PRIORTIZATION OF ITS TRANSIT STRATEGIES IN SMALL URBAN AREAS

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16. Abstract

The majority of problems associated with the passenger transportation system in the United States are focused on large metropolitan area highway congestion. However, there is a need to investigate Intelligent Transportation Systems (ITS) impacts on public transit and smaller urban areas (under 200,000 inhabitants), so that future travel demand and levels of congestion can be positively affected by these new strategies. In order to prioritize these new strategies before capital is allocated from the perspective of the small urban area transit system, a decision methodology is needed and is developed in this study. This decision methodology proceeds through the following steps: cataloging of strategies, initial screening, engineering economic analysis, qualitative analysis, scoring, and conclusions and recommendations. The premise behind the qualitative analysis is the shift from the desire to quantify all qualitative aspects to the approach of gauging the community's likely acceptance of these attributes. In practice, the qualitative analysis consists of tools to translate survey responses into a quantity called desirability. The desirability is then related to results of the economic analysis by graphical techniques that assist a decision-maker in performing a visual trade-off analysis. The methodology is applied to a case study involving the Jefferson Area of Virginia. Conclusions and recommendations are drawn from the results of the case study.

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Abstract

The majority of problems associated with the passenger transportation system in the United States are focused on large metropolitan area highway congestion. However, there is a need to investigate Intelligent Transportation Systems (ITS) impacts on public transit and smaller urban areas (under 200,000 inhabitants), so that future travel demand and levels of congestion can be positively affected by these new strategies. In order to prioritize these new strategies before capital is allocated from the perspective of the small urban area transit system, a decision methodology is needed and is developed in this study. This decision methodology proceeds through the following steps: cataloging of strategies, initial screening, engineering economic analysis, qualitative analysis, scoring, and conclusions and recommendations. The premise behind the qualitative analysis is the shift from the desire to quantify all qualitative aspects to the approach of gauging the community's likely acceptance of these attributes. In practice, the qualitative analysis consists of tools to translate survey responses into a quantity called desirability. The desirability is then related to results of the economic analysis by graphical techniques that assist a decision-maker in performing a visual trade-off analysis. The methodology is applied to a case study involving the Jefferson Area of Virginia. Conclusions and recommendations are drawn from the results of the case study.

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1 Introduction

With the authorization of the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991, a renewed focus on Intelligent Transportation Systems (ITS) was brought to the transportation world. One major catalyst fueling this interest was institution of the Federal Highway Administration's (FHWA) Early Deployment Planning Program in the early 1990's. The Early Deployment Planning Program was intended to investigate feasibility of ITS projects predominately in larger metropolitan areas (> 200,000 inhabitants). The majority of these early feasibility projects focused on highway and automobile modes of transportation in larger metropolitan areas.(1) Although, many of the real and perceived problems concerning the transportation system in the United States have been focused on large metropolitan area highway congestion, there is a need to investigate ITS strategies for public transit and potential ITS impacts on smaller urban areas (under 200,000 inhabitants); so that, future travel demand and levels of congestion can be positively affected by these new strategies.

1.1 Study History

In 1995 the Virginia Transportation Research Council (VTRC), an agency funded jointly by the Virginia Department of Transportation (VDOT) and the University of Virginia, began evaluating FHWA's ITS Planning Process with the goal of developing an enhanced version of the process. From this work on an ITS planning process, came a study titled "Planning for Intelligent Transportation Systems in Small Urban Areas." (2) This Study, completed by Mr. Rich Taylor and Mr. Brian Smith, led a stakeholder committee made up of local transit officials, planners, and members of the Jefferson Area Metropolitan Planning Organization (MPO), through a series of workshops aimed at identifying, cataloging, evaluating and recommending various ITS strategies to the Jefferson Area's local governments.

The scope of the Taylor study was sufficiently broad so that the various conclusions and recommendations for further study could be more fully investigated in an independent manner. Specifically, the ITS Planning Stakeholder Committee expressed a desire to follow-up on three specific aspects of the study, (1) traffic signal coordination between Albemarle County and the City of Charlottesville, (2) construction of a prototype Transportation Information Center (TIC), and (3) investigation of ITS strategies for the Jefferson Area fixed route and paratransit services. Fixed-route service refers to a public transportation service that relies on pre-set routes and fixed stops along those routes. Paratransit service refers to a public transportation service that is demand responsive.

The primary recommendation from the Taylor study concerning transit was the consideration of Automatic Vehicle Location (AVL) for the local paratransit system. However, the ITS Planning Study's broad scope did not include an in-depth evaluation of strategies for public transit, nor did it provide a methodology specific to the transit agencies potentially involved. With these issues in mind, several member's of the ITS Planning Stakeholder Committee formed a separate committee to assist in the study focusing specifically on potential costs and benefits of ITS strategies for the Jefferson Area's transit providers.

1.2 Problem Statement

Small urban areas often have insufficient capital budgets. This condition does not always allow such areas to participate in the most recent federal planning studies or to provide local matching funds for larger state and federal ITS projects. Consequently, small urban areas need to be as efficient as possible when it comes to the choice of ITS strategies, especially as far as public transit is concerned. Unfortunately, such areas do not always have the expertise or the experience to make an informed decision regarding ITS transit strategies, thus risking precious local funds.

1.3 Purpose and Scope

The purpose of this study is to develop a decision methodology to assist small urban areas and small urban transit providers in prioritization of potentially beneficial ITS strategies. The Jefferson Area of Virginia serves as an example of a small urban area throughout the description and the application of the methodology. Furthermore, results and conclusions will be drawn based on and for the Jefferson Area; however, the scope of this study lies primarily in the development of a transferable methodology and the product of this study is this methodology. The tools used in the methodology can also be applied to other problems; however, the methodology is focused on transit by establishing constraints that are used throughout the methodology.

1.4 Methodology Overview

The basic form of the methodology is represented in figure 1.0:

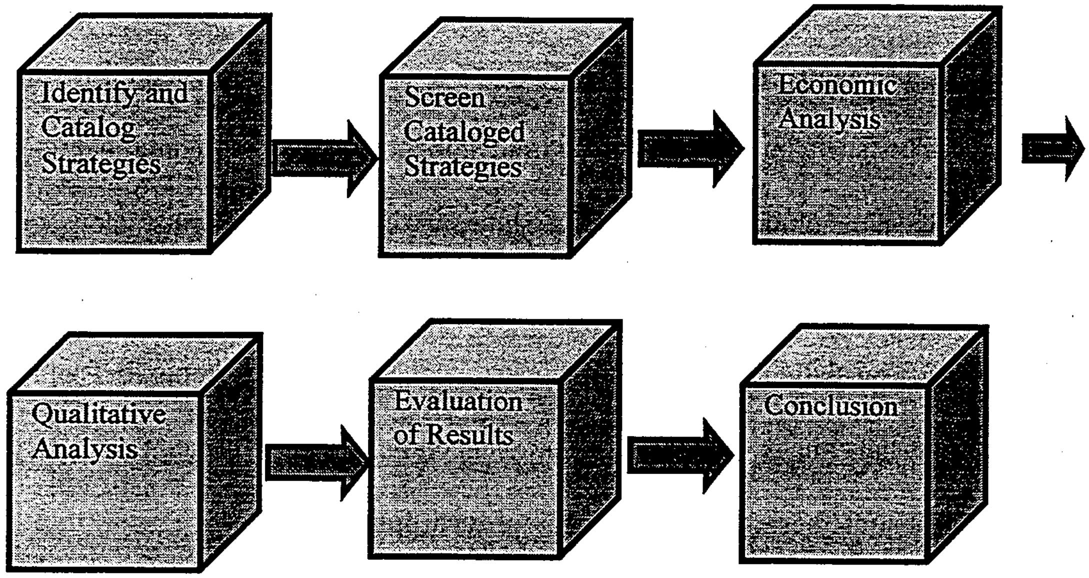


Figure 1.0. Methodology Diagram

1.4.1 Identify and Catalog Strategies

It is necessary to identify and catalog the ITS strategies that relate specifically to public transit. These strategies are typically organized under the title Advanced Public Transportation Systems (APTS) in the literature. In addition, a description is included for each strategy, and will be useful in the subsequent steps of the methodology.

1.4.2 Screen Cataloged Strategies

After cataloging, all strategies are screened. The initial screening is designed to eliminate any strategies that are not appropriate for further analysis. The screening process eliminates the consideration of redundant strategies, or strategies that do not conform to the initial constraints of the study area. For example, the screening process described in the Taylor study is used as an initial step in the screening process.

1.4.3 Economic Analysis

Strategies that survive the initial screening proceed through an economic analysis. Economic analysis is used to discover useful economic information about ITS strategies that can be communicated to decision-makers. The approach to an economic analysis depends on whether strategies being considered are mutually exclusive. If strategies are mutually exclusive then investment in one strategy excludes investment in any other. For instance, a tourist traveling from the North of France to England could conceivably choose air travel, ferry service or train travel through the Channel Tunnel to complete the trip. However, the choice of ferry service does not allow the tourist to take advantage of air or tunnel service at the same time and vice versa. The choices that this methodology is concerned with are not mutually exclusive. Investment on one ITS strategy does not necessarily exclude possible investment in another strategy. In fact, it is conceivable that, if capital were not a concern, investment could be made in all ITS strategies which meet minimum criteria. A Rate of Return (ROR) analysis is used to evaluate economic feasibility of strategies. Strategies that demonstrate a ROR greater than a Minimum Acceptable Rate of Return (MARR) will proceed to a subsequent qualitative analysis.

1.4.4 Qualitative Analysis

It is not possible to quantify each potential benefit of an ITS strategy. Some benefits such as quality of life, public image of the strategy and political and social support do not lend themselves to quantifiable economic analysis. Therefore, it becomes necessary to devise a method, which gauges and evaluates these difficult to quantify aspects and benefits. The completion of this task will rely heavily on various surveys that are designed to gauge the interest and willingness of various groups to support these strategies.

1.4.5 Evaluation of Results

At this point one is presented with results of the economic analysis and results of the qualitative analysis for each strategy. These results are not directly comparable. Furthermore, a particular small urban area may not value the results of the two analyses to the same extent. With these concerns in mind, the development of a technique to communicate results of the two analyses to decision-makers is of primary importance. This will be accomplished through the use of graphical techniques that serve to aid decision-makers in the performance of a trade-off analysis. This will allow decision-makers with limited technical knowledge to compare the results in a visual and intuitive manner.

1.4.6 Conclusion and Recommendations

The results of the analyses will provide a list of the most attractive strategies for the study area involved. Unfortunately, the most attractive strategies as identified by the methodology may be too costly or otherwise unattainable. In light of this possible scenario, strategies will be organized into recommended packages, beginning with a low cost package and proceeding to the highest cost, but most desirable package. The division of the results into packages will aid planners and transit officials in the recommendation of strategies with consideration to the economic realities of the study area.

2 Current State of Practice

Before development of the methodology a review of the applicable literature was completed. The cannon of literature pertaining to this subject can be described as being both relatively scarce and multidisciplinary in nature, thus manifesting itself in widely diverse forms. The literature review process encompasses many different elements such as a journal scan, internet searches, U.S. DOT and other transportation agency reports, ITS manufacture's sales and vendor literature, economic analysis sources and goal programming/multiattribute analysis sources. Another major component of this study's literature review is in the form of discussions held with various professors at the University of Virginia and research scientists at the VTRC concerning areas of expertise which pertain to this study.

Instead of restating various facts, concepts and findings resulting from the literature review process three case studies that demonstrate the current state of practice for small urban area APTS implementation will be discussed. Each of these case studies defines a unique perspective from which to view the potential of APTS strategies in small urban areas. Unfortunately, the evaluation results of each case study are not currently available, however, the descriptions of the cases serve to define the state of research in the field.

Case 1: The Winston-Salem Transit Authority Mobility Management Project Phase 1

Winston-Salem is located centrally in what is identified as the Piedmont region of North Carolina. It is a member, along with the cities of High Point and Greensboro, of a conglomeration of urban and suburban areas known as The Piedmont Triad. In light of this it is difficult to get an accurate account of the share of the metropolitan population attributable to Winston-Salem; however, according to the 1990 census, Winston-Salem has a metropolitan population of approximately 320,000 inhabitants. [3] The Piedmont Triad is defined by linear distances of up to 60 miles separating its principle cities. Thus, the reported metropolitan population may be dispersed over a large area, and the urban core population will likely conform to the constraints placed on a small urban area by this study.

The Winston-Salem Mobility Management Phase 1 plan and proposal was completed in November of 1992 with the Federal and State funding being approved in May of 1993. Phase 1 was applied to the Winston-Salem Transit Authority (WSTA), which has more than 150 vehicles that provide fixed-route, modified-fixed route, downtown circulation, fringe park and shuttle, park and ride, demand responsive paratransit, contract paratransit, vanpools, carpool matching, and vehicle brokerage services. The milestones of Phase 1 called for the use of automated scheduling and dispatching software and hardware with Mobile Display Terminals (MDTs), Automatic Vehicle Location (AVL) and smartcard systems (to be installed in 3 test-bed vehicles), technical assistance to integrate technologies and training and support services. [4] The primary goal of the project was to test the feasibility of dynamic scheduling and demand responsive paratransit for a medium sized city.

The evaluation of Phase 1 can be characterized as a "before and after" evaluation. This is in contrast to the intended use of this methodology as a prioritization tool before a project is undertaken. However, prioritization tools such as this one are dependent on the results of similar before and after studies in order to predict the likely economic and social benefits of the APTS strategies for the study area concerned. Along these lines, the following results and highlights were obtained during the period from September 1994 to February 1995, when the WSTA and North Carolina State University (NCSU) evaluated the effects of computer-aided dispatch and scheduling (CADS) on the operation of 19 small buses used to deliver transportation to clients of human service agencies. The CADS system cost approximately $100,000 exclusive of research and development costs.

- The operating expense per vehicle mile dropped by 8.5% to $1.93. Similarly, operating expense per passenger trip dropped by 2.4% to $5.64 and operating expense per hour dropped by 8.6% to $24.70.

- Distributing the $100,000 capital cost for the CADS strategy over five years, the approximate cost is about 20 cents per passenger trip assuming a constant demand of about 10,000 trips per month. With the current operating cost of about $5.64 per passenger trip, CADS capital costs represent about 3.5% of operating cost, or less if passenger demand continues to increase.

- The larger service area, larger client list, and increased same-day calls have affected total system operating statistics. Passenger trips during the period are up 17.5% to 71,910; vehicle miles are up 25.1% to 208,928; and vehicle hours are up 32.0% to 16,406. The client base grew from about 1,000 to 2,000 as the service area was expanded. [5]

Phase II of the program officially began in January 1997 and has the following objectives:

- Complete the installation of MDT's and AVL on the entire Trans-AID fleet,
- Integrate fixed route trip planning software with the Phase 1 Trans-AID CADS system,
- Install an integrated/automated telephone system to provide touch tone user information for transportation services,
- Test or fully implement MDT's and AVL on the WSTA fixed route system.
- Test kiosk and cable TV to provide information on transportation services [6]

These objectives will allow the WSTA to included trip planning information for human service agencies, demand-responsive passengers and commuters. Unfortunately, according to current estimates, the results of Phase II will not be available until well after the publication of this methodology.

