Innovations Deserving Exploratory Analysis Programs

Transit IDEA Program

Effortless Passenger Identification System

Final Report for
Transit IDEA Project 70

Prepared by:
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June 2013

TRANSPORTATION RESEARCH BOARD
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EXECUTIVE SUMMARY

The objective of this project was to evaluate the technical, operational, and economic feasibility of using medium-range radio frequency identification (RFID) technology to track transit passengers. The stages of the Effortless Passenger Identification System (EPIS) project consisted of four main tasks including field testing, controlled testing, consumer acceptance, and both operational and economic feasibility.

Detailed passenger ridership data can improve the efficiency and effectiveness of transit planning, operations, and reporting. The RFID tags used by an EPIS system can be read at longer distances than contactless or proximity cards currently used in the industry. This characteristic allows passengers to be identified and counted as they board and alight vehicles without requiring them to physically present their card within a short distance of an on-vehicle reader.

The medium-range reader used during field testing at North Dakota State University (NDSU) successfully recorded riders boarding the bus almost 90 percent of the time. The RFID tags used at NDSU were attached to the outside of student backpacks allowing for little interference between the card and the reader. Controlled testing results indicated that the reader received a valid signal from the RFID card if it was in plain sight and there was no interference present. When riders boarded the bus with the card either in their pockets or against their cell phones, the read quality dropped dramatically. However, read quality was very good when the RFID card was attached to a metal wheelchair.

The consumer acceptance task evaluated the RFID perceptions of college students, people with physical and mental disabilities, and parents of school-aged children. Overall, all three groups believed that RFID technology has merit with respect to bus transportation. Many respondents felt that an RFID card kept in a wallet or pocket would be more efficient for the riders and system as a whole. Students largely agreed that they would like to see RFID implemented at their college or university, replacing the use of their current student ID cards. Also, most felt that using RFID technology would reduce boarding times and keep the buses running on schedule, which is a main benefit when implementing an RFID system. However, the main obstacles and resolutions for successful implementation are the issues of multiple reads occurring when riders get too close to the antennas, and the current inability to create a system where the cards are read successfully through clothing and when interference is present from other items such as cell phones. Measures that could be taken to resolve these issues may include more advanced RFID readers and tags that employ technologies limiting interference from clothing and electronic devices.

The economic feasibility of EPIS was evaluated by conducting a thorough cost-benefit analysis simulating different agency and ridership scenarios. The analysis identified the economic impacts of EPIS on the agency, riders, contracting agencies, and other external stakeholders. The economic impacts in this analysis were quantified by identifying explicit and implicit costs and benefits over the life cycle of the investment. Measures including net present value (NPV), cost-benefit ratio (CBR), and internal rate of return (IRR) were calculated for each alternative to determine the economic feasibility of EPIS for different agencies and ridership scenarios. The analysis showed that with proper ridership numbers and varying percentages of non-student riders, EPIS technology can provide an economic benefit to transit agencies.

1. IDEA PRODUCT

Detailed passenger ridership data can improve the efficiency and effectiveness of transit planning, operations, reporting, and accounting. However, existing passenger identification and fare management systems often do not meet transit agency or rider needs and in some cases, these technologies provide costly, unnecessary capabilities that go unused. For example:

- A large number of riders have difficulties using proximity cards because of their physical or mental disabilities.
- Many riders use transit fare-free, notably those in university communities. At the same time, there is growing interest in system-wide, fare-free service as many transit agencies do not recover fare revenues in excess of the cost of collection.
- Transit agencies often contract with organizations to provide service to clients who, in turn, do not pay fares. However, accounting for service use is still required.
- Many riders, including children as well as some elderly and disabled riders are fragile. They and their custodians have special requirements including the need for assurance that riders are transported safely and securely and that they are picked-up and dropped-off at the correct location and time.
- Increased waiting times and travel times often result when riders must take extra time to present their ID cards within a close proximity to the reader while boarding the bus.

In each of these situations the transit agency would benefit from collecting passenger information. However, the agency might be unable to gather that information without rider effort or by operating a relatively costly and complex system. A potential solution to these situations is the use of medium-range radio frequency identification (RFID) technology to track riders.

2. CONCEPT AND INNOVATION

The RFID tags used by an Effortless Passenger Identification System (EPIS) can be read at longer distances than contactless or proximity cards currently used in the industry. This characteristic allows passengers to be identified and counted as they board and alight vehicles without requiring them to physically present their card within a short distance of an on-vehicle reader. The technology has already found a market in pupil transportation. There are many transit agencies, applications, and rider segments that are expected to benefit from deployment of EPIS.

Figure 2.1 illustrates the interface between the RFID Tag or card, RFID Reader, and the Host. The RFID air interface occurs when the tag is read from a distance and the information (time and location) is recorded by the reader. This information is then sent to a host server. Analysis can then occur analyzing various tags including their read times and frequencies.

FIGURE 2.1 RFID interface

3. INVESTIGATION

The objective of this research is to evaluate the technical, operational, and economic feasibility of using medium-range radio frequency identification technology to track transit passengers. Specifically, this study focuses on the technical, operational, and economic feasibility of the technology.
The investigation begins with field testing methodology and results from tests that were conducted in Los Angeles, CA and Fargo, ND followed by a discussion of the controlled testing that was also conducted in Fargo, ND. A consumer acceptance evaluation that includes findings from the field tests and the controlled test as well as additional survey results is then summarized. Finally, both the operating and economic feasibility of implementing an EPIS system are analyzed with a conclusion section summarizing the report.

3.1 FIELD TESTING

Field testing of the EPIS system was conducted in Los Angeles, CA using Foothill Transit agency buses and students from Rio Hondo Community College. Additional field testing was conducted in Fargo, ND using Metro Area Transit (MATBUS) buses and students from North Dakota State University (NDSU). The methodology for both field tests included recruiting students to carry an RFID card while using their respective transit system to travel to and from campus. Students were recruited via blanket LISTSERV emails to the student body and asked to pick-up an RFID card at a specified time in their student union. They carried this card with them while using the transit system that served their respective campus and were also required to keep a travel log of when and where they boarded and alighted the bus. Finally, they were asked to complete a survey of their experience after using of the technology. Students were given a $25 gift card to their campus bookstore once they completed the travel log and the survey.

3.1.1 Foothill Transit Field Test

The Foothill Transit field test was conducted from June 25-29, 2012 with students from Rio Hondo Community College. A route that served the campus on a daily basis was chosen for the testing. The recruitment email was sent to the student body on June 4th and by June 6th, 2012 80 students had enrolled in the study. Because there were only 50 available spots, the last 30 students to register were placed on a waiting list and would be added to the main study participation list if any of the first 50 registered declined to participate.

The radio frequency identification (RFID) readers and cards were provided by Zonar Systems[1]. These were included within their Zpass student tracking system. This system is traditionally used for school transportation. It is designed to track and monitor students as they get on and off the school bus. The reader scans the card when the student boards and alights the bus and records the time and location where the scan took place. Figure 3.1 shows an example of a Zpass reader that is installed in a school bus as well as a student ID card carried by a student.

FIGURE 3.1 Zpass reader and student ID card

A total of 80 students at Rio Hondo College were preregistered to receive RFID cards for testing. A total of 30 students actually signed up including 10 students during the second and final day that had not preregistered ahead of time. The research team found that many students enrolled after they saw the $25 gift card opportunity in the recruitment email and failed to read the requirements to receive the gift card. After they were made aware of the additional requirements (travel log, survey) many were unwilling to participate. Also, 10-15 students showed considerable apprehension towards being tracked by the RFID reader on the bus. They felt it violated their privacy and were unwilling to partake in the testing process. There was a great range of concern with respect to privacy and the RFID field test at Rio Hondo. Students either had no concerns or major concerns related to RFID technology and privacy. Unexpectedly, the Zpass readers that were installed on Foothill Transit buses were unable to read the RFID cards from a medium-range and as a result, usable ridership data was not collected. Zonar no longer sells or supports the medium-range readers for school transportation because they have been proven ineffective while tracking students. However, interesting and useful findings did result from the consumer acceptance student survey and will be discussed in the consumer acceptance section of this report.

