for justifying deployment of RFID technology in the parking operations at this university, we examined how the cost-effectiveness would vary with different parameters used in estimation of benefits and costs. It can be observed from Table 5 that the B/C ratio decreased with increase in interest rate. With higher interest rate cost of initial investment weighed more heavily and hence the attractiveness of the new system diminished slightly. However, the amount of decrease was not significant as the annual equivalent cost of users was more than that of the parking administration (as shown in Table 3) and the annual users' cost was not affected by the interest rate. This indicated that overall cost-effectiveness of the proposed RFID system was quite stable.

Table 5. Change in B/C Ratio with Change in Interest Rate

Interest Rate	5%	10%	15%	20%
[1]B/C Ratio	4.17	4.07	3.97	3.89
[2]B/C Ratio	2.72	2.55	2.40	2.28

1: B/C ratio calculated based on benefits and costs of both parking administration and parking users
2: B/C ratio calculated based on benefits and costs of parking administration only

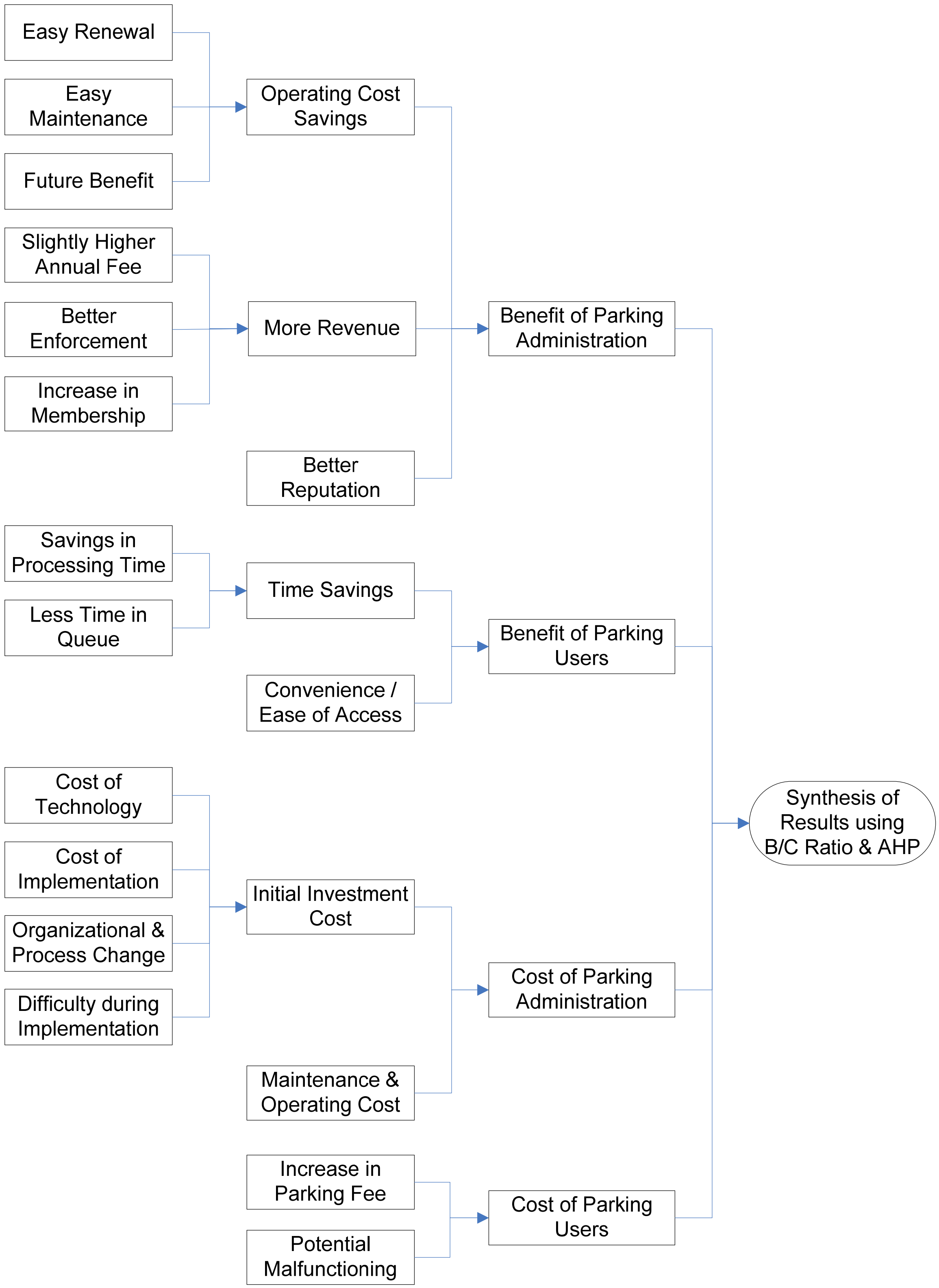

Figure 8. Framework for Estimation of Benefits and Costs in the Case Study

Table 6 presents the pattern of change in B/C ratio with change in service life of the RFID system. As expected, the B/C ratio increased with increase in service life since longer service life would ensure sustained streams of benefit. As the parking administration would spend money on the RFID system, with longer service life of the RFID system the parking administration's return would be much more. This is reflected in the higher percentage change in parking administration specific B/C ratio with increase in service life compared to the corresponding change in the overall B/C ratio.

Table 6. Change in B/C Ratio with Change in Service Life of the RFID System					
Service Life	3 years	4 years	5 years	6 years	7 years
[1]B/C Ratio	3.50	3.89	4.17	4.38	4.55
[2]B/C Ratio	1.72	2.23	2.72	3.17	3.60

1: B/C ratio calculated based on benefits and costs of both parking administration and parking users
2: B/C ratio calculated based on benefits and costs of parking administration only

It is interesting to observe the pattern of the change in B/C ratios with the change in percentage increase in parking fee (as shown in Table 7). The overall B/C ratio decreased with increase in parking fee because it increased the users' cost making it a very significant portion of the overall cost, which in turn reduced the overall B/C ratio. On the other hand, parking administration specific B/C ratio increased with increase in parking fee because the increase in parking fee enhanced the revenue potential for the parking administration and hence it improved the benefit. Although the B/C ratio showed some volatility with respect to change in parking fee, it was above one in all scenarios including the one when the parking fee remained unchanged. This also substantiated the cost-effectiveness of the RFID-based system.

Table 7. Change in B/C Ratio with Change in Parking Fee						