Case 2: The Blacksburg Transit Project, Blacksburg Virginia

In cooperation with the Center for Transportation Research at the Virginia Polytechnic Institute and State University (Virginia Tech), Blacksburg Transit (BT) is serving as a test-bed for the evaluation of several APTS technologies. Figure 2.0, courtesy of the BT web-sight (http://porsche.ctr.vt.edu/bt/) provides a graphical representation of the technologies being tested and their relationship to the central processing and distribution center.

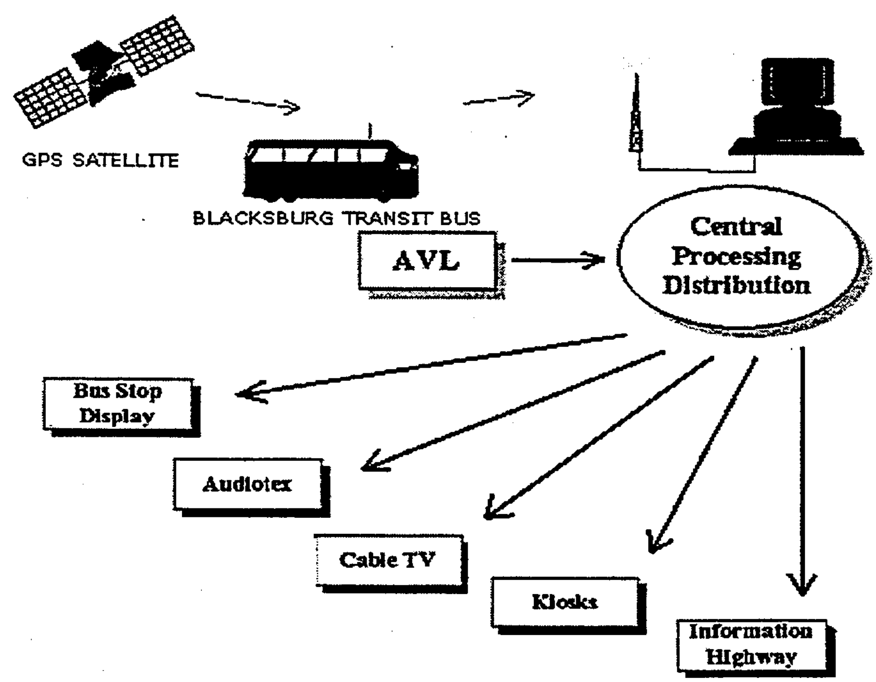


Figure 2.0. Flow Diagram Describing Blacksburg Transit's Evaluation Project

Source :http://porsche.ctr.vt.edu/bt/

The unique aspect of the Blacksburg project is that the AVL units have been purchased for the fixed-route system which consists of approximately 30 buses serving the University, the Town of Blacksburg and some suburban areas of Montgomery County, Virginia, rather than the demand responsive (paratransit) system. This permits researchers to evaluate these strategies in the context of a small urban fixed route operation. The location information is being communicated to the patrons through a variety of means such as: bus stop display boxes, telephone systems, cable TV, kiosks and the internet. The internet and kiosk displays rely on an dynamic transit map which updates the position of each transit vehicle every 30 seconds. An image capture of the dynamic map follows in figure 2.1

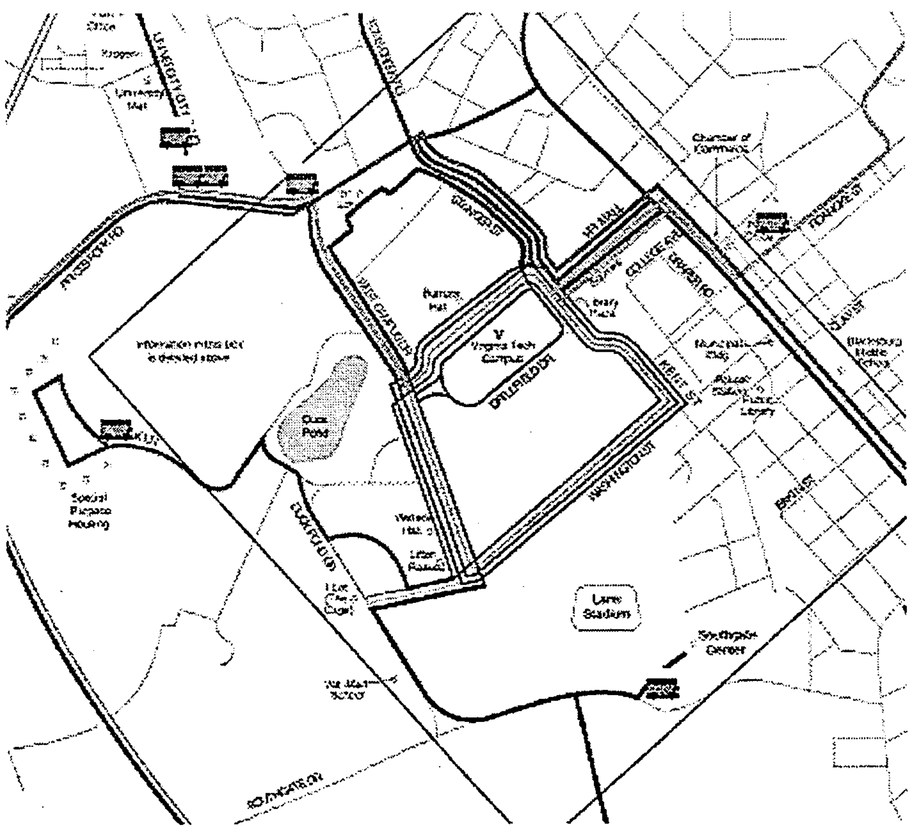


Figure 2.1. Blacksburg Transit's Dynamic Transit Route Map

Source :http://porsche.ctr.vt.edu/bt/

Phase II of the Blacksburg project is projected to provide for the installation of AVL on the paratransit fleet. And Phase III is projected to include the possibility of fixed route transit deviation.(7) Unfortunately, the evaluation report of the Blacksburg project was not available as of the writing of this report. However, a list of cost information that proves useful in the completion of the case study (Chapter 4) was obtained.

Case 3: The Ann Arbor Transit Authority "Smart Bus/Advanced Operating System (AOS) Concept.

The Ann Arbor Transit Authority (AATA) in Ann Arbor Michigan (120,000 inhabitants) is pioneering a concept called the Smart Bus/Advanced Advanced Operating System. Essentially, AATA uses Rockwell International as the primary contractor behind the implementation of this concept. The "Smart Bus" concept relies on the integration of the majority of the APTS market packages currently available into one bundled package. A definition of a "market package" is established in section 3.1 of this report. This project is being carried out for both fixed-route and paratransit service. For instance, the smart bus concept integrates the following technologies and market packages: AVL, Geographic Information Systems (GIS) software, a silent emergency alarm, in-vehicle signage and annunciators, computer assisted transfers, internet and cable television information dissemination, vehicle component monitoring (maintenance), video surveillance, automatic passenger counters and smart card fare payment.(8) The advantages of the Ann Arbor study are that it deals with both fixed route and paratransit transportation in a small urban area context. As with the Blacksburg Study, the evaluation report of the Ann Arbor study was not available at the time of completion of this report. Nevertheless, the case studies provide a convenient introduction into the applied research that is currently being conducted in small urban areas across North America.

3 Methodology

3.1 Identify and Catalog Strategies

The "identify and catalog strategies" step of this methodology pertaining to the case study of the Jefferson Area of Virginia, as defined in Chapter 4 of this report, is based on the technical report titled "Study of Intelligent Transportation Systems"[9] which was completed as an undergraduate thesis, and was tailored specifically towards the transit needs of the Jefferson Area of Virginia. Some additional methods of identifying and cataloging APTS strategies will briefly be explored. Advanced Public Transportation Systems: The State of the Art: Update '96 [10] by the U.S. Department of Transportation provides an excellent starting point in the identification and cataloging process. Update'96 not only comprehensively identifies and describes APTS strategies that are currently in use across the U.S, it provides background and contact information as well. If no other sources can be located for use in the identification and cataloguing step of the methodology, every effort should be made to obtain the most recent APTS State of the Art: Update.

Intelligent Transportation Systems (ITS) Projects Book: January 1998[11] also published by the U.S. DOT contains a brief description of ITS studies in the research and development stage and the operational test stage. Although the publication is devoted to ITS strategies in general, there is a section that deals exclusively with the most current APTS studies and tests and it provides up to date contact information for further research.

The report titled "Advanced Public Transportation Systems Deployment in the United States,"[12] published by the U.S. DOT as a part of the "Operation TimeSaver" series, provides an extremely comprehensive listing of transit agencies and their current or planned APTS projects. The data is presented in spreadsheet format and does not provide descriptions of the projects other than the strategy titles. This source is useful for providing a quick list of the major APTS strategies with the corresponding information identifying the transit agencies in the United States involved in the investigation of each strategy.

The report titled "Benefits Assessment of Advanced Public Transportation Systems"[13] is also published as a part of the U.S. DOT's "Operation TimeSaver" series. The intent of this document is to explore and discuss known and projected benefits of the APTS technologies. In doing so, the document provides a list of the major APTS strategies in use with the corresponding potential benefit streams. This information is extremely useful in the economic and qualitative analysis sections of this report.

Additionally, several sources of information can be found via the World Wide Web (WWW). For instance, the Bureau of Transportation Statistics (BTS) has a menu searchable "National Transportation Library" located at *http://www.bts.gov/ntl/browse.html*. Likewise, the National Transit Library searchable menu is located at *http://www.fta.dot.gov/ntl/index.htm*l and provides an online link to several of the aforementioned sources through the Intelligent Transportation Systems option. Finally, the Community Transportation Association of America (CTAA) maintains online documents related to rural and smaller urban area public and community transportation located at *http://www.ctaa.org/its/*. If all else fails, and the transit agency concerned is unable to acquire any of the aforementioned sources, the catalog included in Table 4.0 can be used as an example.

3.2 Screen Cataloged Strategies

Once the APTS strategies have been identified, it becomes necessary to screen out those that are not appropriate for further analysis. The screening eliminates the consideration of redundant strategies or strategies that do not conform to the initial constraints of the study area. There are several ways in which one could screen the catalogued strategies, a brief discussion of some of the most popular and reliable methods follows.

First of all, it is possible to establish a study (screening) advisory committee consisting of transportation officials, local government officials or other interested parties. A well-diversified advisory committee can effectively articulate the communities' requirements and can serve to identify strategies which will not likely garner the support of either the local governments, local transit officials or the public. It is no accident that the study advisory committee method resembles the Delphi Method of transportation planning. The Delphi Method essentially relies on the experience and knowledge of those considered experts in the transportation field, local policy or local politics.

It should be noted that in the "ITS Planning Study" conducted by Taylor, immediately before the screening process, the "stakeholders" were encouraged to develop a "vision of transportation in the area" as a part of a visioning session workshop. The resulting vision was then used in the initial market package screening.

Parties who are interested in employing this methodology will not always have the resources to formulate a study advisory or stakeholder committee. Fortunately, there are other ways to obtain data that will be useful in an initial screening of the cataloged

APTS strategies. One such way, which is not demanding on time and resources, is to use the local government's Comprehensive Plan as a tool. Comprehensive Plans typically articulate the community's goals on the general, physical, social and economic problems and opportunities for the area.

If the Comprehensive Plan of a community is unattainable or otherwise not useful, another method, which should prove useful in establishing screening parameters, is the survey method. Surveys can be carried out in many forms: direct mail, manually distributed, telephone, computer/internet, etc. One may find that it is not extremely important which method is chosen, except where financial resources are concerned; rather, every effort should be made to choose an appropriate survey audience (sample). It is beyond the scope of this methodology to discuss the intricacies and theories of survey sampling; however, a few considerations will be explored. First of all, in the absence of a stakeholder committee, one may wish to survey transportation professionals, local business leaders and/or local government officials. These groups would contain many of the same members as a typical study advisory or stakeholder committee. If this approach is infeasible, it is possible to survey the business leaders of the area using the directories provided by the local chamber of commerce. Essentially, distributing surveys to business leaders accomplishes two goals: first, a cross section of the support or opposition to particular projects and or ideas can be obtained, and second, business surveys can provide an indirect measurement of likely community acceptance. Specifically, by surveying the business leaders (employers) of an area, an indirect forecast of citizen behavior can be taken due to the fact that employers have a great deal of impact on transportation decisions. Employers and businesses can choose to limit or expand parking, offer transit subsidies, give discounts to those using transit, advertise on transit, encourage employees to use transit, and so forth. On the other hand, if the business community objects to certain measures, these measures, regardless of local government support, may find difficulty in being successful.

3.3 Economic Analysis

Economic analysis evaluates alternatives and delivers information regarding the alternatives' economic feasibility. The information derived from an economic analysis depends on the question being asked. A situation involving a choice among alternatives that address the same need will require a separate analysis from a choice among alternatives that address different needs. For example, a commuter, who lives 15 miles from her place of employment, reports to work in a downtown office at 8:30 each weekday morning. It is possible for her to report to work by driving herself, Single Occupancy Vehicle (SOV), carpooling, High Occupancy Vehicle (HOV) or taking the metro. Each of these alternatives has associated costs and benefits. After evaluating the alternatives, the commuter may discover that the rate of return (ROR), which is the return (benefits) received over a certain period of time related to the costs of the alternatives, indicates that the metro option is the most economically feasible for her situation.

This analysis is appropriate from the commuter's point of view because all three alternatives are mutually exclusive, such that the commuter cannot both drive herself and take the metro at the same time. However, economic decisions must often be made between alternatives that are not mutually exclusive. For instance, a student who is about to graduate from University has a goal of making a down payment on a house in five years. The student determines that he can set aside $100 a month to meet his goal. In order to leverage the $100 monthly contribution the student considers placing the money in a bank savings account, investing in bonds and placing the money in a mutual fund. Although, each of these alternatives has an expected rate of return (ROR) and an associated risk they are not mutually exclusive. The student is free to put some money in the bank, put some in bonds, and put some money in a mutual fund. Provided that the $100 a month limit is not surpassed, contributions to the bank account do not preclude the purchase of a bond and so forth. In reality, the student would likely make a trade-off between the expected ROR and the risk in an effort to make the most money for his down payment in five years. Economic analysis of APTS strategies is similar to the student's down payment example in that investment in a single APTS strategy does not necessarily exclude investment in another strategy.