3.1.2 MATBUS Field Test

The Metro Area Transit (MATBUS) field test was conducted from Sept. 17-21, 2012 with the help of students from North Dakota State University (NDSU). Two different routes that serve the NDSU campus were chosen based on high student ridership and frequency of service. A recruitment email was sent to the student body on Sept. 10th and 200 students had enrolled by the end of the following day. The research team decided to use a first come first serve approach with this test and the first 50 students to arrive and receive their RFID tag at our information table would participate. The tags were distributed to students in less than two hours.

The RFID reader for this field test was provided, along with the tags, by Alien Technology[2]. Traditionally, RFID readers are used for tasks such as tracking packages along a conveyor belt, tolling and vehicle tracking, luggage tracking at airports, as well as race/marathon tracking. Tracking students boarding and alighting a bus is not its normal function. Two antennas were installed on the bus, one near the front and another near the rear door to record reads when students entered at the front door and alighted through the back. Figure 3.2 shows the specific reader (the ALR 9900+) that was used for the field test. Three different RFID tags were also used by students to determine whether or not there was a difference in read quality among them.

FIGURE 3.2 Alien Technology ALR 9900+ reader

The RFID tags were laminated and attached to a plastic loop that was fastened onto student book bags. This allowed the reader antenna to locate and read the tag without any interference from a student's cell phone, wallet, car keys, etc. Interference was a problem with the controlled testing and to get the best results, fastening the tags to student book bags was deemed necessary. As opposed to Rio Hondo College where a number of students showed apprehension towards using the technology, no students at NDSU showed any apprehension nor did they ask any privacy related questions.

When a read was recorded on the Alien ALR 9900+ reader the Tag ID number along with the time of the first and last read are shown. The number of reads and which antenna picked-up the reads are also shown. Unfortunately, a global positioning system (GPS) was not connected to the reader so it was unknown where the student boarded the bus. Also, during the test, all three of the RFID tags worked similarly with respect to read quality.

Comparing the travel logs to the reads from the RFID tags indicated that the reader picked up and recorded a signal nearly 90 percent of the time. This was acceptable, but the technology would need to be almost 100 percent effective to be implemented successfully. A single reader was installed and ran on two different routes during the weeklong test and, unfortunately, many of the trips recorded in the travel logs occurred on a bus without a reader, so these trips could not be included in the analysis. Results for the NDSU field test are shown in Table 3.1.

TABLE 3.1 NDSU Field Test Results

Day	Log Rides Recorded	RFID Rides Recorded
Monday	4	3
Tuesday	6	6
Wednesday	7	6
Thursday	3	3
Friday	5	4
Totals	**25**	**22**

3.2 CONTROLLED TESTING

Controlled testing was conducted on Sept. 10 with help from the Vocational Training Center (VTC) in Fargo, ND. The VTC specializes in providing vocational services and employment opportunities for individuals with disabilities. A MATBUS paratransit cutaway bus was used for the testing and equipped with the same RFID reader and antennas that were used in the MATBUS NDSU test (Figures 3.3-3.5). Five individuals aided us in testing the reader and tags. The eight different scenarios used to test the effectiveness of the equipment included:

1). Boarding the bus with riders holding the RFID cards
2). Boarding the bus with the RFID cards in riders empty pockets
3). Boarding the bus while riders held their cell phones and RFID cards
4). Boarding the bus while riders held their keys and RFID cards
5). Boarding the bus while riders held their cell phones and keys and RFID cards
6). Boarding the bus while having some riders stand near the back antenna holding RFID cards
7). Wheelchair rider boards holding an RFID card
8). Boarding wheelchair with RFID attached to the frame

FIGURE 3.3 RFID reader mounted in paratransit bus

FIGURE 3.4 Front RFID antenna in paratransit bus

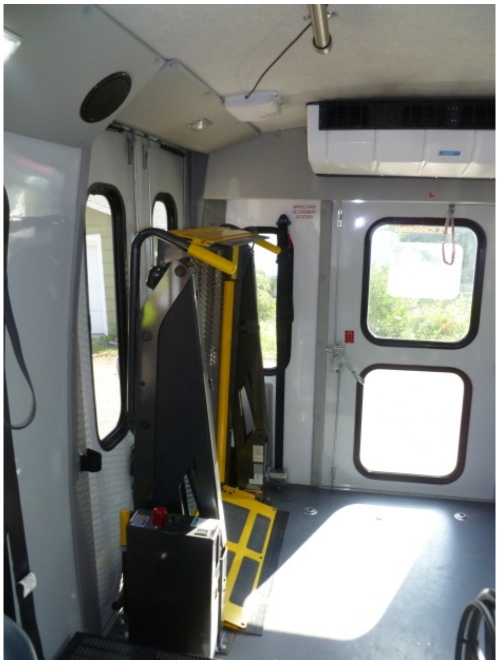

FIGURE 3.5 Wheelchair antenna in paratransit bus

When riders boarded the paratransit bus while holding the RFID tag, the reader read every tag successfully, however, when the tag was placed in the rider's pocket, only two out of six tags were read successfully. Cell phones were then held in the same hand as the RFID tag and only one tag was read. The next test had riders board the bus while holding their keys and an RFID tag in the same hand. All six tags were read successfully with this test. Then, three riders boarded holding cell phones and three others boarded holding keys and the riders holding the cell phones tags were not read while the riders holding keys were read successfully. The next test involved three riders standing near the back antenna close to the wheelchair lift while three other riders boarded at the front of the bus. With this test we were trying to see whether or not both antennas could pick up a signal and send it to the reader simultaneously, and all six tags were read successfully. A wheelchair rider then boarded the bus via the wheelchair lift holding an RFID tag. The antenna picked up the signal correctly until the rider placed one of his fingers over the tag and the signal lapsed. Finally, an RFID tag sticker was secured to the frame of the wheelchair and loaded with the wheelchair lift. The tag was read successfully with this scenario. Complete results for the controlled testing are seen in Table 3.2.

TABLE 3.2 Controlled Testing Results

Scenario	Successful Reads
Boarding the bus while holding the RFID cards	6 of 6
Boarding the bus with the RFID cards in empty pockets	2 of 6
Boarding the bus while holding cell phones and RFID cards	1 of 6
Boarding the bus while holding keys and RFID cards	6 of 6
Boarding the bus while holding cell phones and keys and RFID cards	3 of 6
Boarding the bus while having some riders stand near the back antenna	6 of 6
Wheelchair rider boards holding an RFID card	1 of 1
Boarding wheelchair with RFID attached to the frame	1 of 1

3.3 CONSUMER ACCEPTANCE

Consumer acceptance data was collected using three main groups including disabled adult transit riders, parents of K12 and early education students, and adult university student transit riders. Focus groups as well as surveys were used to collect the relevant consumer acceptance information.

3.3.1 Disable Adult Transit Riders

The Vocational Training Center (VTC) volunteers were asked about their attitudes towards using RFID technology to track transit passengers on Paratransit vehicles. They felt that the technology was useful and easy to use. Due to cognitive disabilities, however, they were unable to answer many of the consumer acceptance questions accurately. The supervisors at the VTC felt the technology showed merit and would be easy for disabled riders to use. Overall, they felt that an RFID tag that could be kept in a pocket or wallet would be more effective than one held or attached to a purse or backpack. The risk of loss or damage to a tag attached to a purse or wallet was thought to be too great for effective use.

3.3.2 Parents of K12 students

Parents of school-aged children were asked to complete a short five question online survey regarding their attitudes towards RFID technology and school transportation. They were contacted via email and asked to provide some general comments and possible concerns on the topic as well. A total of 14 out of 20 parents contacted in the West Fargo School District completed the survey. The respondents were all employees of the school district who had elementary age children. Parents were initially asked whether or not they felt RFID cards would increase safety for students riding the school bus. Almost all parents felt that safety would increase due to the use of this technology. Parents were then asked if using this technology would give parents peace-of-mind when their own children ride the bus and all but three respondents either agreed or strongly agreed while all but two parents responded that they would have their child use an RFID card if it were available.