Percentage Increase in Parking Fee	0%	1%	2%	3%	4%	5%
[1]B/C Ratio	8.20	6.74	5.78	5.09	4.57	4.17
[2]B/C Ratio	1.05	1.38	1.72	2.05	2.38	2.72

1: B/C ratio calculated based on benefits and costs of both parking administration and parking users
2: B/C ratio calculated based on benefits and costs of parking administration only

V. CONCLUSIONS

In the preceding sections we have discussed how a pilot study can be used to justify implementation of technology projects. The pilot study often involves not only the agency or owner of the project, but also the customers/users of the technology who would eventually benefit from the project. Hence, it is important to capture users' feedback in a systematic way and incorporate it in the decision making process. This is even more important in justification decisions for user-centric technology. One approach is to estimate all possible benefits and costs in terms of monetary amounts and weigh benefit against cost. Alternatively, relative importance of various decision criteria may be established and the ratings under each of the criteria can be assimilated into overall normalized scores. Irrespective of the evaluation scheme the essence of the pilot study remains important to take the next big step, i.e., implementation of the full scale project. While a pilot study may or may not be able to capture all intricate details of the actual project, with careful planning and design it can address many potential issues which would not be possible to consider without a pilot. With the help of an actual pilot study, we demonstrate how such a study can help the decision makers to justify implementation of technology projects.

Another important contribution of the paper is to identify and estimate some of the tangible and intangible components of benefits from RFID technology. While few articles in the literature discuss these benefits of RFID, we are yet to see any numerical estimates. Here, with the help of a real life pilot study we estimate various dimensions of benefits for the project owner as well as the users, and analyze feedback received from both parties. While the findings are specific to RFID application in parking, they can provide useful guidelines for evaluating the cost-effectiveness of the RFID technology for other applications.

MANAGERIAL IMPLICATIONS

There are several managerial implications of this research. From academic perspectives, we proposed a structured methodology for using pilot study to economically justify a new technology project; and listed the important steps involved in design and evaluation of pilot studies, and interpretation of results. We proposed a general purpose framework and showed how a well-established technique such as AHP can be used for doing a formal cost and benefit analysis in a pilot study. We provided a thorough breakdown of the various tangible and intangible benefits and costs that could be included in a pilot study. We also provided validation to the proposed framework for cost benefit analysis by using it in a real life pilot study involving RFID tags for automatic operation of parking gates at a US university.