3.3.1 Issues Confronting Economic Analysis

Before proceeding to a development of the economic analysis used in this methodology, several important issues confronting economic analysis are discussed. First of all, a project evaluation perspective needs to be selected; for example, a project which impacts a single locality could demonstrate economic feasibility for the locality, but be infeasible for the region, state or nation as a whole. This is due to the fact that some projects produce social gains and some projects merely produce transfers (i.e. capital is transferred to one area at the expense of another). Although it is very important to invest in strategies and opportunities which produce social gains, rather than, social transfers, by its focus on the small urban area, the methodology presented is concerned with the regional and more precisely the local perspective.

Secondly, one needs to resolve the discount rate dilemma. Since the costs and benefits accrued from ITS projects often are realized over a period of many years a discount rate is used to help determine the net present value of benefits and costs that will be realized in the future. The use of a discount rate is motivated by the simple fact that if the capital were not spent on the project in question, it could be used for other purposes, left in the private sector through a reduction in taxes or even invested in the marketplace, and, therefore produce a return on the capital. Due to the fact that the majority of ITS and transportation projects demonstrate rather substantial capital costs in the first few years of the project, while, the benefits of the project are realized over a substantially longer period of time. Use of a low discount rate risks making a project appear more attractive than otherwise; conversely, a high discount rate will make the project much less attractive than otherwise.

From the previous description it is not surprising that determining an appropriate discount rate for the discounting of future cash flows to a present value (PV) can be a daunting task. Fortunately, there are several strategies with which the decision-makers or planners of the small urban area can attack the problem. First of all, one or more of the local governments involved may have a standard established discount rate for all projects under its jurisdiction. If this is the case, a consensus needs to be built with all localities involved (if applicable) on the question of whether or not to adopt the established discount rate. If there are no officially endorsed discount rates, one can research the public works projects and utility projects completed by the locality(ies) during the previous 10 years, and determine which, if any, discount rates were used and why they were chosen. If there is no past data available, another popular approach is to use the current prime lending rate for banks. If one's desire is to be completely thorough, one could use several values for the discount rate representing the low, middle and high likely values of the discount rate. This approach will give the results a sensitivity analysis.

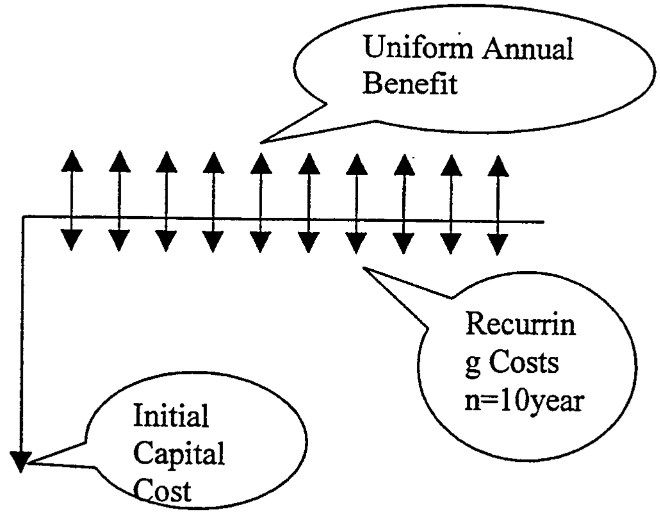
Assigning a value for time and timesaving can be the subject of some controversy. For instance, one may ask: What is the relationship between one's wage and the personal value of travel time?; Is the value of a passenger's time equal to that of the driver?; Or is travel on business trips worth more than leisure travel? [15] The "ITS Planning Study" estimated that the value associated with time spent in traffic in the Jefferson Area is $13.50 per automobile, per hour based on the procedures established by Chui et al. at the Texas Transportation Institute. [16]

Finally, economic analysis can become complicated when cross-benefit/cross-funding issues are considered. For example, suppose that a particular project was to benefit both the emergency response network and the transit system, however, the transit authority is to pay the complete costs of the system implementation. Obviously, the benefit streams flow to two separate entities, while the costs are borne by only one. This can be resolved by adjusting the perspective of the economic analysis to include several agencies; however, this still does not resolve the equity issues raised by such a procedure.

3.3.2 Cost and Benefit Streams

The student, who recently made the down payment on a house, may wish to buy a lawn mower to tend to his new yard, to replace the old windows with insulated windows, or both. For simplicity sake, it will be assumed that there is only one model of mower and one model of insulated window from which to choose. Both the mower and the insulated windows have an initial cost and yearly maintenance costs. The initial price plus sales tax and all applicable fees is called the initial capital cost or the initial capital investment. The yearly costs, maintenance, fuel and cleaning are called recurring costs or total annual costs. Although most of the PV costs for a mower and insulated windows are included in the initial capital cost the benefits are likely to occur throughout the useful life of the products. Since it is impossible to forecast exactly when individual benefits in a stream of benefits will occur, the benefit stream is typically summarized on a yearly basis and is called uniform annual benefit (UAB). Finally, each mower may have a different useful life expectancy. For this example both the mower and the insulated windows are assumed to have an identical useful life expectancy of 10 years. If the useful life expectancy is not identical then the analysis period should be the least common multiple (LCM) of the useful life expectancies. For instance if the useful life expectancy of the mower is 5 years and the useful life expectancy of the windows is 10 years the analysis period would be 10 years with the mower being repurchased after 5 years have passed. [17]

Cost and benefit streams are often represented in diagrams depicting a downward arrow as a cost and an upward arrow as a benefit. The horizontal line represents the passage of time.



Mower and Windows

Figure 3.0 Cost Benefit Stream Diagrams

In order to determine the NPW of the two alternatives the future capital streams must be discounted into present dollars using present worth factors. The present worth factor that describes a single payment in the future is represented as (P/F, *i*, n) where *i* is the interest rate and n is the analysis period. Likewise the present worth factor that describes a uniform payment is represented as (P/A, *i* , n) specific values of these expressions can be obtained in economic tables. Thus the NPW for each alternative would be:

- NPW = [Net Present Value (NPV) of Benefits] – [NPV of Costs]
- NPW = (Uniform Annual Benefit) (P/A, *i*, 10) – [(Initial Capital Cost + Uniform Annual Cost (P/A, *i*, 10)][18]

(3.0)

Fortunately, the benefits reported in the literature concerning APTS strategies are generally in the form of UAB. However, the useful life of an APTS technology is more difficult to ascertain. Current studies have not yet determined the average useful life for a majority of APTS strategies. Therefore, it is assumed that the project analysis period is the same for all strategies. Since the length of the project analysis period influences the results, it is recommended that several periods be used in a sensitivity analysis.

3.3.3 Calculating Rate of Return

The rate of return ROR is calculated by setting the NPW to zero and solving for the interest rate. For a ROR analysis the choice of a discount rate identifies the Minimum Acceptable Rate of Return (MARR) for which decision-makers will accept a project. For instance if the MARR is set at 4% all projects which do not project a ROR of greater than or equal to 4% will be discarded. As discussed in section 3.3.1 the choice of the MARR (discount rate) has a great influence on whether a particular project is deemed desirable or not. In consultation with Mr. Jim Gillespie at the Virginia Transportation Research Council (VTRC) the following strategies in the determination of the MARR were suggested:

- Non-Taxation Approach (If the costs of the projects were not taken from tax money and the capital were left in the private sector, what are the rate of returns for the region with regards to private capital and this will be the MARR?)
- Prime Rate (Use the prime interest rate minus inflation)
- Public Works (Review the MARR for other public works projects, waterways, schools, parks, emergency network, etc. and set the average as this project's MARR.)

It is suggested that several values for the MARR be used in order to perform a sensitivity analysis. The results of the ROR analysis for each value of the MARR should be communicated to the decision-maker for a final decision.

Suppose that new homeowner will not invest in anything that does not at least match the annual rate returned by his mutual fund last year, 13% (MARR), and that the costs and annual benefits associated with the thermal windows and the mower are summarized in the following table.

Alternative	**Benefits**	**Costs**
Thermal Windows	UAB = $150	Initial $500 Recurring $50
Mower	UAB = $150	Initial $700 Recurring $40

Table 3.0 Example Costs and Benefits

Setting Equation 3.0 equal to zero and solving for the rate of return,

- NPW(Thermal Windows) = 0 = ($150) (P/A, *i*, 10) – [($500 + $50 (P/A, *i*, 10)]
  5 = (P/A, *i*, 10) => *i* is approximately 15%

- NPW(Mower) = 0 = ($150) (P/A, *i*, 10) – [($700 + $40 (P/A, *i*, 10)]
  6.364 = (P/A, *i*, 10) => *i* is approximately 9%

According to the aforementioned criteria, the homeowner will only invest in the installation of thermal windows because it is the only option that produces a ROR greater than his MARR. However, if the MARR were reduced to 6%, his expected investment return for bonds, and the capital is available for both options then the homeowner would install the thermal windows and purchase a new mower. The purchase of thermal windows does not necessarily exclude the purchase of a mower.

3.3.4 Issues Facing ROR Analysis

There is one major issue facing a ROR analysis. Namely, a ROR analysis assumes that the uniform annual benefits are being reinvested at the ROR value. According to the following diagram

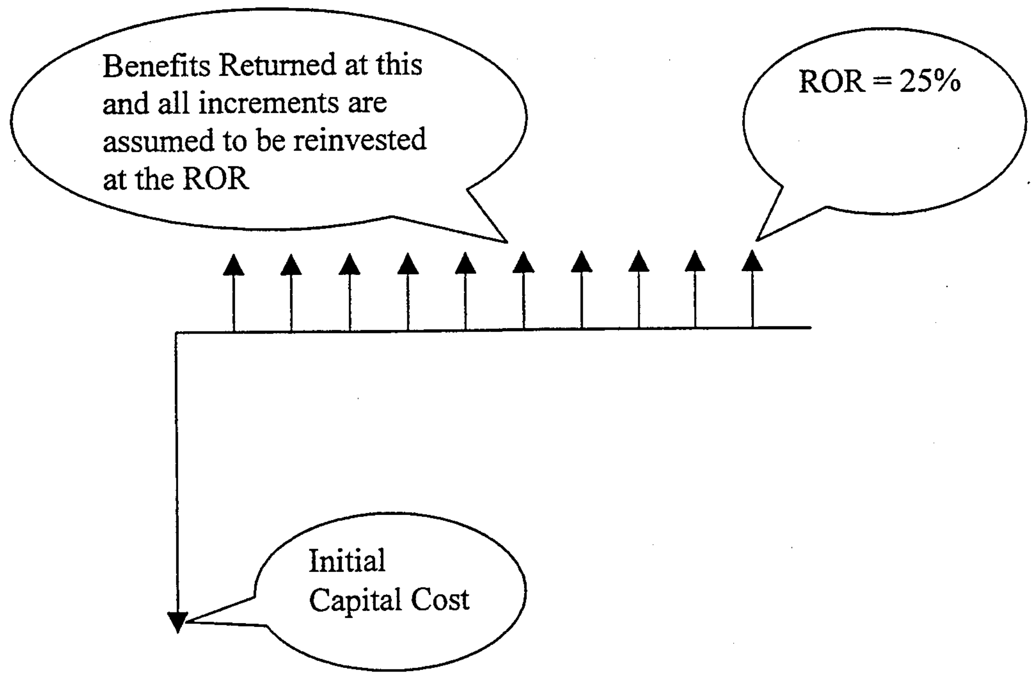


Figure 3.1 Rate of Return Diagram

According to Figure 3.1 the UAB would be reinvested at the ROR of 25%. For a high ROR it may not be possible to reinvest the incremental benefits at the ROR. Thus, the ROR analysis has a potential to overestimate the attractiveness of an option at high ROR. In order to guard against this possible error in the ROR analysis, a NPW analysis should be performed for a variety of constraints (discount rate, and analysis period), when the ROR is above 15%. This will be used to verify that a large ROR is justified by the NPW.

3.3.5 Illustrative Example

An example serves to illustrate the concepts discussed in sections 3.3 through 3.3.5. Suppose that the following table summarizes the costs and benefits associated with several APTS strategies.

	Smart Card	Signal Preemption	AVL
Initial Costs	$50,000	$100,000	$150,000
Recurring Costs (Annual)	$100	$1,000	$500
Uniform Annual Benefit	$12,000	$22,000	$50,000

Table 3.1 Sample Costs and Benefits

Assuming project analysis periods of 5, 7 and 10years for all strategies and MARR of 4%, 7% and 10% the following results are obtained.

Project Analysis Period = 5 years

- NPW(Smart Card) = 0 = ($12,000) (P/A, *i*, 5) – [($50,000 + $100 (P/A, *i*, 5)]
  4.202 = (P/A, *i*, 5) => *i* is approximately 6%

- NPW(Signal Preemption) = 0 = ($22,000) (P/A, *i*, 5) – [($100,000 + $1,000 (P/A,*i*,5)]
  4.762 = (P/A, *i*, 5) => *i* is approximately 1.75%

- NPW(AVL) = 0 = ($50,000) (P/A, *i*, 5) – [($150,000 + $500 (P/A, *i*, 5)]
  3.03 = (P/A, *i*, 5) => *i* is approximately 19.5%

The results resulting from the previous assumptions are collected in the following table.

Strategy	Analysis Period	NPV Costs	Rate of Return
Smart Card	5 years	$50,420	Approximately 6%
	7 years	$50,558	Approximately 13%
	10 years	$50,736	Approximately 20%
Signal Preemption	5 years	$104,762	Approximately 1.75%
	7 years	$106,535	Approximately 11 %
	10 years	$109,101	Approximately 16.5%
AVL	5 years	$151,652	Approximately 19.5%
	7 years	$151,803	Approximately 27%
	10 years	$152,096	Approximately 30%

Table 3.2 Example Rate of Return

Note that the length of the analysis period has a profound impact on the ROR in the above example. This is due to the fact that for each strategy the UAB is much greater than the recurring cost for any given year. However, the length of analysis does not have an effect on the economic ranking of the alternatives. If a decision-maker had $350,000 and accepted an analysis period of 5 years and a MARR of 7% he/she would choose both the AVL and the Smart Card strategies. However, if the decision-maker were to choose an analysis period of 7 years he or she would choose the AVL and the Signal Preemption strategies.

3.4 Qualitative Analysis

In the past it may have been sufficient to take the results of the economic analysis and to recommend the strategy that appears to demonstrate the most value based on the results. However, in recent years much attention has been paid to evaluating the so-called "qualitative" benefits of various projects. These "qualitative" benefits could potentially take the form of quality of life issues, livability, sustainability, convenience, public perception and image. Although it can be argued that the definitions of many of the preceding terms are yet to be formalized, and that there is great debate as to whether a consensus definition can be attributed to a concept such as sustainability. The fact remains that a conventional economic analysis alone may ignore some of these difficult to quantify benefits and concepts, that could be important to the transit operators, local officials or the community as a whole.