Parents were also asked if they felt that the use of RFID cards would reduce boarding times and keep the buses running on time compared to using proximity student ID cards. Eight respondents agreed with this statement while six were either neutral or disagreed. Finally, parents were questioned about privacy issues with the use of RFID cards and only three respondents indicated they had some concerns while six indicated they had no concerns. Five respondents were neutral regarding this statement.

When parents were questioned regarding concerns related to RFID technology, a couple felt that students do not necessitate this kind of technology and that utilizing such a system would result in parents "hovering" over their children too much. Another parent had concerns when school transportation is contracted out to a bus company. They felt that this may be a problem because the school district does not control the bus company and the company may not be willing or able to implement such technology. Finally, regarding privacy concerns, one parent indicated that there would have to be strict regulations put in place as to who could see the information collected by the cards for legality reasons.

3.3.3 University Students

The students who completed the field test were sent an eight question survey regarding their attitudes towards RFID technology. A total of 59 students completed the survey and provided some general comments as well. This included 15 students from Rio Hondo College and 44 students from NDSU, and in general, there was little noticeable difference in responses between students at the two colleges. Initially, students were asked if the RFID card was easy to use and more than 90% either agreed or agreed strongly while no students felt the card was not easy to use (Figure 3.6).

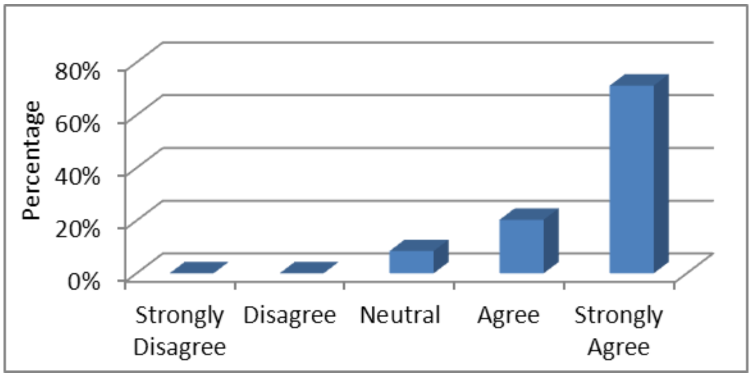

FIGURE 3.6 The RFID card was easy to use

Students were then asked to indicate whether or not they were worried about privacy issues with the use of RFID cards. Almost 90 percent of respondents were either neutral, disagreed, or strongly disagreed while only six students indicated they had some privacy concerns regarding the technology (Figure 3.7). There would have a larger number of students with privacy concerns represented if more of those with concerns would have elected to participate in the study.

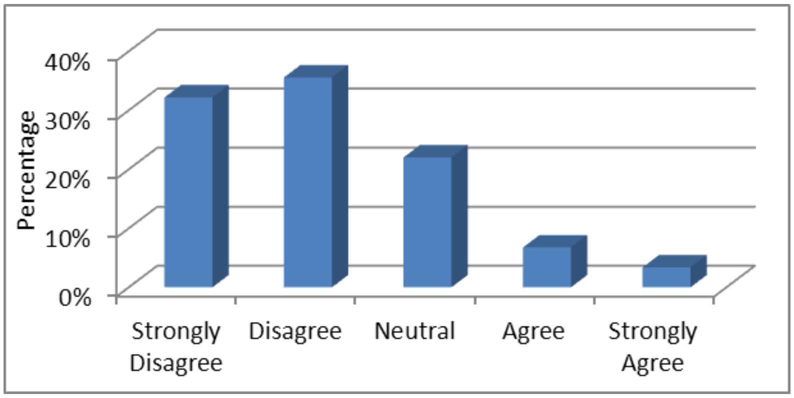

FIGURE 3.7 Initially, I worried about privacy issues with the use of RFID cards

Regarding the personal use of RFID technology, students were asked if they would use RFID cards if they were available and whether or not they preferred RFID technology to traditional ridership ID or student ID cards. Nearly 80 percent of respondents indicated that they would use RFID cards if available (Figure 3.8) while almost 70 percent preferred the RFID cards to their student IDs (Figure 3.9).

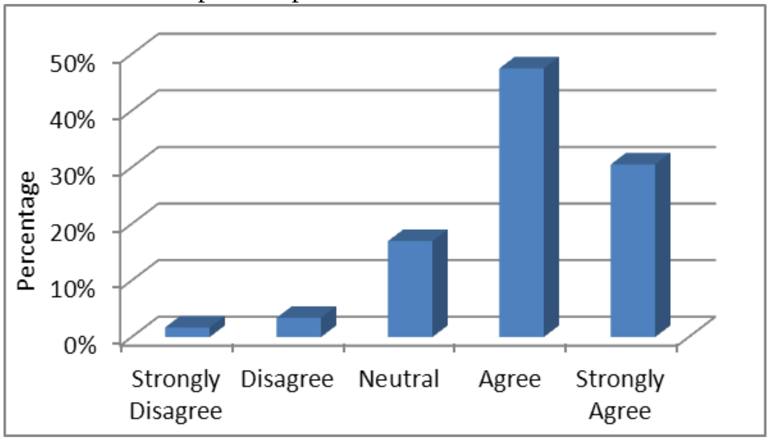

FIGURE 3.8 I would use the RFID card regularly if it was available

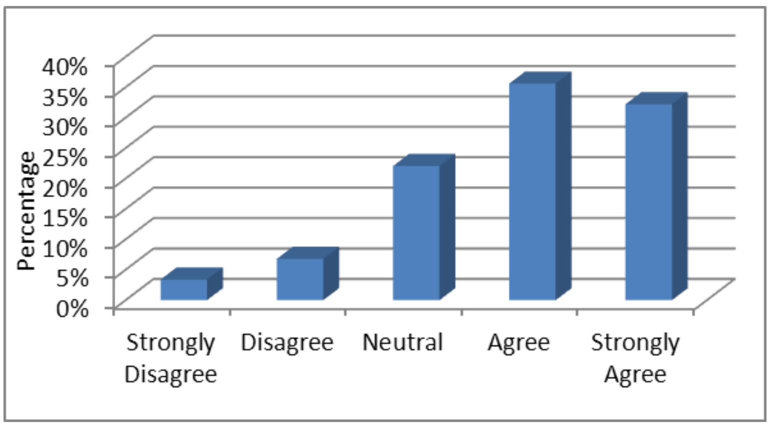

FIGURE 3.9 I prefer the RFID card over my student ID card

Although RFID is currently not useable as a form of payment for transit riders, students were asked if it was used as a form of payment, would they consider it safe. A little more than half of respondents indicated that they believe the card could serve as a safe form of payment while 27 students indicated they were either neutral or disagreed with the statement (Figure 3.10).

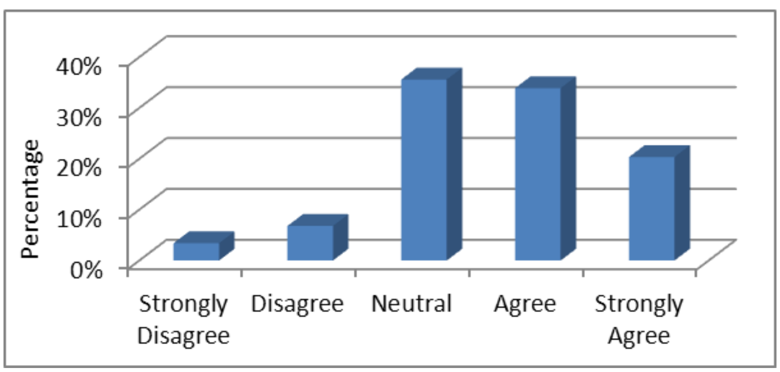

FIGURE 3.10 I consider RFID to be a safe form of payment

Students were then asked if they felt RFID cards would reduce boarding times and keep the buses running on time. More than 80 percent agreed with this statement while only one disagreement was recorded (Figure 3.11). Finally, students were asked if they would like to see RFID cards implemented within the current system and how often they used public transportation. More than 70 percent agreed or strongly agreed that they would like to see the technology implemented (Figure 3.12) while almost 30 percent were neutral in answering this question. Regarding their use of public transportation, 50 of 59 (85%) respondents indicated that they use the service either two to three times per week or everyday (Figure 3.13).