There are a number of implications from practitioners' perspectives. The paper shows how to do a pilot study for RFID based new technology projects. In this paper, the application of RFID was in parking operations. But similar pilot studies can be undertaken to verify if use of RFID in other application areas is justifiable. The research also details cost-benefit analysis from the perspective of different agents that are involved in the implementation of a technology project and shows that the results of the pilot study may convey different lessons to different participants in the project. The authors justify the use of sensitivity analysis for cost-benefit calculations while keeping in mind the long term changes in conditions that may affect the sustenance of the RFID parking project. Both tangible and intangible costs and benefits associated with the RFID parking project are identified and generalized methods are presented to compare them on a numerical basis.

FUTURE RESEARCH

It is possible to extend the research described in this paper in a number of ways in future. Apart from benefit-cost ratio, we used AHP for deciding the tradeoffs between benefits and costs of the project for parking administration as well as parking users. Although AHP is an elegant method that allows us to compute unit-less scores, other methods may be used in the future. An interesting future study will be to compare the performance of AHP with that of the other methods such as payback period, internal rate of return, multi-criteria scoring model, balanced scorecard, and multi-attribute utility theory. Also, the pilot study using the RFID based system was conducted at a university setting. If a similar study is conducted at a commercial parking lot located in a busy metropolitan area, the results may or may not be different as the cost and benefit considerations will vary. Although we have used the pilot study to test the viability of a RFID-based parking system, a similar pilot study can be envisaged for the use of RFID tags in retail stores like Wal-Mart, Target, GAP, and Louis Vuitton. The varying user population of these retail stores and their different costs and benefits makes such a pilot study interesting, challenging, and potentially useful.

The current study focuses on viability of new technology project mainly from perspectives of various dimensions of benefits and costs. Other environmental factors such as social, technological, and competitive conditions may also potentially influence the justification decision. It may be an interesting future work to investigate how these factors may be considered in a pilot study.

LIMITATIONS

In this paper we did not deal with details of statistical design of experiments since it was outside the scope of the current study. However, it may be relevant in some pilot studies and pilot designer should consult appropriate references. We also did not discuss the reliability and validity of the questionnaire used. For studies where design of survey instrument is absolutely critical, testing reliability and validity is a must. The interested readers may refer to the rich literature available in social sciences regarding this matter. Also, multiple case studies with more detailed sensitivity analysis may provide additional insight.

We want to point out another limitation of this paper. Based on the results obtained from the pilot study the university parking officials felt very positively about RFID technology deployment. However, a final decision has not been reached yet. It will be interesting to study if the justifications provided from a pilot study are closely related to the returns from the actual project in future. Nonetheless, the current research provides several useful guidelines for conducting pilot study and interpreting the results, and it is hoped that practitioners can benefit significantly from this real-life study.

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APPENDIX

Questionnaire for the participants of the pilot study

Once you have used the parking lot gate at least once, complete the following questionnaire and return it to us (use the provided envelope).

1. The new RFID system that you have used in this pilot is likely to save your time.
How much would you be willing to pay to save 5 hours of your valuable time over a year? $______

2. What type of parking permit do you presently use? ___A ___B ___C ___R ___Handicap ___Other

3. How much extra would you be willing to pay annually to take advantage of easy access from this new system? $________

4. Rate the convenience of the parking system on a 1-10 scale (10 being the best, 1 being worst)
Current system: ________ **New** system: ________

4. On a scale of 1-10, compare the relative importance of saving time and convenience of easy access.
Saving time: ________ Easy access: ________

5. Most likely, the new system will be as stable as the current swipe card system. However, there may be some risk of malfunctioning during the initial stage of deployment.
Suppose you get reimbursed for an event of malfunctioning, how much would you expect to receive? $________

6. On a scale of 1-10 how would you rate your inconvenience in the case of a malfunction? (10 – most inconvenient, 1 – least inconvenient)
Current system: ________ **New** system: ________

7. Do you have any comments on this system? Please write any comments or reactions you have after using this system. All comments you write will be confidential.

Thank you for your participation.

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