One of the most straightforward ways to accomplish such a task is in the distribution of a survey or surveys. It was previously stated that the scope of this report did not include an in-depth discussion regarding some of the theories associated with surveys. However, a brief mention of some of the most common and elegant styles of surveying is appropriate to the aid in the description of the methodology. The choice of a target audience (sample) is extremely important to the results of the survey. Where possible multiple samples should be taken which include: the current fixed route ridership, the current demand responsive ridership, transit officials, local planners, local politicians and local business leaders. Due to time and budget restraints, one or any combination of the above may be selected as a survey audience. If capital resources are a concern it is recommended that surveys be either distributed or mailed. Telephone surveys are likely to carry a significantly higher cost due to the intensity of the labor involved for a given sample size.[19] However, the budding technology associated with web based surveys offers promise and convenience to planners in the future. By analogy, in Traffic Engineering at least 30 samples should be taken per hour in a spot speed study.[20] However, for this methodology, the author estimates that at least 100 surveys should be distributed.

3.4.1 The Likert Scale

One of the most elegant and straight forward methods of eliciting survey response is with the use of the Likert Scale. The Likert Scale can take many forms; however, it is usually represented as a descending discrete set of choices. For example, a survey employing the Likert scale will most often state something to the effect of "Please select the box which most closely approximates your level of agreement to the statement: strongly disagree, disagree, neither disagree nor agree, etc." A version of the Likert scale called the rating scale takes the central theme of agreement or disagreement and translates the ideas to a numerical value. For instance, the instructions for a rating scale based survey may state "Please comment on the degree of usefulness that each of the following scenarios would have for you and/or your business on a scale from 1-5 (1 being the most useful and 5 being the least useful).[21] The main advantage of the rating scale for this methodology resides in the fact that the scale approximately ranks responses relative to each other using an integer or some other value.

The phrasing of survey questions is very important. A survey can unintentionally undermine its results by phrasing questions in such a manner as to leave the audience confused. In most cases it is also important to avoid directly mentioning any certain strategy or brand name associated with any strategy. This could lead to name or product recognition which could undermine the results of the survey. In the evaluation of the potential APTS benefits it was found that questions should be phrased in generic terms. Furthermore, questions should be phrased regarding the usefulness(utility) of certain scenarios made possible by the strategies. For instance, questions pertaining to the utility of:

- Participation in an area-wide prepaid cash card system
- A printout of the number of customers delivered by transit
- Advertising products to transit users
- Reduction in the parking space needed for employees and customers
- Willingness to encourage employees to use a demand responsive transit system

are appropriate.

3.4.2 Results of the Survey

The results of a survey based on questions resembling the ones described in the previous paragraph essentially provide an estimate of the community's or certain portions of that community's willingness or lack of willingness to support some of the potential benefits and aspects of various APTS strategies. Specifically, the surveys assign an average integer value, according to the rating scale, to represent the desirability of each of the various scenarios described. If several versions of the surveys have been distributed, for example, distributed to the existing fixed route ridership, the existing demand responsive ridership, and the members of the Chamber of Commerce a very important question arises: "Should the results of the surveys distributed to these various groups be considered equally in the analysis, or should special consideration be given to certain results?" A research study designed to respond to these concerns would not be trivial; in fact, such a study would be very interesting and thought provoking.

The question remains, however, regarding the proper way to analyze the survey data. Any particular ITS strategy may fulfill one or more of the surveyed scenarios. If this is the case, one may find oneself in the difficult position of comparing an ITS strategy which only fulfills one of the scenarios, and, consequently only demonstrates an association with one average integer value, with an ITS strategy that is capable of fulfilling several scenarios and taking on several of the average integer values reported in the survey. Indeed, several very interesting questions arise from this situation. First of all, it is necessary to inquire about the interrelations of the surveyed scenarios. For example, one could ask "Is the total or composite desirability of an ITS strategy the sum of the integer values representing the scenarios that it fulfills?" Likewise, the question could be asked as to whether the scenarios are mutually exclusive or whether there is a diminishing return associated with an ITS strategy fulfilling more than one scenario. The question regarding mutual exclusivity is an especially interesting one, because it deals with the situation in which an ITS strategy that fulfills many scenarios, which obtained poor results in the survey, is compared to an ITS strategy that fulfills only one strategy that obtained excellent results in the survey. If , by analogy, the discussion were to center around the trading of players between professional basketball teams, then a team would most likely seek to accomplish the following:

- Making sure that several mediocre players are not selected over the superstar of the league
- Making sure that slightly better player does not out shine several good players
- Making sure that the team does not consist only of mediocre players

In conversations with Jim Lambert, an assistant professor at the Risk Management Center of the University of Virginia, it was brought to the author's attention that the discipline known as "Goal Programming" may prove very useful in the resolution of some of these concerns. Essentially, "Goal Programming" finds its roots in a paper published in 1955 by Charnes, Cooper, and Fergusion that deals with executive compensation methods. A boon of papers occurred in the late 1970's and the early 1980's leading to the first major textbooks in "Goal Programming" and the current structure of the discipline.(22) In its current form, "Goal Programming" can be described by its relationship with the fields of management science(MS), operations research(OR) and multiple criteria decision making (MCDM). Specifically, "Goal Programming" is a subject within MCDM which, in turn, is a subject within MS/OR.(23)

Basically, "Goal Programming" techniques are divided into two categories: Weighted Goal Programming techniques and Lexicographic Goal Programming techniques. The weighted techniques rely on the researcher to determine adequate scoring weights for the alternatives involved. Since the acquisition of appropriate weighting factors can be infeasible or time consuming for small urban areas, the discussion will center on the lexicographic techniques. In their most basic form the lexicographic techniques seek to evaluate alternatives using various priority levels. [24] The lexicographic techniques which deal with preference modeling can be summarized as follows:

- *Increase in Preference* occurs when a decision-maker desires to increase the per unit penalty at some distance from the goal. Using the basketball trade analogy, a team owner applies the concept of increase in preference when he/she favors the player with a higher rating (superstar) over several other players with mediocre ratings (i.e. the penalty for being mediocre is increased the further the players are from being a superstar, the goal). Likewise a decision-maker could favor the strategies which fulfill the highest rated scenarios (the superstars).
- *Decrease in Preference*, occurs when a decision-maker desires to decrease the per unit penalty at some distance from the goal. In this case the team owner would settle for acquiring several adequate players in a trade; rather than, trying to acquire one brilliant superstar (i.e. the per unit penalty of not being a superstar is decreased). Likewise, a decision-maker may prefer to focus the strategies which fulfill several adequate scenarios rather than just one superstar scenario.
- *Discontinuity in Preference*, occurs when there is a sudden rise in penalty in crossing some threshold in an objectives value.[25] In this case the team owner may decide that

no player should be selected that does not at least average 10 points a game (the threshold).

The analysis approaches presented in the following sections will rely on the principles summarizing the Lexicographic Goal Programming techniques. The exact approaches were formulated following discussions with Mr. Jim Lambert at UVA's Center for Risk Management and consultation with various resources on the subject of Goal Programming. The approaches are designed to be simple and straight forward so that any small urban area can apply these tools with a minimum of effort and reeducation of personnel.

3.4.3 Maximum Value Approach

Since it is possible for the APTS strategies being considered to fulfill one or more of the scenarios described in the survey, the simplest method of analyzing the results involves assigning the maximum value of the applicable scenarios to the strategy. In other words, there is a discontinuity in preference because the only value that is of interest is the value that is above the threshold, the maximum value. The average values, returned by the survey, for a particular scenario will be known as the i^{th} desirability, d_i. The maximum value approach is merely the maximum$\{d_i\}$, for the applicable scenarios. Needless to say, this approach demonstrates several liabilities. First of all, the approach ignores all of the incremental desirability values, d_i, except for the maximum. Thus, a potential strategy, which could be very valuable due to its ability to fulfill several different scenarios, may be overlooked in favor of a strategy that returns a single slightly larger d_i. In other words, a slightly better player may overshadow a group of good players in basketball trade negotiations.

3.4.4 Summation Value Approach

The summation value approach takes the sum of the i^{th} desirability, Σd_i, associated with the scenarios that fulfill the various strategies. This would certainly account for the case of multiple scenarios being fulfilled by one strategy. At first glance, this approach may strike one as the most intuitive; however, this approach does present a daunting concern. Namely, in basketball trade negotiations, it is possible for the poor and the mediocre players to outshine the brilliant superstar. For instance, suppose that the survey(s) report that there is one scenario that is overwhelmingly supported by the community, and the analysis finds that there is one and only one strategy which fulfills that scenario. In the summation value analysis, this said strategy is compared to a strategy which fulfills seven scenarios, however, each of these scenarios obtain very poor results according to the surveys. Unfortunately, the strategy which fulfills the 7 strategies (even if all the values are a 1.0, least useful by the Likert scale), returns Σd_i=7 ; whereas, the maximum Σd_i of the superstar strategy could only be 5, as defined by the survey scale. Therefore, a team full of poor players has been selected over the most brilliant superstar in the league.

3.4.5 Preferences Analysis

In order to balance the concepts of increase in preference, decrease in preference and discontinuity on preference, it becomes desirable to approach the analysis in a way which does not ignore the all the various scenarios that an ITS strategy could provide for, while, at the same time, not allowing the scenarios that score poorly to greatly influence the results at the expense of the scenarios that score exceptionally well. Applying the general mathematical form:

$$D = \left(\sum d_i^c \right)^{\frac{1}{2}}$$

Where: D is the Composite Desirability (3.1)
d_i is the score returned by the survey for the i^{th} scenario
c is a positive real number

allows the researcher to investigate the results of the analysis over many different levels of preference. As c increases from 0 to 1 then the mediocre and poor scores are given a preference over the excellent scores (decrease in preference); whereas, as c increases from 1 to ∞ the better scores are given a preference over the mediocre scores (increase in preference). At this point, the researcher should plot the trends in preference, which are defined by equation 3.1 using a range of values for c, and observe any changes in preference that occur. To illustrate this point, an example is appropriate. After the completion of the economic analysis, two potential strategies remain signal preemption and AVL. Table 3.3 contains a summary of individual scenario scores returned by a hypothetical survey for each strategy:

Strategy	Signal Preemption	AVL
NPW Costs	$100,000	$200,000
ROR	10%	15%
ith Desirability (survey scores)	5,2,2	3,3,3

Table 3.3. Hypothetical Survey Scores

Therefore, the results of the various analyses can be described by the following table and graph:

Strategy	Signal Preemption	AVL
Maximum Value Approach	5	3
Summation Value Approach	9	9

Table 3.4. Maximum and Summation Values

Sample Desirability calculation for Signal Preemption for c = 2

$$\mathbf{D = \Sigma\ [(5)^2+(2)^2+(2)^2]^{1/2} = [25+4+4]^{1/2} = 5.7} \qquad (3.2)$$

Allowing c to vary over a specific range from 0 to 2 for each strategy produces the following graph.

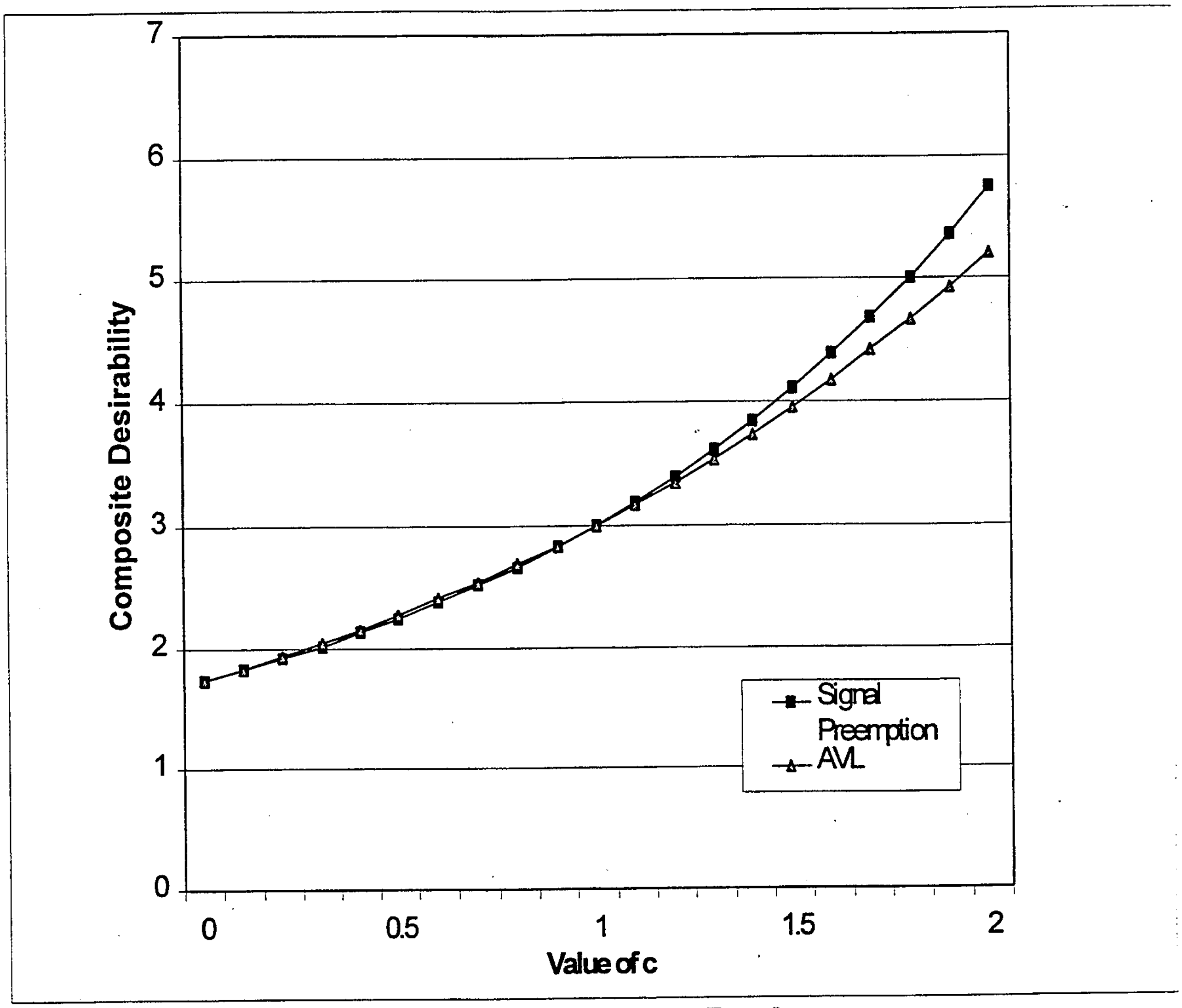


Figure 3.2. Example Preference Trends

According to Table 3.4 and Figure 3.2, signal preemption is preferred using the maximum value approach, there is no preference resulting from the summation value approach, and each strategy is almost equally preferred up to the point where the value for c approximately equals 1.2. The decision-makers of the small urban area should choose the analysis, which best fits the goals of the area concerned. For instance, if the decision-makers in the small urban area wish to emphasize the scenarios which obtain the higher scores (the superstars), then the results obtained from the analysis using a higher value of c would be used. In any event, a plot resembling the graph in figure 2.5 will allow decision-makers to determine visually the points at which the preferences of strategies change, and to use these points as decision opportunities. Using this information the decision-makers could select the specific analysis that is tailored to the needs of a specific small urban area. For the example, the report will assume that the decision-maker prefers the analysis at the value of c = 1.8, which states that the signal preemption strategy is preferred to the AVL strategy.