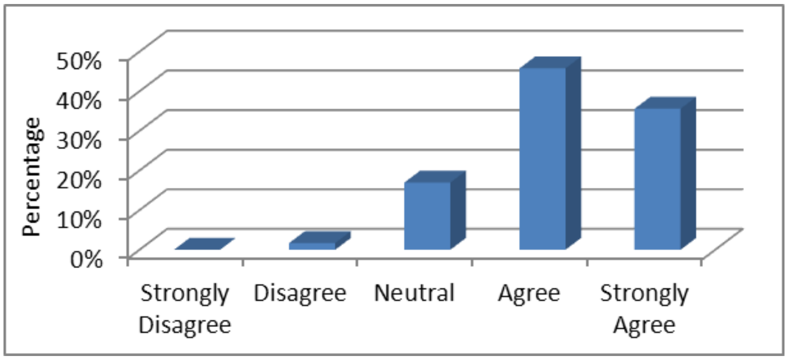

FIGURE 3.11 RFID cards would reduce boarding times and keep buses running on time

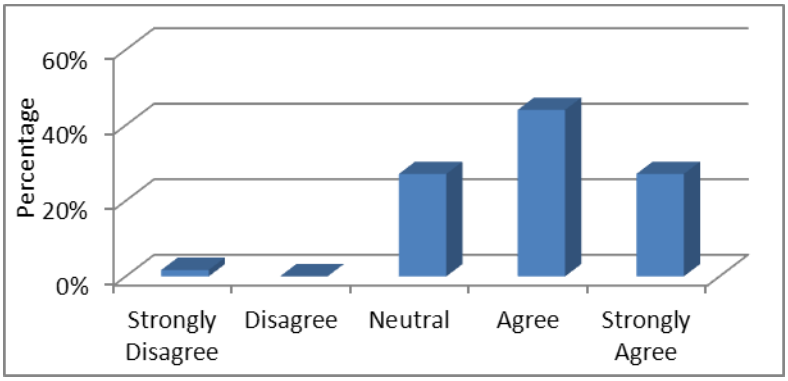

FIGURE 3.12 I would like to see RFID cards implemented within the current system

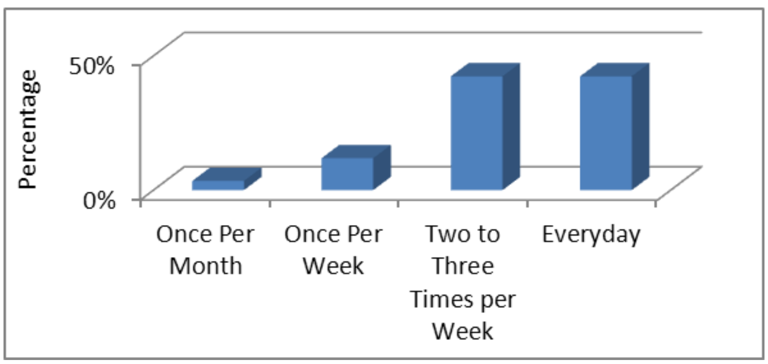

FIGURE 3.13 How often do you use public transportation?

Students were also asked to provide general comments regarding their experience using the RFID cards as well as their opinion about RFID technology as a whole. A few indicated that because the card was carried outside of their backpack attached by a plastic cord, someone who wanted it could cut it off without them knowing and use it themselves. So, they believed that if the card could be detected without being shown, that would be an improvement. Some riders also felt that carrying the card while attached to their backpack was not a good idea because it got in the way and was too large, but others indicated that having the card attached to their backpack was a good idea because they would be less likely to lose or misplace the card if it was already attached. A few other students were worried about the card being counted multiple times while they rode the bus, particularly if they were seated too close to an antenna or if they were to step off of the bus to let someone else board and then board again themselves. Overall, however, most students indicated that the technology was efficient and more convenient than having to show your student ID card every time they boarded the bus.

3.4 OPERATIONAL AND ECONOMIC FEASIBILITY

The operational and economic feasibility of EPIS was investigated to determine the effectiveness of EPIS in meeting transit agency needs. The operational needs were analyzed via the hands-on experiences from SURTC staff that aided with the installation and performed the functional tasks associated with the implementation and use of the EPIS system. The economic needs were evaluated by conducting cost-benefit analysis for different agency and ridership scenarios. Measures including net present value (NPV), cost-benefit ratios (CBR), and life cycle costing were calculated for various scenarios.

3.4.1 Operational Feasibility

The Alien Technology EPIS equipment was installed and evaluated by MATBUS and SURTC. The installation went smoothly on the paratransit cutaway bus as well as the fixed-route bus. All of the necessary components were then tested to assure accurate RFID tag reads. The Alien Gateway software was used to run the reader and test tag functionality. The Alien RFID Demonstration Software Guide[3] was helpful during all testing phases.

Different demonstration utilities are available within the Alien Gateway software to test the Alien equipment. These utilities include a tag grid, readometer, and tag programmer as well as a command line interface. The tag grid utility allows one to display a large number of tag reads on one computer screen simultaneously. This is ideal for testing the speed and efficiency with which a large number of tags can be identified. The readometer shows the tag being read as well as the relative strength and read speed of the tag. These features allow for signal strength to be captured and evaluated. The tag programmer can reprogram individual tags, but was not used during our testing. The command line interface, however, was used frequently and was effective in changing reader settings based on varying testing needs. Tag information was downloaded to a notebook computer for analysis using the command line interface as well. Overall, the equipment and software was user friendly and showed flexibility as changes made to reader settings were simple to execute.

3.4.2 Economic Feasibility

Economically, the focus was to evaluate different bus route and ridership scenarios and measure whether or not the benefits of implementing EPIS would be greater than the costs of installation and maintenance over a hypothetical equipment life cycle. The costs of the system are presented with greater detail below while the benefits were calculated based on two quantifiable advantages that would likely result from EPIS implementation. These included a decrease in engine idling time due to less waiting time at high ridership bus stops and an increase in ridership resulting from better on time route performance. For all of the scenarios below, engine idling time was decreased by 20 minutes per day. This was calculated by decreasing idling time by one minute for every half-hour route. Therefore, over a period of 10 hours, a bus would save 20 minutes in idling time. There are other potential benefits that may also occur including the benefit to riders from reducing travel time, and due to better on-time performance, a transit agency could avoid other, more costly alternatives, such as shortening routes, removing stops, or adding another bus to a route. This research does not quantify these benefits, however, as they are more abstract and difficult to quantify.

The EPIS system would allow riders who do not pay for individual rides to board the bus without presenting and scanning their bus pass through the reader. This allows for boarding to occur more rapidly and result in decreased bus idling time. Another benefit that would result from decreased idling time is that buses would be able to improve on time performance on individual routes and throughout the system as a whole. Transit agency and research findings alike have indicated that improvements in on time performance have resulted in increased ridership. Because specific increases in ridership due to better on-time performance are difficult to quantify, the cost/benefit scenarios use relatively small increases in ridership to illustrate that it does not take a large percentage increase in ridership to make the EPIS system viable. These benefits along with the applicable costs are presented in the following discussion.

The economic feasibility of EPIS was evaluated by conducting a thorough cost-benefit analysis simulating different agency and ridership scenarios. The analysis identified the economic impacts of EPIS on the agency, riders, contracting agencies, and other external stakeholders. The economic impacts in this analysis were quantified by identifying explicit and implicit costs and benefits over the life cycle of the investment. Measures including net present value (NPV), cost-benefit ratio (CBR), and internal rate of return (IRR) have been calculated for each alternative to find the economic feasibility of EPIS for different agencies and ridership scenarios.