3.5 Scoring the Results

It is interesting that, during the example problem, the qualitative analysis determines that the signal preemption strategy is the more desirable, while the economic analysis, as summarized in table 3.3, determines that the AVL strategy demonstrates a larger ROR. Since the investment in AVL does not exclude the investment in Signal Preemption, assuming that more than $300,000 is available in NPV of capital, a decision-maker may wish to invest in both strategies. However, if the funds available only allow for one strategy to be chosen should the two analyses be considered equally, or is one analysis more important than the other to the community involved?

Instead of attempting to apply, arbitrarily or hypothetically, weighting factors to the results of the two analyses, one could communicate the results of the analyses in a manner that would allow a decision-maker to perform a trade-off analysis visually. An increasingly popular method of communicating such information that was documented in "A Tool to Aid the Comparison of Improvement Projects for the Virginia Department of Transportation" by Haimes et al.[26], involves projecting the area of the data points in proportion to the desirability factors obtained as a part of the qualitative analysis. For example, if the following information, concerning several hypothetical strategies were obtained as a part of a study,

Strategy	Strategy #1	Strategy #2	Strategy #3
NPV Costs	$100,000	$200,000	$300,000
ROR	5%	10%	15%
Desirability	3.2	7.1	4.7

Table 3.5. Hypothetical Cost, Benefit and Desirability Data

then it is possible to plot the NPV Costs on the abscissa (x-axis), plot the ROR on the ordinate (y-axis) and to relate the area of the data points to the Desirability. For instance, a unit size of 1 (lowest allowable score) can be chosen as the default data point size (see figure 3.3) and the resulting data points will have an area defined by D times the unit area.

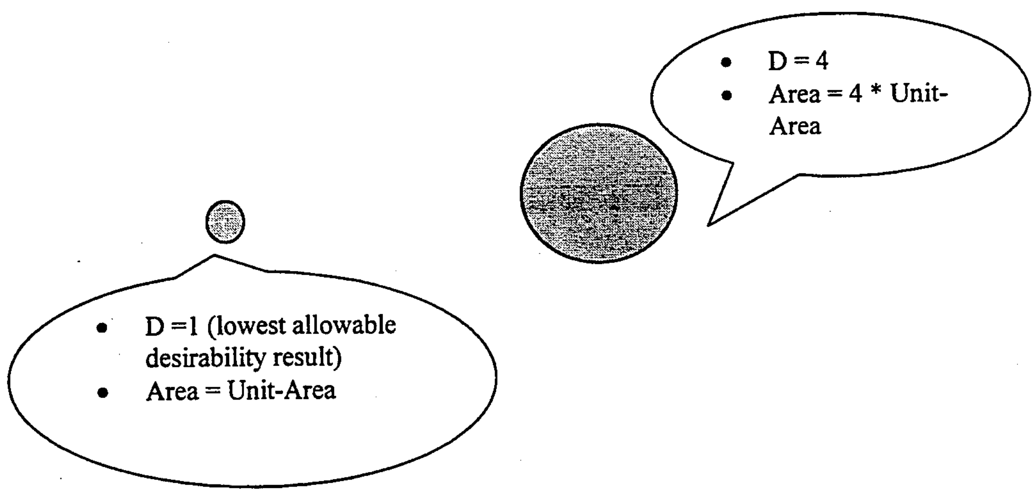


Figure 3.3 Size of the Data Points

This allows the data points to be displayed with a relative size corresponding to the results of the qualitative analysis, thus producing a visual impact on the decision-maker.

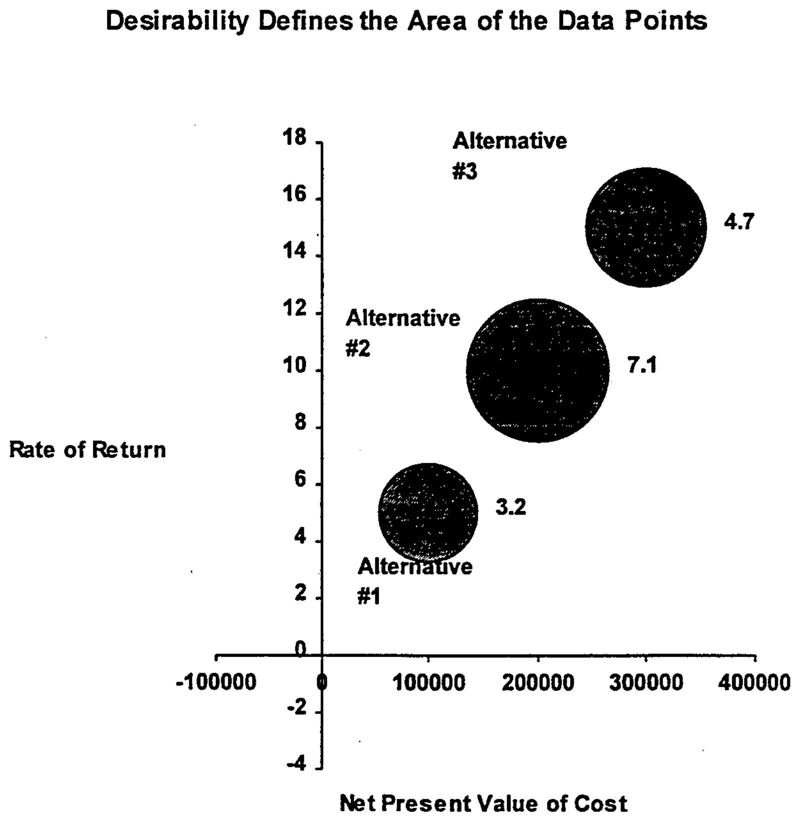


Figure 3.4 Visual Trade-Off Assistant

Using Figure 3.4 a decision-maker can visually trade off the differences in desirability with the differences in ROR. For instance if only $300,000 were available to the decision-maker he/she would trade off the higher rate of return of Alternative #3 with the greater desirability of investing in Alternatives #1 and #2 together.

A complementary method of relating the results of the respective analyses is to plot the desirability against the ROR. Using the example data in Table 3.5 such a plot would take the following form:

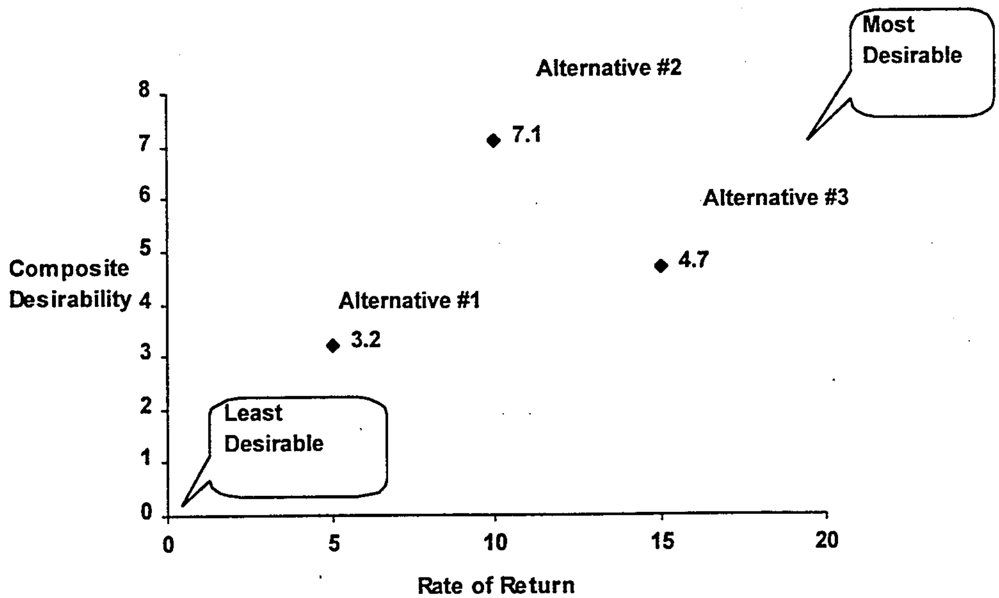


Figure 3.5. Desirability vs. ROR Graph

In Figure 3.5 decisions can be made by a trade-off between the alternative's position on the abscissa and its position on the ordinate. Alternatives that are superior in both desirability and ROR lie towards the upper right corner of the graph. Conversely, alternatives that are inferior in both desirability and ROR lie to the lower left of the graph near the origin. In most cases decision-makers should be able to visually determine which strategies are desirable for the small urban area involved.

4 Case Study: Methodology Applied to the Jefferson Area of Virginia

The Jefferson Area is located in the geographic region where the Piedmont approaches the Foothills of the Blue Ridge Mountains in Central Virginia. The metropolitan area contains an approximate population of 130,000. The public transportation system in the urban core of the Jefferson Area is defined by three major players: Charlottesville Transit Service (CTS), JAUNT and the University Transit Service (UTS). CTS provides fixed-route service for the city of Charlottesville and parts of Albemarle county with 13 traditional busses and 2 trolley busses along 8 fixed routes. Routes either operate on thirty minute or one hour headway. JAUNT provides Americans with Disabilities Act (ADA) and general paratransit service. With JAUNT's 56 vehicles (typical vehicle 14 seat van), a 24-hour reservation is required to request paratransit service. UTS provides service in and around the University of Virginia with activities fees paid by enrolled students. Portions of the major UTS routes operate on a 10 minute headway during peak University hours.

4.1 Identification and Cataloging Strategies

In the Taylor Study an ITS market package is defined as "a collection of equipment capabilities which satisfy a market need and are likely to be deployed as a group". [27] This notion of a market package is important, for it sets the stage of what is currently available in the marketplace and it spares the consumer, in most cases, from purchasing redundant or inappropriate hardware and software. In a sense, a market package can be described as a bundled solution to a specific ITS or transportation need. For instance, the market package known as automatic vehicle location (AVL) incorporates a position receiver, usually a global positioning system, (GPS), a land based communications transceiver, and a multi-display terminal, MDT. Each of these components could be purchased and installed separately, however an individual component would not likely be beneficial without the other components being present. Likewise, each of the constituent components could be evaluated using this methodology, but the results would be meaningless because real world implementation would depend on the installation of the companion systems. It if for this reason that in the identification of the strategies, which are likely to serve the transit operations in the Jefferson Area, "The Study of Intelligent Transportation Systems" report[28] primarily focused on market package strategies. Also, this convention allows this methodology to be reapplied in the future, regardless of the changes in the technical landscape, as long as the marketplace still offers the strategies as "bundled" solutions in the form of market packages.

The "Study of Intelligent Transportation Systems"[29] report grouped the APTS strategies under five major headings. Table 4.0 contains a summary of the study's findings for the Jefferson Area, where a brief description of the strategy has been included. The strategy group headings are in boldface type while the various strategies grouped under the heading are bulleted and italicized. If no strategies are provided the strategy group headings serve as the strategy.

Strategy	Description
Transit Management	Control technology that is used to improve planning scheduling, and operation of the transit system that relies on a fleet based communication system
• *Automatic Vehicle Location (AVL)*	These are technologies that determine precise locations of receivers. There are many technologies that can be used for AVL including; dead reckoning, signpost technology, Loran C and Global positioning system (GPS) satellites. However, modern AVL systems almost exclusively incorporate GPS. The location technology is often coupled with ground based communication systems and display terminals in the vehicle.
• *Automatic Passenger Counting*	Devices which take accurate passenger counts without requiring the attention of the vehicle operator
• *Computer Aided Dispatching/Automated Operations Software*	These systems are software algorithms that attempt to find a least time path between a series of points or stops, often in the context of paratransit or route deviation. They may or may not be used with AVL systems.
• *Mobility Manager*	Operations and systems designed to link riders with the trip options and travel options they need to reach desired destinations
• *Transportation Management Centers*	Centers used to effectively coordinate transit vehicles
Automated Traveler Information Systems	These systems make use of advanced communication and computer technology to provide better up to date transit information needed to make better travel decisions.
• *Advanced Transit Information Systems*	These systems make use of advanced technology to provide better up to date transit information.
• *In-Vehicle Annunciators*	Automatic anunciator that automatically announces information to riders.
• *Smart Kiosks*	Touch screen systems designed to give user real time information about arrivals, departures, fares, tele-communicating and tolls.
• *Telephone Information Systems*	Telephone and related information systems designed to give user information in a convenient way.
• *Cable and Interactive Television*	Cable and television applications which are designed to give user information in a convenient manner.
• *Internet*	Internet uses that are designed to give user information in a convenient manner.
• *Transit Fixed Route Operations*	Devices placed on the vehicle and at the intersection give the vehicle the ability to extend a green signal phase (transit signal preemption)
Transit Passenger and Fare Management	These are technologies that are designed and used to facilitate fare payment and to make transit easier and more manageable for the user.
• *Automated Fare Payment*	Technologies that automatically collect tolls and fares from users of public transportation.
• *Smart Cards*	Cards which allow passenger to pay toll and fares from electronic accounts, some are magnetically based and require contact with a card reader while others are radio based and can be read remotely.

Transit Security	These are applications which enhance the safety and security of operating systems under normal and emergency situations.
Transit Maintenance	These are strategies that assist in both preventative and routine maintenance of transit fleets.

Table 4.0. Summary of "Study of Intelligent Transportation Systems"

The results in table 4.0 were compared with the results found by Melissa Mawyer for the Taylor Study in order to verify that no transit specific market packages are being overlooked. Mawyer was charged with the completion of an environmental scan, which consisted of scanning the literature for good and bad examples of ITS deployments. Her efforts returned 53 total market packages with potential for the Jefferson Area; sixteen of which could be labeled as either Advanced Public Transportation Systems (APTS) or Advanced Transit Information Systems (ATIS).[30] The results of Mawyer's work are included in section 4.2 of this report.

4.2 Initial Screening of Catalogued Strategies

Section 3.2 of this report stated that the purpose of the initial screening is to prevent redundant strategies or strategies that do not meet the initial constraints of the region from consuming valuable time and resources during subsequent steps of the methodology. It was also stated that one of the most effective ways to screen strategies is to use the assistance of a study advisory committee. Fortunately, this study's "Advisory Committee", which was formed from a subset of the members of the ITS Planning Study's "Stakeholder Committee," communicated their preferences as a part of the Taylor Study's screening process. The Taylor Study used a four step screening process which incorporated: the results of the environmental scan, a strengths, weaknesses, opportunities and threats (SWOT) analysis, a goal mapping analysis and an analysis to determine if the strategy matched the vision articulated as a part of the "visioning workshop." The results of the ITS Planning Study's screening process as it applies to transit and advanced traveler information systems follows:

Market Package	Envir. Scan	SWOT Analysis	Goal Mapping	Match Vision
APTS01- Transit Vehicle Tracking	√	√	√	√
APTS02- Transit Fixed-Route Operation	√	√	√	√
APTS03- Demand Responsive Transit Operations	√	√	√	√
APTS04- Transit Passenger and Fare Management	√	√	√	√
APTS05- Transit Security	√	√	√	√
APTS06- Transit Maintenance	√	√	√	√
APTS07- Multimodal Coordination	√	√	√	√
ATIS01- Broadcast Traveler Information	√	√	√	√
ATIS02- Interactive Traveler Information	√	√	√	√
ATIS03- Autonomous Route Guidance	*X*	*X*	*X*	*X*
ATIS04- Dynamic Route Guidance	*X*	*X*	*X*	*X*
ATIS05- ISP Based Route Guidance	√	*X*	*X*	*X*
ATIS06- Integrated Transportation Management/Route Guidance	*X*	*X*	*X*	*X*
ATIS07- Yellow Pages and Reservation	√	√	√	√
ATIS08- Dynamic Ridesharing	*X*	√	√	√
ATIS09- In Vehicle Signing	*X*	*X*	*X*	*X*

Table 4.1 Initial Screening (31)

These results will be used with other information specific to the Jefferson Area and applied to the strategies described in Table 4.0 to complete the initial screening.

For the Jefferson Area, the initial screening should eliminate the strategies that are the direct jurisdiction of other projects. The other investigations will serve as a case study constraint because the scope of the other studies will permit these issues to be evaluated in a much greater depth than this methodology would allow. For example, the strategies labeled mobility manager, transportation management centers, telephone information systems, cable and interactive television and the internet are being investigated and evaluated as a part of the TIC. Secondly the initial screening should screen out redundant technologies. For instance, the functions of an Automatic Passenger Counter can be duplicated by a smart card/smart fare payment system. Likewise, an AVL system, by its nature, can provide location information in response to transit security and incident response concerns and the functions of the advanced transit information systems and the smart kiosks are almost identical, as reported by Alsberry.

Applying the results of the initial screening from the Taylor Study (Table 4.1), with the local constraints, namely the TIC, the following strategies result.

Strategy
Transit Management
• Automatic Vehicle Location (AVL)
• Computer Aided Dispatching/Automated Operations Software
Automated Traveler Information Systems
• Smart Kiosks/Advanced Transit Information Systems
• In-Vehicle Annunciators
• Transit Fixed Route Operations
Transit Passenger and Fare Management
• Smart Cards/Automated Fare Payment
• Transit Maintenance

Table 4.2. Results of the Initial Screening

4.2.1 Addition to Initial Screening

The previous section described the relation that the initial screening of the strategies had to the case study area; however, the original initial screening did not take changes in the ITS and transit market place into account. For instance, many of the automated transit maintenance activities (engine sensors, pressure sensor, maintenance schedule reminders etc.) are now being packaged with other strategies such as the system designed by Rockwell for the AATA. Therefore, such packages are now increasingly becoming standard equipment and are included in a transit vehicle's purchase price. Likewise, methods of annunciating or informing people with disabilities of transit stops are helping meet compliance requirements with the Americans with Disabilities Act (ADA).[32] Consequently, automatic annunciators are now being included in transit market packages, or are being purchased solely on the basis of ADA compliance. With this in mind, the updated results of the additional initial screening are as follows:

Strategy
Transit Management
• Automatic Vehicle Location (AVL)
• Computer Aided Dispatching/Automated Operations Software
Automated Traveler Information Systems
• Smart Kiosks/Advanced Transit Information Systems
• Transit Fixed Route Operations (traffic signal preemption)
Transit Passenger and Fare Management
• Smart Cards/Automated Fare Payment

Table 4.3. Final Results of the Initial Screening

4.3 Economic Analysis

The case study assumes that the ITS strategies will be installed on the entire transit system. This is due to the fact that for many strategies full benefits can only be realized if the entire or large portion of the fleet is equipped. Furthermore, many 'before and after" analyses, where several test-bed vehicles are equipped with APTS technology, recommend subsequent installation for the entire fleet. The only exceptions to this approach will be in dealing with strategies that are designed exclusively for paratransit or fixed route use. In some cases the cost and benefit data will come from "before and after" studies dealing with either fixed-route or paratransit systems. Every effort will be made to use data from similar systems in the case study. In some cases CTS service and JAUNT service will be evaluated separately and then aggregated together. Potential use of APTS strategies for UTS will not be considered due to the fact that UTS demonstrates unique operating characteristics such as concentrated service area and the lack of on-board fare collection instead relying on student fees. Moreover, UTS representatives have declined several invitations to participate in the Taylor Study, consequently, their input was not received as a part of the initial screening of strategies.

Transit Management:

Automatic Vehicle Location (AVL):

The term AVL normally refers to the combination of technologies that incorporate: Global Positioning Satellites (GPS) location, radio communications with a base station and Mobile Display Terminals (MDT's). Furthermore, all or part of a communications backbone is typically included as a part of an AVL strategy; especially, since AVL is often the first APTS strategy implemented by many urban areas. Although it is appropriate to consider AVL as a separate strategy in this particular case study, parties who implement this methodology several years after the publication of this report, may be faced with an ITS marketplace in which AVL is a required starting point into the world of APTS. If this is the case it may make sense to apply this methodology with the understanding that AVL will be implemented so that the other strategies could be useful. An analogy of the impending phenomena can be drawn with the computing world. In the late 60's and early 70's computer software packages increasingly relied on being interpreted (compiled) by computer language kernels. However, as the industry progressed graphical based user interfaces (GUIs) and operating system toolboxes became the standard of practice. In a certain sense AVL may become the "operating system toolbox" of the APTS industry.

Regarding the paratransit and fixed-route cases, the cost per unit vehicle will be the same; however, the benefits may vary depending on the eventual service characteristics. The costs summarized in the following table assume that the dispatch and coordination center will be housed at theTransportation Information Center (TIC):

Service Characteristic	**Reference Study**	**Applied to the Jefferson Area**
One-time costs:		
Paratransit Service	Iowa State University[33], Winston Salem Mobility Manager	• $2500 x 56 = $140,000 • FM Subcarrier can be shared • Computers and Dispatch are not necessarily shared $14,000
Fixed Route Service	Blacksburg Transit Study: • AVL equipment $2500 per vehicle • Computers and Central Dispatch $14,000 • FM Subcarrier base station $6,000	• $2500 x 17 = $42,500 • $14,000 • $6,000 • Total Fixed Route = $62,500
Total One-time costs:		***$216,500***
Recurring Costs:		
Maintenance	Iowa State University	Approximately $1000
System Coordinator Salary	Iowa State University	Approx. $45,000
FM Subcarrier Rental	Iowa State University	Approx. $1,000
Total yearly recurring costs		***$47,000***

Table 4.4. AVL Costs

AVL Benefits:

Service Characteristics	Reference Study	Applied to the Jefferson Area
One-Time Benefits		
Fixed Route Service	ITS Planning Study (Taylor) • Fleet Size can be reduced by 8%	• CTS could reduce fleet size by approximately 1 vehicle at an annual operating cost of $78,279
Paratransit Service	ITS Planning Study (Taylor) • Fleet Size can be reduced by 8%	• JAUNT could reduce fleet size by approximately 4 vehicles: (4 vehicles) x ($32,727 annual operating cost) = $130,908
Total One-Time Benefits		***$209,178***
Recurring Benefits		•
	Iowa State University: Linking Real Time and Location is Scheduling Demand Responsive Transit • Reduction in dispatcher time, savings $16,000	• Approximate savings of $16,000 in dispatcher time
	Winston Salem Mobility Manager • AVL + CADS passenger trips increase 17.5%	• Passenger Trips: (228,191)(.175) = 39,933 x $1.00 fare per passenger = $39,933
Total Recurring Benefits (Annual)		***$55,933***

Table 4.5. AVL Benefits[34]

Rate of Return

- NPW(AVL) = 0 = $209,178 + ($55,933) (P/A, *i*, 5) –[($216,500+$26,000(P/A,*i*,5)]
  $7322/$29,933 = 0.245 = (P/A, *i*, 5) => *i* is greater than 60%

Analysis Period	NPV Costs	ROR
5 years	$222,870	greater than 60%
7 years	$222,870	greater than 60%
10 years	$222,870	greater than 60%

Table 4.6. AVL ROR

Computer Aided Dispatching and Automated Operations Software:

Computer Aided Dispatching and Automated Operations Software are primarily intended for the paratransit market. There is one software package offered by Trapeze

Software (*http://www.trapezesoftware.com/pages/fx.html*) which applies Computer Aided Dispatching techniques to fixed route transit systems. However, the online literature implies that the fixed route package is suited primarily for large fixed route systems, and the executives at Trapeze Software were not forthcoming in responding to the author's numerous inquiries. Therefore, Computer Aided Dispatching Software (CADS) strategy will be evaluated only as it relates to paratransit service.

Computer Aided Dispatching/ Automated Operations Software can provide both planning and up to date information. In the planning mode, the trip requests are taken from the previous day and the next day's paratransit routes are determined by the software package. In up to date (real time) mode, it is assumed that both AVL and Mobile Display Terminals (MDTs) have been installed on the transit fleet.

The most relevant evaluation of CADs software is reported in the Final Report 3rd Draft of the Winston Salem Mobility Management Project Phase 1: July 31, 1995.[35] It is stated that the WSTA and NCSU evaluated the effects of CADs dispatch and scheduling on the operation of 19 small buses used to deliver clients of human services agencies. As a result of this test it was found that approximately 10% of the trips are "same day" demand responsive trips while the remainder were 24-hour advance reservation and subscription trips, therefore, the results can be extrapolated for both the subscription and the real time cases. The results and the likely projections for JAUNT based on the following data taken from JAUNT's report to the Board follow:

Operating costs for one year $1,725,252
Annual Vehicle Miles 1,449,891
Annual Passenger Trips 228,191
Annual Revenue Hours 76.872

Expenses/ Vehicle Mile $1.19
Expenses/Passenger Trip $7.56
Expenses/Revenue Hour $22.44 [36]

Summary of Costs

WSTA Results	Projections for JAUNT Paratransit Service (Annual Calculations)
One-time costs	
Initial Cost of $100,000 (includes software, training, installation etc.) exclusive of research costs	Near term projection likely to resemble the WSTA result, however, as economies of scales arrive the initial costs will fall
Total one-time costs	***$100,000***
Recurring costs	
CADS costs represent about 3.5% of operating cost, or less if passenger demand continues to increase	From JAUNT's report to the board ($1,725,252)(.035) = $60,384
Total Recurring Costs Annualized	***$60,384***

Table 4.7. CADS Costs

WSTA Results	Projections for JAUNT (from Report to the Board)
One-time benefits	
During the five month period passenger trips rose 17.5 % and vehicle miles rose 25.1%	Passenger Trips: (228,191)(.175) = 39,933 Vehicle Miles: (1,449,891)(.251)=363,923
Operating expenses per vehicle mile dropped by 8.5%, operating expenses per passenger trip dropped by 2.4% and operating expenses per hour dropped by 8.6%	Vehicle Mile: ($1.19)(1,449,891)(.085)=$146,656 Passenger Trip:($7.56)(228,191)(.024)=$41,403 Hour: ($22.44)(76,872)(.086)=$14,835 Sum Total of annual savings = $202,894
Total one-time Benefit	***$202,894***
Recurring Benefit	
Not Cited. Estimated at 5% One time benefit	
Annual Benefit	***$10,145***

Table 4.8. CADS Benefits

ROR

- NPW(CADS) = 0 = $202,894 + ($10,145)(P/A, i, 5) –[($100,000+$60,384(P/A,i,5)]
  $102,894/$50,239 = 2.05 = (P/A, i, 5) => i is approximately 40%

Analysis Period	NPV Costs	ROR
5 years	$142,372	approximately 40%
7 years	$142,372	approximately 45%
10 years	$142,372	approximately 47%

Table 4.9. CADS ROR

Automated Traveler Information Systems:

Smart Kiosks/ Advanced Transit Information Systems

Smart Kiosks and Advanced Transit Information Systems can be used with both paratransit and fixed route systems. Some of the benefits include, increased ridership due to dissemination of information, reduced waiting time for transit riders, possible advertising revenues, tourism benefits, and convenience. In most cases, Smart Kiosks rely on a communications backbone that benefits from information from various sources, a previously installed AVL system on transit vehicles, traffic counters and sensors, autoscope intersection cameras etc. The Following table summarizing the costs assumes a five year time horizon.

Technology	Study (Source)	Applied to Jefferson Area
One-time Costs		
Kiosk with touch screen	Blacksburg Transit	4 Kiosks (4 x $12,000)=$48,000
Bus Stop variable message sign	Blacksburg Transit	50 at selected stops (50 x $500)=$25,000
Installation and Training	Blacksburg Transit	$2,000
Total One Time Costs		$73,000
Recurring Costs		
Communications	Blacksburg Transit	$2,000
Maintenance	Not Cited	Estimated 5% of one time costs $3750
Private Advertisement on Kiosk Structure	Martin Media (Specialists in Outdoor Advertisement)	-($25,200) per year 4 kiosks
Kiosk Yellow Page Service	ROYMR.COM (Specialists in Online Yellow Page Service)	Approximately -($5,000) in recuperated costs per year
Total Recurring Costs (annual)		-$28450 (Benefit)

Table 4.10 Smart Kiosks and VMS Costs (37)

Sources: Martin Media (804) 295-9339
ROMYR.COM (http://www.tfsinc.com/p85.htm)

Benefits: The extent of benefits has not been quantified in the literature.

Calculating the ROR for 5, 7 and 10 year analysis periods yield.

- NPW(kiosks and VMS) = 0 = – [($73,000 - $28,450 (P/A, *i*, 5)]
  $73,000/$28,450 = 2.57 = (P/A, *i*, 5) => *i* is approximately 27%

Analysis Period	NPV Costs	ROR
5 years	$146,117	approximately 27%
7 years	$146,117	approximately 34%
10 years	$146,117	approximately 38%

Table 4.11. Smart Kiosk ROR

The negative value for the NPW costs presented in table 4.10 indicates that the net income recuperated from advertisement more than exceeds the NPV of the initial one time costs and the annual costs over the 5, 7 and 10 year periods . However, most of the Smart Kiosk related technology is only useful if AVL has previously been installed. Therefore, it is recommended that Smart Kiosk and VMS technology should be installed if AVL is chosen as a result of the methodology; however, Smart Kiosk and VMS technology should not be purchased without the addition of AVL since the costs reported by the literature assume the presence of AVL.