3.4.3 Base Case Settings

The base case scenario was developed to simulate the services provided by a bus route servicing a university. The amount of service was set at a level similar to a typical route within Metro Area Transit's (MATBUS) system in Fargo, North Dakota. A useful comparison can be established with this scenario because of the ridership numbers on the route, as well as the number of non-student riders on the route. MATBUS' ridership numbers on university routes are representative of the national average. These ridership numbers were used to determine the economic feasibility of implementing the EPIS using RFID technology. The benefits of increased ridership are based on increased fare revenue generated by non-student riders. Base Case settings include:

- Two buses serving a university route within an agency's system
- Route ridership equals 130,000 annually with 40% non-student riders
- Non-student riders pay $1.50 per ride, students ride the bus route for free
- 20 minute decrease in idling time on the route throughout the day, which using the EPA Fuel Costs Savings Calculator[5] amounts to a fuel savings of $240 per year, (based on a $4 per gallon of diesel fuel).
- Assumes Discount Rate for Cost/Benefit Analysis of 8%
- 5 year life-cycle cost analysis

The Base Case included three scenarios illustrated in Table 3.3. These scenarios were used in each of the life cycle cost and benefits analyses. The three scenarios included:

- Scenario 1: 1% annual increase in ridership throughout the life cycle analysis
- Scenario 2: 3% increase in ridership in Year 1, followed by 1% annual increase each following years throughout the life cycle analysis
- Scenario 3: 5% increase in ridership in Year 1, followed by 1% annual increase each of the following years throughout the life cycle analysis

TABLE 3.3 Scenarios for each test analysis

Scenario #	Description
1	1% annual increase in ridership
2	3% increase in ridership in Year 1, followed by 1% annual increase for each following year
3	5% increase in ridership in Year 1, followed by 1% annual increase for each following year

3.4.4 Base Case Costs

Cost variables used in the simulation based on Table 3.4 included cost of equipment and labor to install the equipment on two buses. Cost also included yearly operating costs of the RFID technology. This included data management, equipment management and the costs of RFID tags. Data management was included in the cost because of the amount of time it can take to manage and analyze the data obtained from the RFID technology.

TABLE 3.4 Base Case Setting Costs

Description	Manufacturer/ Vendor	QTY	UOM	Unit Cost	Total Cost	
Alien 9900+ Reader	Alien	2	ea	$2,199.00	$4,398.00	
Alien 9680 Antenna	Alien	4	ea	$229.00	$916.00	
Fiberglass NEMA Enclosure (reader)	Hoffman	2	ea	$246.00	$492.00	
Sub panel (reader enclosure)	Hoffman	2	ea	$20.75	$41.50	
Angle Micro-Mount	Panavise	4	ea	$22.99	$91.96	
Adjusting Knuckle	Panavise	4	ea	$15.99	$63.96	
Conduit	Multiple sources	200	ft	$2.40	$480.00	
Power Inverter	Multiple sources	2	each	$50.00	$100.00	
Miscellaneous Material		2	ea	$100.00	$200.00	
Labor						
Installation/Testing		8	hr.	$98.00	$784.00	
Project Manager (for large installations)			hr.	$180.00	$0.00	
					$7,567.42	
Life cycle 3-5 years						
Data Management		5	hrs./ mo	$20.00	$100.00	per month
Equipment Maintenance		2	hrs./mo	$30.00	$60.00	per month
					$160.00	Total cost per month
RFID Tags	Alien	2000	ea	$0.20	$400.00	per year
					$2,320.00	Total cost per year

3.4.5 Base Case Results

The results of the Base Case scenarios indicate the sensitivity that ridership has on the economic feasibility of EPIS. Figure 3.14 illustrates the importance of initial ridership increases due to the benefits of EPIS; these benefits include on-time services, efficient routes and less idling times at major stops. When analyzing the life-cycle cost of each scenario with a discount rate of 8%, Scenario 1 has a benefit cost ratio of -0.23 and a net present value of ($2,262.15). While there was still a positive internal rate of return of 0.56% for Scenario 1, the costs of installation, as well as data and equipment management would not be recovered by the end of Year 5. Scenarios 2 and 3 both account for an increase in ridership during the first year and have benefit-cost ratios of 0.58 and 1.38, with net present values of $5,706.05 and $13,674.24, respectively.

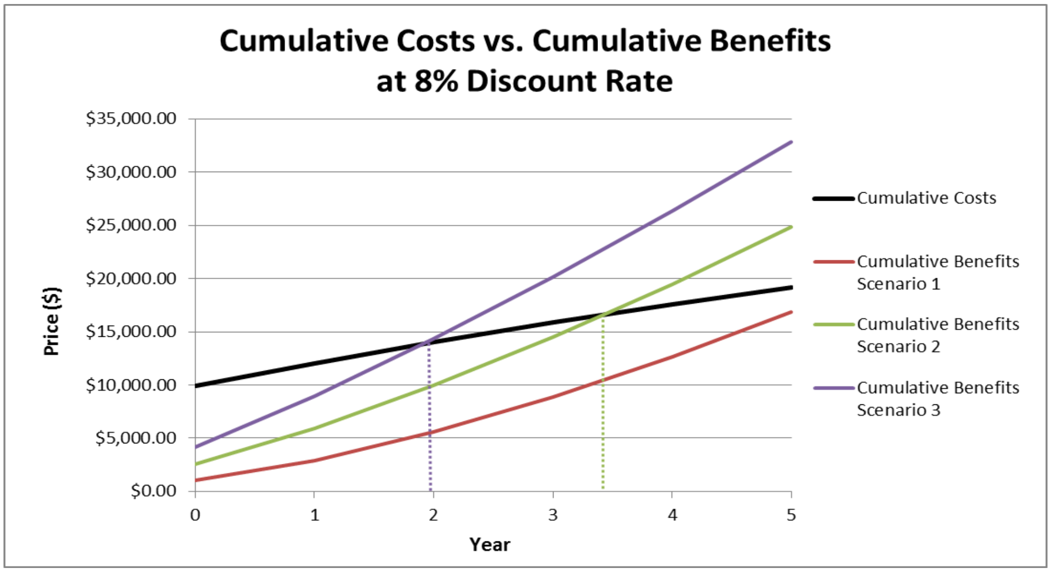

FIGURE 3.14 Base Case Life-Cycle Cost

Altering the discount rate versus net present value was not as sensitive as anticipated. Primarily, this was due to a low initial investment cost and a relatively short life-cycle (five years). Figure 3.15 shows the discount rate versus net present value for the duration of the life-cycle analysis.

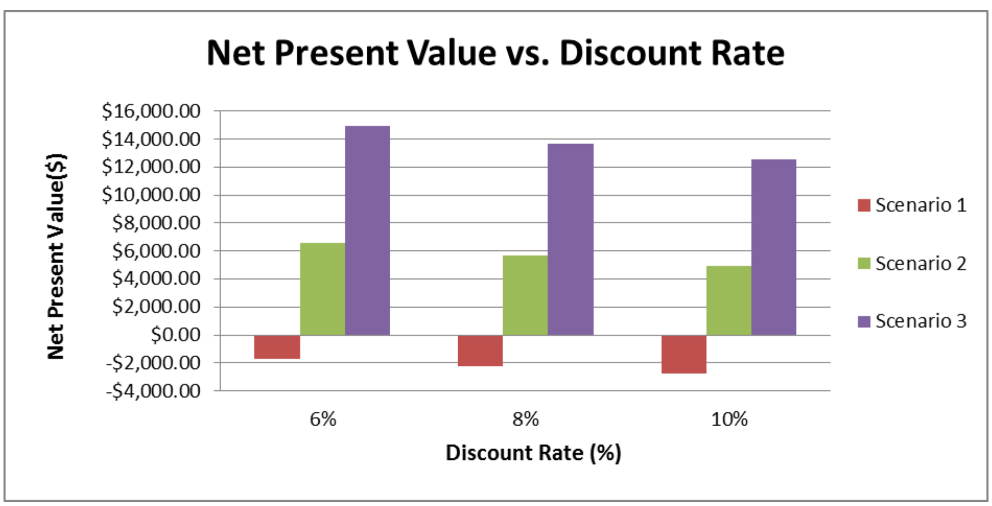

FIGURE 3.15 Base Case Discount Rate vs. Net Present Value

3.4.6 Alternative Life-Cycle Analyses

The following figures show the life-cycle costs and benefits of alternative situations a transit agency may consider before implementing EPIS technology within their system. In order to understand the economic feasibility of implementing EPIS, alternative settings were analyzed to further understand the economic benefits of this technology. The differences between the Base Case and each of the three alternatives are highlighted in Table 3.5. It should be noted that each alternative tested the same three scenarios as in the Base Case explained in Table 3.3.