Transit Fixed Route Operations (Transit Signal Preemption)

The idea behind transit signal preemption is to give transit vehicles some sort of preference in the extension of or the allocation of a green phase. In general there are at least two levels of priority built into a transit signal preemption system. The highest level of priority is generally reserved for emergency vehicles and allows for the interruption of the current phasing system by requiring a green phase in the desired direction. The second level of priority, which is typically reserved for transit vehicles, allows a green phase to be extended so that a transit vehicle can pass through the intersection.

There are four major technologies that provide for transit signal preemption Loopcom, TOTE, Sonic Systems and Opticom. Loopcom relies of loops buried under the road surface that can read a tagged request transmitted by the transit vehicle, TOTE systems use radio frequency (RF) communication between the vehicle and the signal controller, Sonic Systems emit a burst of ultrasonic sound waves to a detector mounted near the traffic signal heads, and Opticom systems transmit and electromagnetic burst of light to detectors mounted near the signal heads.[38]

The systems differ slightly in service and price characteristics. However, it should be noted that the Jefferson Area currently has approximately 7 to 10 Opticom receivers mounted along U.S. Route 29 in Albemarle County. Furthermore, the vast majority of reports and research findings obtained by the author deal almost exclusively with Opticom systems. Therefore, it will be assumed that an Opticom type system will be installed in the Jefferson Area.

In dealing with signal preemption systems there are two important variables that must be accounted for: the number of intersections involved and the number of vehicles involved. For this case study, it is assumed that traffic signal preemption will benefit both CTS and JAUNT (while it is operating in the urban core). An estimate, based on the transit route maps provided by CTS, indicates that there are approximately 35 signalized intersections encountered by CTS buses in Charlottesville and Albemarle county. However, at least 7 of these intersections are contained within the U.S. 29 corridor mentioned above; therefore, the approximate number of signalized intersections needed to be equipped is 28. It is assumed that the JAUNT vehicles, while operating in the urban core will encounter, on average, a similar number of signalized intersections as the fixed route service. Based on previously reported statistics 17 CTS vehicles and 56 JAUNT vehicles would require Opticom transmitters. A summary of the one-time and recurring cost follows:

System	Source	Vehicle Costs	Intersection Costs
One-time product costs	Telephone Quote		
CTS	3M March 6,1998	$1,000x 17 vehicles = ***$17,000***	
JAUNT	Same	$1,000 x 56 vehicles =***$56,000***	
Both Systems	Same		$2,200 x 28 intersections = ***$61,600***
Vehicle Installation Costs	Not cited in literature	estimated $600 per vehicle	
Intersection Installation Costs	Not cited		estimated $1000 per intersection
Total One time costs			***total = $205,800***
Recurring costs			
Maintenance	Not cited	estimated	10% of one time costs
Communication	Not cited	estimated	10% of one time costs
Total Recurring Costs			***$41,160***

Table 4.12. Signal Preemption Costs[39]

Potential Benefits are summarized in the following table:

Benefit	Reference Study	Application to the Jefferson Area
Common travel reduction time for patrons between 5%-7%	• Pierce Transit, Tacoma WA • revenue hours for CTS and JAUNT were obtained from The Corrandino Report[40] and JAUNT's report to the board[41] respectively and then summed • The value of time is assumed to be the same as previously reported for vehicle travel	• Averaging the travel reduction time to 6%: Benefit = (reduction in travel time) x (revenue hours) x (value of time) Benefit = (0.06)(111,333)($13.50)=***$90,180***
Increase in Ridership	• Anecdotal information given in the literature; however no specific information if cited	
Uniform Annual Benefit		***$90,180***

Table 4.13. Signal Preemption Benefits [40]

Rate of Return for 5 year analysis period

- NPW(Signal Preemption) = 0 = ($90,180) (P/A, *i*, 5) – [($205,800 +$41,160(P/A,*i*,5)]
  $205,800/$49,020 = 4.20 = (P/A, *i*, 5) => *i* is approximately 6%

The ROR and Present Value of Costs at the ROR are summarized in the following table.

Analysis Period	NPV Costs	ROR
5 years	$378,672	approximately 6%
7 years	$378,672	approximately 14.5%
10 years	$378,672	approximately 20%

Table 4.14. Signal Preemption ROR

Transit Passenger and Fare Management:

Smart Cards and Automated Fare Payment:

In general there are two different types of smart cards used in automated fare payment. Contact smart cards contain an embedded microchip that contains payment information; whereas, contactless smart cards contain a small radio frequency RF transmitter that allows for payment to be debited as a result of the card passing in front of a sensor. There are some attempts to combine the technologies of contact and contactless operation into one smart card package.

Smart card technology offers a great potential for cost sharing and crosscutting from different agencies. In Europe and Asia, smart cards are often used for public phone calls, parking and banking operations. Furthermore, a ubiquitous smart card system has the potential to serve as an advertising vehicle. For these reasons, the NPW of costs and the NPW of benefits may be difficult to estimate for the Jefferson Area.

The potential cost savings resulting from the adoption of smart card technologies include: open system/ public private partnership, improved flexibility in fare setting, improved revenue accountability and security, reduced fare abuse, improved ridership data, improved convenience, additional revenue from unused value on the cards, expansion of employer programs and faster throughput.[41]

Fortunately, a thorough report entitled "Potential of Multipuropse Fare Media" was published in August 1997 by Multisystems, Inc, Dove Associates, Inc, and Mundle

& Associates, Inc, as a part of the Transit Cooperative Research Program of the Transportation Research Board (TRB).[42] With the cost estimates pertaining to a Small/Medium Bus System on page 123 of the report the following cost table can be projected for the Jefferson Area:

Cost Element	Unit Cost	No. of Units CTS + Jaunt	Total Cost
One Time Costs			
• Card-accepting device	$2,000	17+56=73	$146,000
• Mechanical farebox	$2,000	73	$146,000
• On-board probe	$1,000	73	$73,000
• Garage/hardware/software	$10,000	2	$20,000
• Add-fare machine	$10,000	5	$50,000
• Spare Parts	10% of costs		$43,500
• Support Services	15% ""		$62,250
• installation	5% ""		$21,750
• fare media (contactless)	$3.00	15,000	$45,000
Total one-time Costs			**$607,500**
Recurring Costs			
• maintenance costs	7% of one – time costs		$30,450
Total Recurring Costs			**$30,450**

Table 4.15. Automatic Fare Payment Costs

Name of Benefit	Observed Benefit	Application to the Jefferson Area
One-time Benefit		
Increased Ridership/ Employer Pass Subsidy Program	*Central Puget Sound Study*, Smart cards can increase ridership by 20% if an employer pass subsidy program is used	CTS, 674,980 (annual ridership from Corradino Group) x 0.20 = 134,996 new riders x $0.65 fare = ***$87,747*** JAUNT (228,191) x 0.20 = (45,638) x ($1.00, average fare per passenger) = ***$45,638***
Total One Time Benefit	-	***$133,385***
Recurring Benefits		
Float on Prepayment or Card Balances	Central Puget Sound Study, A non-refundable buffer of around $10 can be set.	$10 x 10,000 cards = ***$100,000***
Advertising Fees	A conservative estimate of 10% of fare media costs	***$4,500***
Cross funding issues with other agencies potentially using the fare media: taxies, merchants, parking garages etc.	A conservative estimate of 10% of operating costs	***$3,450***
Total Uniform Annual Benefit		***$107,950***

Table 4.16. Automatic Fare Payment Benefits [43]

- NPW(Smart Card) = 0 = \$133,385 + (\$107,950)(P/A, i, 5) – [\$607,500+\$30,450(P/A,i,5)]
  \$474,115/\$77,500 = 6.11 = (P/A, i, 5) => i is less than 0.25%

Analysis Period	NPV Costs	ROR
5 years	\$142,372	less than 0.25%
7 years	\$142,372	approximately 3.5%
10 years	\$142,372	approximately 10.5%

Table 4.17. Smart Card ROR

4.3.1 Summary of Results

The following table summarizes the results of the economic analysis obtained so far.

Strategy	Analysis Period	ROR
AVL	5 years	greater than 60%
	7 years	greater than 60%
	10 years	greater than 60%
CADS	5 years	approximately 40%
	7 years	approximately 45%
	10 years	approximately 47%
Kiosks/VMS	5 years	approximately 27%
	7 years	approximately 34%
	10 years	approximately 38%
Signal Preemption	5 years	approximately 6%
	7 years	approximately 14.5%
	10 years	approximately 20%
Smart Cards	5 years	approximately 0.25%
	7 years	approximately 3.5%
	10 years	approximately 10.5%

Table 4.18. Summary of ROR Analysis

Inspection of Table 4.18. indicates that there are three strategies which generate a relative greater projected ROR than the other strategies at each analysis period: AVL, CADS and Kiosks/VMS. Concerning the CADS and Kiosks/VMS strategies the high returns are due to the fact that each of these strategies requires the prior installation of AVL in order to generate the projected benefits. In other words, the costs of the AVL infrastructure are not internalized into the costs of the individual strategies. This would be similar to performing a ROR analysis on a popular office suite software package for a personal computer and to neglect that a purchase of a new computer is required to run the package. Thus, the AVL, CADS and Kiosks/VMS strategies will be combined into one strategy called Location , Scheduling and Communications (LSC) for the purposes of this report. Combining the projected costs and benefits of the three strategies would produce the following totals.

Strategy	**Costs**
LSC	
Total One-time Costs	$389,500
Total Recurring Costs (Annual)	$57,934
Total One-time Benefits	$370,669
Total Recurring Benefits	$66,078

Table 4.19. Costs and Benefits for LSC

ROR

- NPW(LSC) = 0 = \$370,669 + (\$66,078)(P/A, *i*, 5) –[(\$389,500+\$57,934(P/A,*i*,5)]
  \$18,831/\$8,144 = 2.31 = (P/A, *i*, 5) => *i* is approximately 33%

Analysis Period	NPV Costs	ROR
5 years	$523,328	approximately 33%
7 years	$523,328	approximately 39%
10 years	$523,328	approximately 41.5%

Table 4.20. LSC ROR

Combining the results in Table 4.20 with the results in Table 4.18 the analysis projects the ROR as summarized in the following table.

Strategy	Analysis Period	NPV Costs	ROR
LSC	5 years	$523,328	approximately 33%
	7 years	" "	approximately 39%
	10 years	" "	approximately 41.5%
Signal Preemption	5 years	$378,672	approximately 6%
	7 years	" "	approximately 14.5%
	10 years	" "	approximately 20%
Smart Cards	5 years	$142,372	approximately 0.25%
	7 years	" "	approximately 3.5%
	10 years	" "	approximately 10.5%

Table 4.21. Revised Summary of ROR Analysis

Since the ROR for the LSC strategy is very high, thoroughness dictates that a NPW analysis be performed to verify the results.

- NPW(LSC, 4, 5years) = \$370,669 + (\$66,078)(P/A, *i*, 5) – [(\$389,500+\$57,934(P/A,*i*,5)] = \$17,426

Strategy	**Interest Rate**	**Period**	**NPW**
LSC	4%	5 years	$17,426
	4%	10 years	$47,225
	10%	5 years	$12,042
	10%	10 years	$31,213
Signal Preemption	4%	5 years	$12,434
	4%	10 years	$191,801
	10%	5 years	-$19,965
	10%	10 years	$95,428
Smart Card	4%	5 years	-$129,085
	4%	10 years	$154,488
	10%	5 years	-$180,313
	10%	10 years	$2,123

Table 4.22. NPW Analysis

The NPW analysis confirms the ROR from the LSC strategy for analysis periods less than 10 years. However, if the analysis period were to increase beyond 10 years the Smart Card and the Signal Preemption strategies would eventually demonstrate a greater ROR than the LSC strategy. This is due to the fact that the UAB for these two strategies provides fulfills scenarios 3, 4, 6, 7, 10, 11, 12, and 14, whose respective average scores are: 2.302, 2.455, 2.670, 2.909, 2.932, 2.523, 3.091, and 2,670. Therefore the qualitative analysis yields the following the results:

Qualitative Method	Signal Preemption	Smart Fare Payment	AVL/CADS
Maximum Value	3.542	2.909	3.091
Summation Value	11.956	15.344	21.633

Table 4.24. Maximum and Summation Value

Sample Desirability calculation for Signal Preemption for c = 2

$$D = \Sigma\ [(2.909)^2+(2.414)^2+(3.091)^2+(3.542)^2]^{1/2} = 6.0 \qquad (4.0)$$

The Desirability calculations for the range c = 0 to 5 follow.