TABLE 3.5 Differences between the Base Case and the Three Alternatives

Alternatives	Buses	Routes	Ridership	% non-students	Fuel Cost Savings/Year
Base Case	2	1	130,000	40%	$240
Alternative 1	2	1	130,000	25%	$240
Alternative 2	1	1	75,000	75%	$120
Alternative 3	10	7	700,000	50%	$1,200

3.4.7 Alternative 1 Life-cycle Cost Analysis

The alternative represented in Figure 3.16 analyzes the cost-benefit analysis similar to the Base Case settings. However, the non-student ridership percentage was lowered from 40% to 25%. This shows the impact student ridership has on fare box revenue. Because student riders do not pay a fare, an increase in student ridership relative to non-student ridership generates less fare box revenue. Alternative 1 simulated a transit route with 2 buses, 130,000 riders with 25% non-student riders. Because this was also a two bus analysis, all life-cycle costs were the same as in the Base Case. Figure 3.16 illustrates the sensitivity in non-student ridership percentage, in which Scenario 3 is the only scenario that would have a positive IRR (19.2%) and net present value of $2,837.17 over five years, recovering the costs of the EPIS technology at the beginning of Year 5.

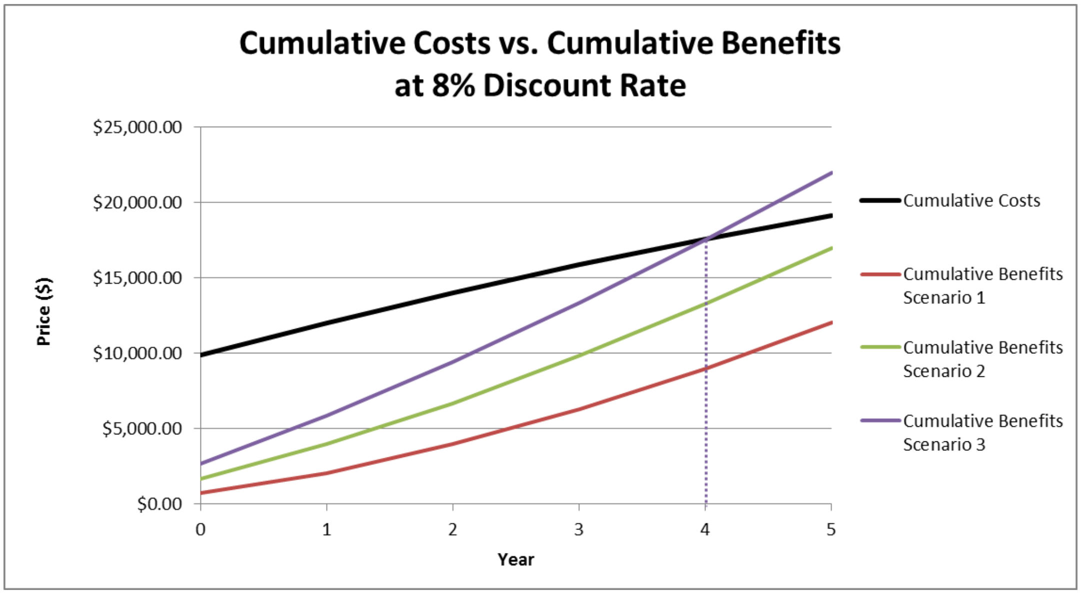

FIGURE 3.16 Life-cycle Cost Analysis for 25% Non-student Riders

Based on the 25% non-student rider alternative, Scenarios 1 and 2 would not recover costs within five years. Scenario 1 has a benefit-cost ratio of -0.72 and an IRR of -18.98% which equates to a net present value of ($7,123.08) at the end of Year 5. Scenario 2 came closer to recovering the costs within five years, but still had a negative IRR (-0.12%) and NPV of ($2,142.95). The discount rate did not play a significant role in providing a positive economic impact for Alternative 1. Figure 3.17 shows the difference between each scenario's discount rate and net present value.

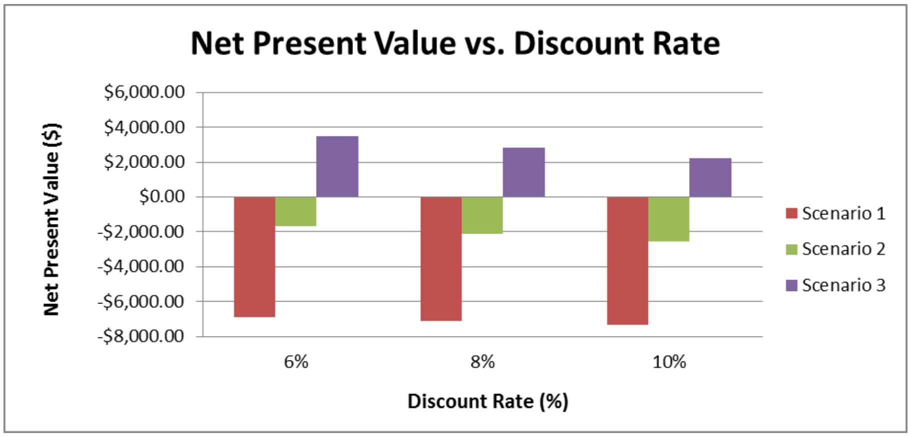

FIGURE 3.17 Alternative 1 Discount Rate vs. Net Present Value

3.4.8 Alternative 2 Life-cycle Cost Analysis

Figure 3.18 illustrates Alternative 2 results of using EPIS technology on one route, with one bus that serves 75,000 riders, of which 75% of those riders being non-student. This alternative also analyzed the three scenarios found in Table 3.3 to further help determine the feasibility of EPIS technology. Costs for this alternative were adjusted to reflect the cost of installing and maintaining the data and equipment on one bus. The yearly benefit from fuel cost savings from idling was reflected in this analysis as well. The results were favorable for each of the three scenarios. Because of lower initial investment costs and a higher percentage of non-student riders, Scenarios 1, 2, and 3 each had a positive IRR and benefit-cost ratio.

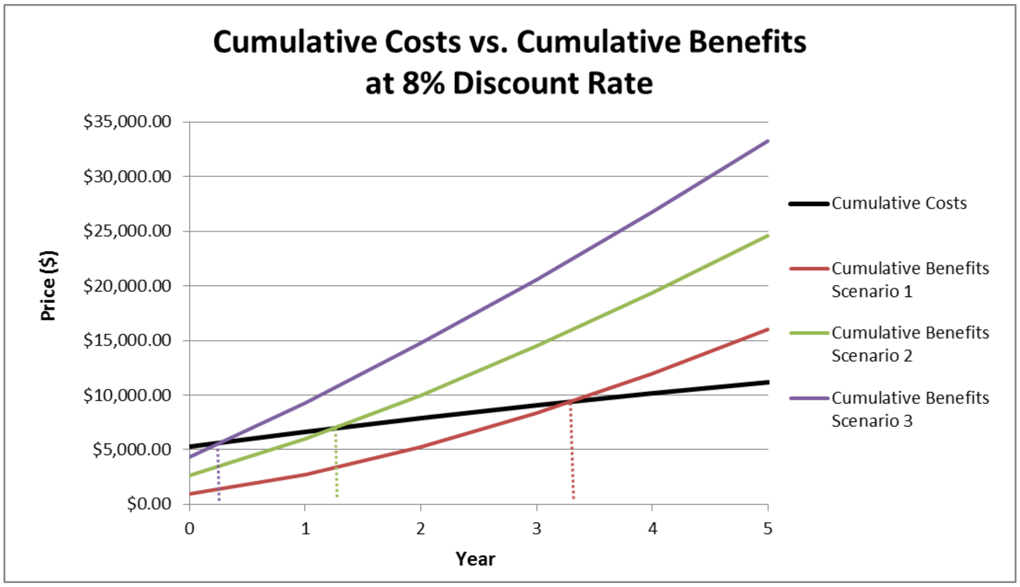

FIGURE 3.18 Alternative 2 Life-cycle Cost Analysis

Scenario 1 recovered costs in the fourth year of the life-cycle cost analysis with an IRR of 33.4% and a NPV of $4,811.93 at the end of Year 5. Scenario 2 had a NPV of $13,431.37, recovering costs in the second year of the analysis. Scenario 3 shows a strong benefit-cost ratio of 4.19 and an IRR 442.5% resulting in costs recovered its first year and a NPV of $22,050.81. Figure 3.19 shows the discount rate versus net present value for each scenario, with each of the three scenarios recording a positive net present value with a higher discount rate.