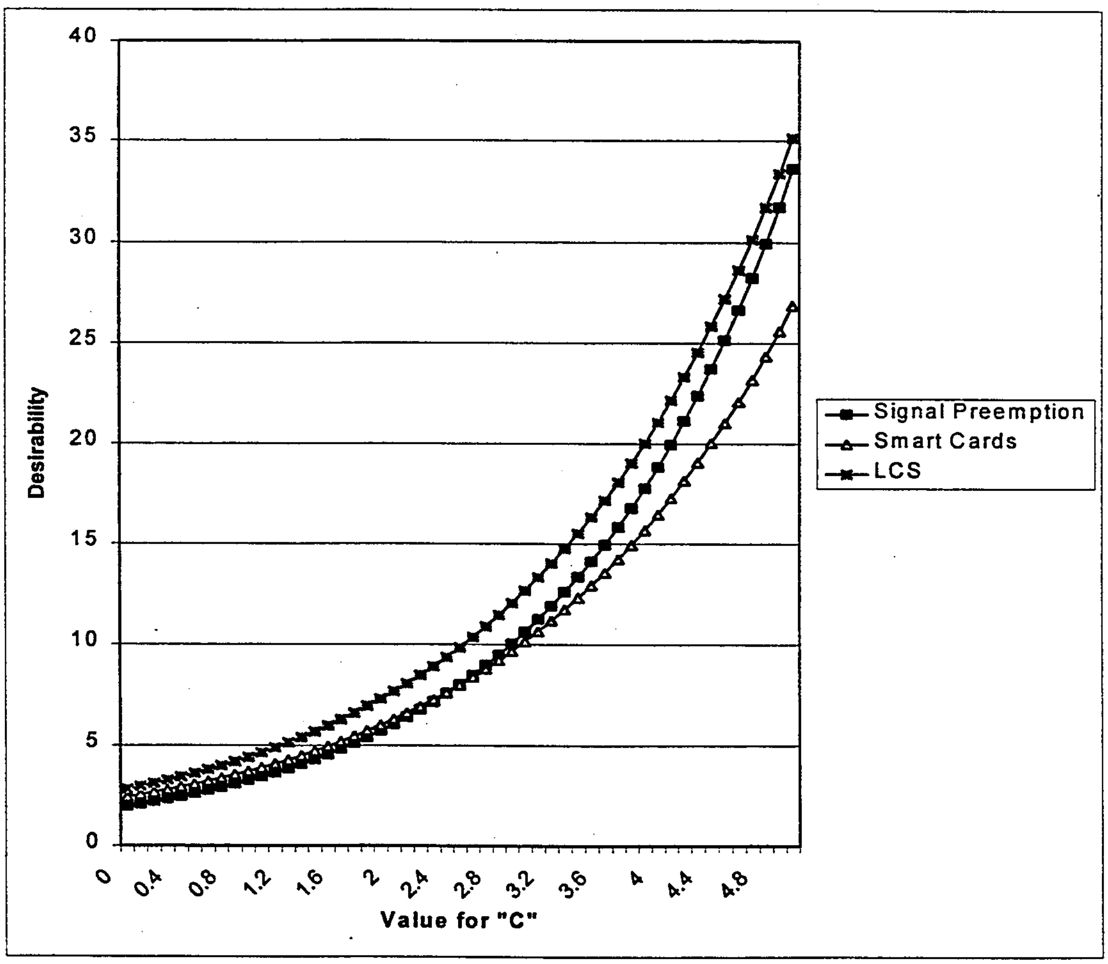


Figure 4.0 Trends in Preference

The LCS strategy is the most desirable throughout the range of values for c; however, the preference order between the Smart Card and the Signal preemption strategies changes around the value c = 2.3. This indicates a decision point for the local decision-maker. If the decision-maker wishes to emphasize strategies which fulfill multiple scenarios over the strategies which fulfill the highest ranked scenarios (superstars) then a choice to the left of the decision point would be appropriate. However, if the opposite is true then the choice of a value to the right of the decision point is most likely.

Assuming that a decision maker would choose the analysis for c = 2 for the Jefferson Area, the results chosen for the ROR analysis (analysis period = 10 years) would be synthesized in the visual tools to form the following plots.

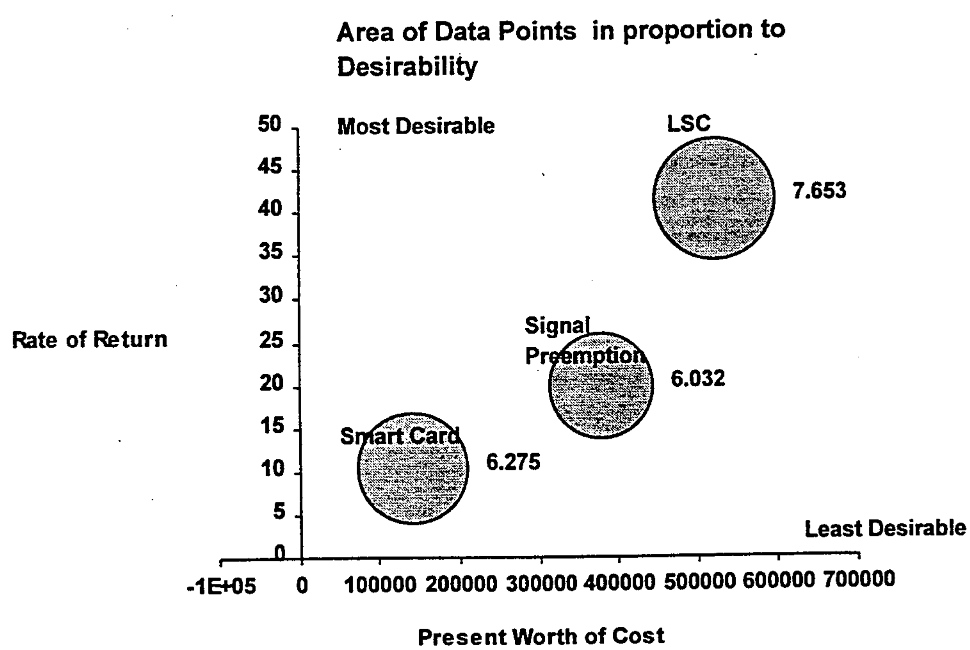


Figure 4.1. Graphical Trade-Off Tool for C = 2

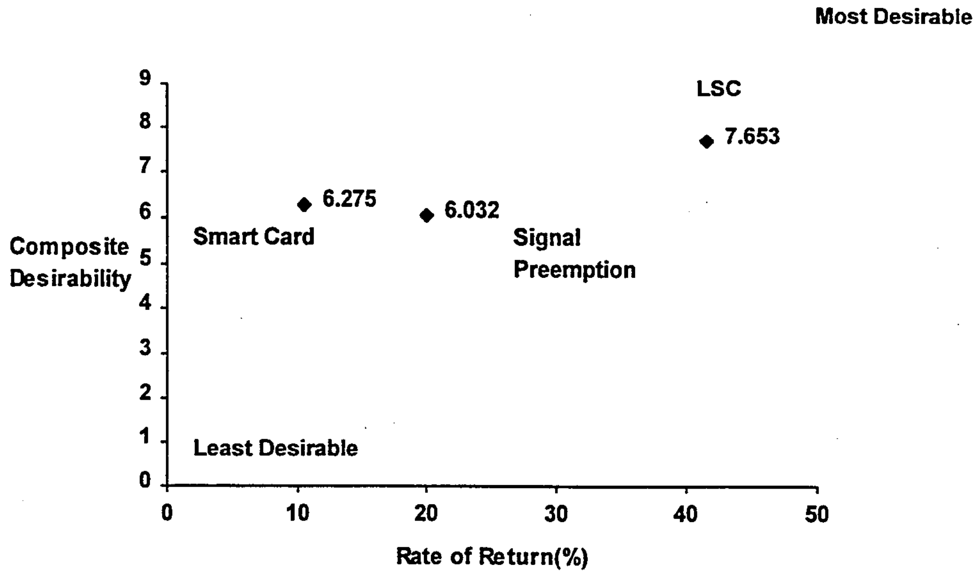


Figure 4.2. Desirability vs. ROR for c = 2

It is evident with the above representation that the decision-maker's choice would likely lie with the AVL strategy, the signal preemption strategy is a low cost alternative, however, it does not provide the benefits or the desirability rating that AVL provides. For argument's sake, suppose that the decision-maker decides that the summation analysis is the best representation of his/her community's "desirability" concerns, then the resulting composite plot would follow:

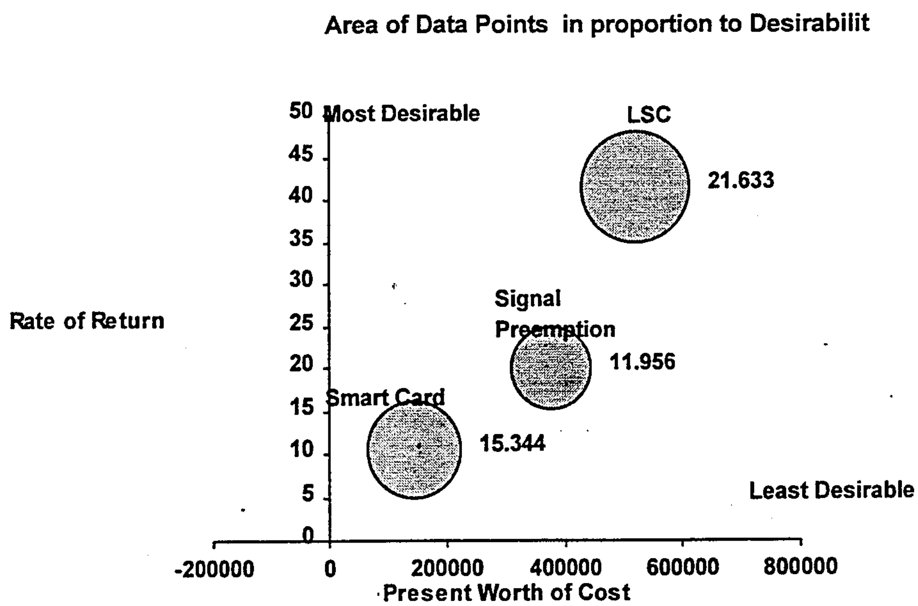


Figure 4.3. Graphical Trade-Off Tool For Summation Value Approach

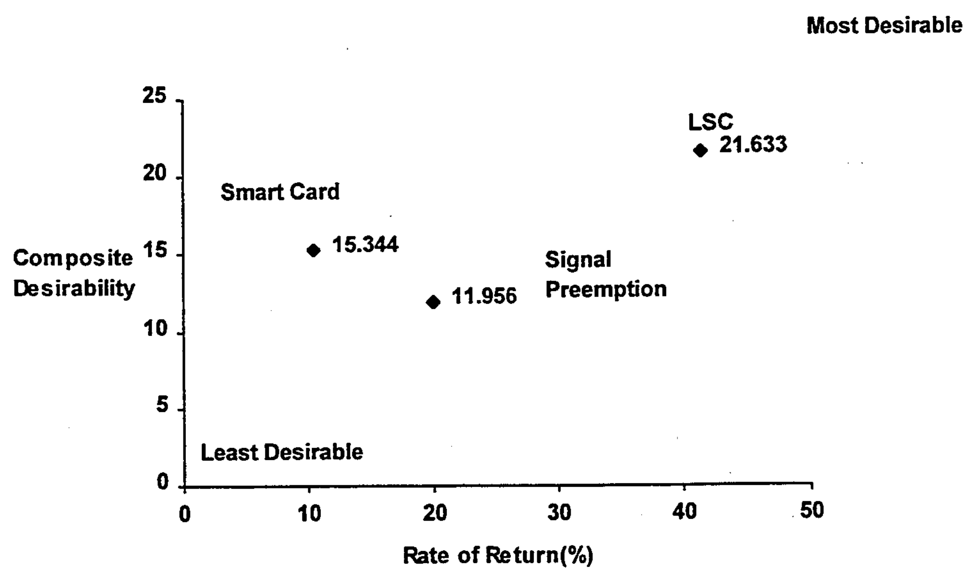


Figure 4.4. Desirability vs. ROR for Summation Value

The summation value recommends the LSC strategy as well, however there is a much greater trade off between the Signal Preemption and the Smart Card Strategies. This is an opportunity for a decision-maker to make a true trade-off because there is no clear preferred strategy.

As assumptions and conditions change, graphs provided to decision-makers should reflect such changes and should be provided with appropriate explanations.

5 Conclusions

The description of this methodology presents an innovative approach to the prioritization of potential benefits of APTS strategies for small urban areas. This research was based on several premises which were discussed throughout Chapters 3 and 4 of this report: (1) A potential APTS strategy should be both economically feasible and acceptable to the community. (2) It is infeasible for a small urban area to quantify every difficult to quantify benefit; rather, an effort to gauge the willingness of the community to support the potential benefits of the APTS strategies should be made. (3) Often, decision-makers are not technically trained; therefore, results should be presented in a visual manner so that, decision-makers can make a more informed decision. These criteria lead to the formation of a methodology that is neither difficult to implement nor difficult to understand. Moreover, the methodology is adaptable as market conditions change.

The Location, Scheduling and Communications (LSC) strategy was chosen as the most desirable strategy in the case study based both on the results of the c=2 preference analysis and the summation value analysis as reported by the graphical tool. In fact, the LSC strategy is the most desirable strategy, according to the range of preference analysis, as c varies from 0 to 5 (Figure 4.0. Trends in Preference). Therefore, the LSC strategy is the only strategy represented in the low cost package, which assumes that the Jefferson Area is only able to allocate $400,000 for the capital costs of an APTS project. This is also a sound decision with regard to the increasing role of AVL as the backbone to additional strategies. The decision to not implement AVL technology would likely put the region at a disadvantage as far as future strategies are concerned. A medium cost strategy (under $600,000) would incorporate the signal preemption strategy with that of AVL. Finally, a high cost package (under $1,500,000) could incorporate a smart card system with the other two strategies. The author does not recommend the selection of the high cost package unless cross-institutional concerns (banks, merchants, taxies etc.) come on-board and share the capital and administrative costs of a smart card system.

Package #1 Low Cost	**Package #2 Medium Cost**	**Package #3 High Cost**
Includes: AVL/CADS and Smart Kiosks, Initial Costs Approximately $350,000	Includes: Package #1 plus Signal Preemption, Initial Costs Approximately $600,000	Includes Package #2 plus Smart Fare Payment, Initial Costs Approximately $1,500,000

Figure 5.0. Solution Packages

5.1 Sources of Error

The results of the economic analysis in the case study are dependent upon the accuracy of the input data obtained. Input data concerning quantifiable costs and benefits come in a variety of sources: similar before and after evaluations, Transportation Research Board (TRB) reports and papers, vendor literature etc. Errors or omissions in any of these sources would have the potential to compound through the analysis. Although, as of the writing of this report, APTS strategies constitute an emerging field and the market is far from mature, in the future the quantifiable costs and benefits will likely be known with a much greater accuracy. Consequently, the methodology presented in this report will likely become more robust.

Likewise, the results of the qualitative analyses are primarily subject to survey and sample error. Specifically, it could be found that the business community does not have as much an influence on the willingness of the community to support the specific strategies as originally asserted. Another source of survey error could result in the unintentional omission or duplication of benefit scenarios on the distributed surveys. Either case would result in strategies being either unfairly bolstered or disadvantaged with respect to the other strategies. Finally, error could result in the survey method in the survey method itself. The direct mailing of surveys could result in the reception of responses from the most passionate. While, the administration of an Internet based survey would result in responses from those with access or willingness to use the World Wide Web (WWW).

Lastly, the decisions of the decision-makers themselves could provide a source of error. Generally, engineers, research scientists and planners are not responsible for the choice of the decision-makers. However, the misrepresentation or the representation of facts in a confusing manner could influence decision-makers towards a particular decision. The techniques of visually representing the results of the various analyses were chosen by this methodology to more intuitively represent complex situations for non-technically trained decision-makers. However, the engineer/scientist should fully explain the concepts and techniques involved to the decision-maker before any decision is made.

5.2 Further Research

An interesting follow-up study would include attempting to gauge accurately the influence of business leaders and employers on transportation decisions in a small urban area. Such a study would be useful not only to this methodology but to transportation management and planning in general. A possible next step for the Jefferson Area would be to implement one of the packages and to conduct a before and after study concerning the package. This would serve to either validate or detract from the predictions made by this methodology. In any case, such a study would provide valuable information that could be incorporated in the methodology. In fact, it is conceivable that a researcher could apply this methodology to small urban areas that are slated to evaluate one or more APTS strategies and then compare the predicted decisions with the actual results. The resulting differences could serve to further calibrate the methodology for future use.

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