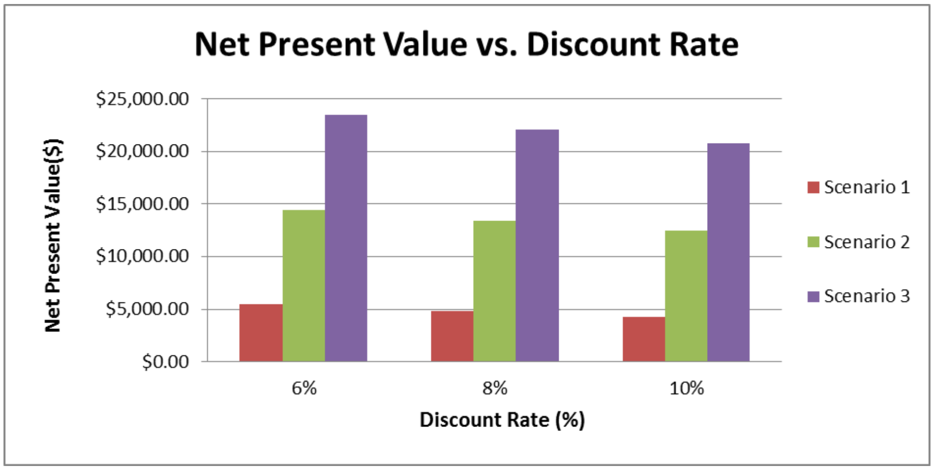

FIGURE 3.19 Alternative 2 Discount Rate vs. Net Present Value

3.4.9 Alternative 3 Life Cycle-cost Analysis

Figure 3.20 illustrates Alternative 3's life-cycle cost results. Alternative 3 analyzes 10 buses equip with the EPIS technology that served seven routes with a total ridership of 700,000, and of those riders 50% are non-student. All costs for Alternative 3 have been adjusted to reflect the costs of installation, as well as data and equipment management for the EPIS technology. The initial investment cost for 10 buses is $49,637.10, a significant difference from the other alternatives. However, the higher ridership numbers for Alternative 3 allow the costs to be recovered in each of the three scenarios before the end of the life-cycle cost analysis.

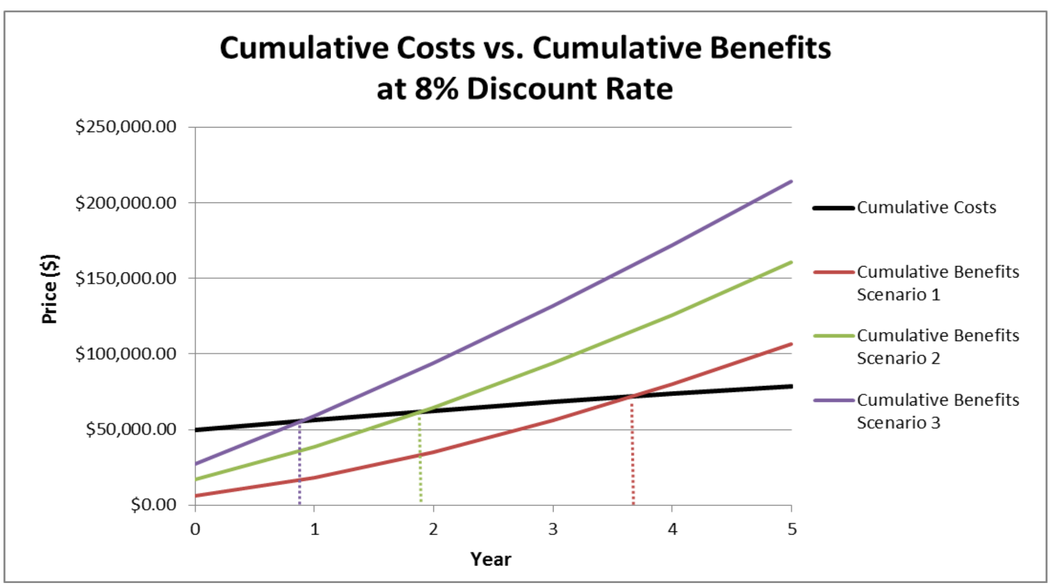

FIGURE 3.20 Alternative 3 Life-cycle Cost Analysis

Scenario 1 proved to recover its costs before the end of Year 4. The net present value of Scenario 1 at the end of Year 5 was $28,252.68, with a benefit-cost ratio of 0.57 and an IRR of 24.9%. Scenario 2 recovered its initial costs before the end of Year 2 and had a NPV of $81,884.76. As expected Scenario 3 had the highest NPV, totally $135,516.85 at the end of Year 5, and recovered its initial investment costs before the end of Year 1. The discount rate had more of an impact in this alternative because of the higher initial investment costs of the EPIS technology. Figure 3.21 shows the discount rate for each of the three scenarios versus the net present value after the five year life-cycle cost analysis.

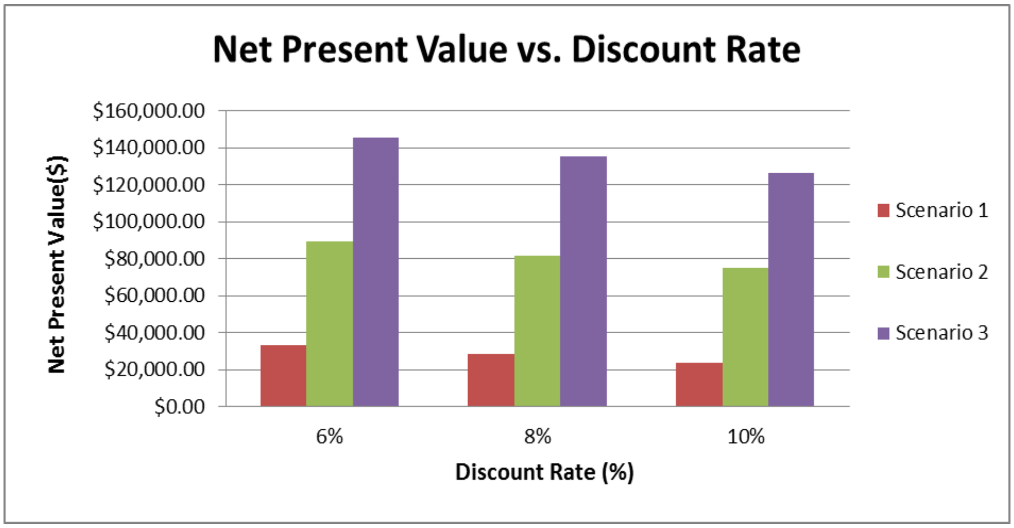

FIGURE 3.21 Alternative 3 Discount Rate vs. Net Present Value

3.4.10 Economic Feasibility Summary

The objective of the economic feasibility analyses was to determine the life-cycle costs and benefits of EPIS technology for different transit agency scenarios. Life-cycle costs proved to be tougher to recover when the percentage of non-student riders were low. This is because students represent fare-free riders in these scenarios and their ridership increases do not generate additional revenue. The majority of economic benefits from the EPIS technology were due to an increase in non-student ridership resulting in an increase in a transit agency's fare box revenue. Table 3.6 gives a summary of the life-cycle cost analysis for the Base Case, as well as each of the three alternatives tested.

TABLE 3.6 Economic Feasibility Summary

Scenario #	Benefit-Cost Ratio	IRR (%)	Life-cycle Cost ($)	NPV($)
		Base Case		
1	-0.23	0.56%	$19,150.51	($2,262.15)
2	0.58	28.35%	$19,150.51	$5,706.05
3	1.38	64.74%	$19,150.51	$13,674.24
		Alternative 1		
1	-0.72	-18.98%	$19,150.51	($7,123.08)
2	-0.22	-0.12%	$19,150.51	($2,142.95)
3	0.29	19.20%	$19,150.51	$2,837.17
		Alternative 2		
1	0.91	33.41%	$11,172.92	$4,811.93
2	2.55	110.01%	$11,172.92	$13,431.37
3	4.19	442.45%	$11,172.92	$22,050.81

		Alternative 3		
1	0.57	24.89%	$78,624.17	$28,252.68
2	1.65	66.37%	$78,624.17	$81,884.76
3	2.73	139.46%	$78,624.17	$135,516.85

Based on the analysis, Scenario 1 in each alternative took the longest time to recover costs. Scenario 1 only accounted for a 1% growth in ridership each year, which could mirror an agency's growth rate had the EPIS technology not been implemented. Scenario 2 accounts for an initial 3% growth in ridership due to more efficient and on-time routes for riders. Scenario 2 was able to recover its costs in the Base Case, as well as Alternative 2 and 3. Scenario 2 was unable to recover costs in Alternative 1 because of the low percentage of non-student riders not accounting for enough fare box revenue to recover costs before the end of Year 5. Scenario 3 analyzed the impact of a 5% increase in ridership. This represented a best case scenario in which the percentage of non-student riders and the number of buses equipped with EPIS technology allowed for full cost recovery well before the five year life cycle ended.

4. PLANS FOR IMPLEMENTATION

Findings indicated that consumers felt RFID technology has merit with respect to bus transportation. Economic analysis also showed that RFID can bring an economic benefit to transit agencies assuming its implementation leads to higher ridership due to better on-time performance. However, controlled testing of the equipment indicated that when interference was present, from clothing, cell phones, etc., card read quality dropped considerably. Because of this, field testing at NDSU was conducted with students attaching RFID cards to the outside of their book bags to minimize interference between the cards and the reader. Also, Zonar Systems has discontinued selling and supporting their medium-range readers because of their inefficiencies in tracking elementary aged children riding school buses. Therefore, in order for transit agencies to implement an effective EPIS system utilizing medium-range RFID readers and cards, current technology must be improved upon to address both read quality and interference issues that deem the system insufficient in its current form.

5. CONCLUSIONS

The study consisted of four main tasks including field testing, controlled testing, consumer acceptance, and both operational and economic feasibility. The field testing in Los Angeles, CA with Foothill Transit and Zonar Systems was incomplete because the readers installed on the buses were not medium-range readers. Therefore, field testing was also completed in Fargo, ND with Metro Area Transit (MATBUS) and Alien Technology using medium-range RFID readers. Controlled testing was conducted with MATBUS and the Vocational Training Center (VTC) in Fargo, ND using an Alien Technology medium-range reader on a Paratransit bus. The consumer acceptance task was evaluated utilizing information obtained through surveys and focus groups in both Los Angeles, CA and Fargo, ND.

The student recruitment process went well at both Rio Hondo College in West Covina, CA and North Dakota State University (NDSU) in Fargo, ND. More than enough students volunteered to help, believed to be a direct result of the $25 bookstore gift card incentive. Many students at Rio Hondo College failed to pick-up their RFID card after registering and were not included in the study findings. Others were hesitant about volunteering due to perceived privacy issues regarding RFID technology. Students at NDSU were much more responsive and the RFID cards were distributed very quickly. Also, nearly all of the NDSU student volunteers completed their travel logs and surveys while only 15 students at Rio Hondo completed both the travel log and survey. The medium-range reader used at NDSU successfully recorded riders boarding the bus almost 90 percent of the time. The RFID cards used at NDSU were attached to the outside of student backpacks allowing for little interference between the card and the reader.

Controlled testing results indicated that the reader received a valid signal from the RFID card if it was in plain sight and there was no interference present. When riders boarded the bus with the card either in their pockets or against their cell phones, the read quality dropped dramatically. However, read quality was very good when the RFID card was attached to a metal wheelchair. Multiple reads also occurred when riders boarded and stood close to the back antenna after their card read was already recorded by the front antenna near the entrance of the bus.

The consumer acceptance task evaluated the RFID perceptions of college students, people with physical and mental disabilities, and parents of school-aged children. Overall, all three groups believed that RFID technology has merit with respect to bus transportation. Many respondents felt that an RFID card kept in a wallet or pocket would be more efficient for the riders and system as a whole. Students largely agreed that they would like to see RFID implemented at their college or university, replacing the use of their current student ID cards. Also, most felt that using RFID technology would reduce boarding times and keep the buses running on schedule, which is a main benefit when implementing an RFID system. However, the main obstacles and resolutions to successful implementation are the issues of multiple reads occurring when riders get too close to the antennas, and the current inability to create a system where the cards are read successfully through clothing and when interference is present from other items such as cell phones. Measures that could be taken to resolve these issues may include more advanced RFID readers and tags that employ technologies limiting interference from clothing and electronic devices.

Economic analysis showed that with proper ridership numbers and varying percentages of non-student riders, EPIS technology can bring an economic benefit to transit agencies. Overall, varying the discount rate did not show much of a difference when compared to the net present value. This was due to relatively low initial investment costs and the short five year life-cycle. Had the investment costs been higher and the life-cycle period been longer, we would anticipate greater sensitivity when altering the discount rate with respect to net present value. It should be noted that the alternatives highlighted a range of costs, not just an average. This provides a more real-world analysis for transit agencies when considering trade-offs and the feasibility of different service options.

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APPENDIX A. PARENT SURVEY INSTRUMENT

The Upper Great Plains Transportation Institute (UGPTI) at North Dakota State University (NDSU) is studying the use of radio frequency identification (RFID) on buses. The RFID tags used can be read at longer distances than contactless or proximity cards currently used in the industry, and would be attached to a student's backpack. Therefore, riders would not have to show or scan their cards through a reader when they board the bus. The RFID reader would collect the time and location information as the rider boards the bus. This would allow for parents and school district transportation managers to know exactly where and when the student rider gets on or off a bus without any effort from the student. This technology is already being used by various school districts throughout the country. Please take a couple minutes to respond to this brief survey and let us know how you feel regarding this technology.

RFID Parent Survey

I believe RFID cards would increase safety for students.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

RFID cards would give parents piece-of-mind when their children ride the bus.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

I worry about privacy issues with the use of RFID cards.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

The use of RFID cards reduces boarding times and helps keep the buses running on time.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

I would have my child use an RFID card if it were available.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

General comments/concerns

APPENDIX B. STUDENT SURVEY INSTRUMENT

Students,
Thank you for helping us collect some valuable information regarding RFID technology on transit buses. If you haven't already, please complete the travel log and survey.

The radio frequency identification (RFID) card was easy to use

Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree

Initially, I worried about privacy issues with the use of RFID cards.

Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree

I would use the RFID card regularly if it was available.

Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree

I prefer the RFID card over the traditional bus ridership ID card or student ID card.

Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree

I consider RFID to be a safe form of payment.

Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree

The use of RFID cards reduces boarding times and helps keep the buses running on time.

Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree

I would like to see RFID cards implemented within the MATBUS system.

Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree

How often do you use public transportation?

Everyday   Two or three times per week
Once per week   Once per month

General comments