Integrating ITS and Traditional Planning - Lessons Learned

I-64 Corridor Major Investment Study

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Executive Summary

This paper describes some of the planning techniques used to analyze the need for intelligent transportation systems (ITS) as part of a corridor study conducted for the Virginia Department of Transportation (VDOT). The I-64 Study is one example of where a traditional planning study was modified to incorporate specific analytical and modeling procedures necessary to evaluate ITS improvements. The purpose of this paper is to provide ideas and suggestions on how one might integrate ITS and traditional planning practices.

I-64 Corridor Study

The I-64 major investment study followed basic planning principles common to a traditional planning study:

- defined the corridor study area
- identified the purpose and need for improvements
- developed transportation alternatives (i.e., potential transportation solutions)
- established evaluation criteria (performance measures)
- performed technical studies necessary to produce evaluative information
- analyzed evaluation results in order to identify a preferred alternative

However, the I-64 study was somewhat unique in that it contained a strong ITS planning element as part of the overall study process. In other words, the I-64 study analyzed the need for ITS improvements in conjunction with transit improvements, travel demand management strategies, high speed rail service, high occupancy vehicle lanes (HOV), added general purpose lanes, and interchange improvements.

I-64 Study Challenge

Including intelligent transportation systems analysis in a conventional planning study posed several technical challenges to the study team. It was important that the technical analyses remain objective and unbiased across all modes and types of improvements, including ITS. Therefore, the study team had to develop a comprehensive evaluation framework that addressed the following concerns:

Reconciling Two Different Planning Approaches and Ways of Thinking — the Early Deployment Plan (EDP) and the Major Investment Study (MIS). The methods used to identify and evaluate the need for ITS improvements are different from those used in a traditional planning study or corridor analysis.

Systems Perspective versus Corridor Perspective. ITS planning studies take a systems approach to problem-solving, whereas major investment studies typically focus on improvements to a specific corridor or subarea.

Short Term versus a Long Term Planning Horizon. Although there are exceptions to this rule, the planning horizon is generally shorter (5-7 years) for ITS projects compared to major corridor studies or regional planning studies (20 years or longer).

Individual ITS Projects are Small Compared to Major Capital Projects. ITS projects, if viewed individually, are smaller, less costly, and have a less discernible impact on the performance of the transportation system - especially when compared to capital-intensive projects such as added highway lanes or a new light rail system.

Average Peak Period Conditions versus Incident Management. Evaluation of ITS strategies cannot exclusively assume typical, everyday circumstances or utilize a predictable timeframe such as the peak hour. Whereas in traditional transportation planning, it is common to study the need for transportation improvements based on peak travel conditions, since this is when the highest stress is placed on the transportation system.

Rapidly Evolving Pace of Advanced Technologies. The operational capabilities, performance characteristics, and costs of advanced technologies that comprise ITS improvements are constantly shifting as these technologies continue to evolve.

Lack of Information on ITS Deployments. In many cases, ITS strategies have yet to be developed and systematically deployed under "real world" conditions. Consequently, actual evaluation data on ITS costs and performance were not always available.

Constrained Study Funds. In the I-64 MIS, the amount of study funds that could be devoted exclusively to the ITS tasks was limited.

Lack of a Single Travel Demand Forecasting Model for the Corridor Study Area. The lack of a single travel demand forecasting model which encompassed the entire 75-mile corridor presented the study team with several technical obstacles, not all of them related to ITS.

I-64 Study Approach

The I-64 Study pursued an integrated approach, in which the ITS planning tasks were formally included in the overall study structure. Although ITS was present in almost all aspects of the study, ITS planning activities figured significantly in alternatives development; alternatives refinement (i.e., conceptual engineering and operating plans); operations analysis; and study evaluation.

ITS improvements were proposed for all of the transportation alternatives under study in the I-64 MIS at various levels of investment. Proposed improvements consisted of ITS strategies such as: traffic control and management systems; pre-trip and en-route travel information programs; commercial vehicle operations strategies; transit route deviation; ramp metering; and advanced signal systems.

Once a final set of multimodal alternatives was approved by the regional metropolitan planning organizations, the study team undertook four major tasks which focused exclusively on ITS planning activities necessary for the overall project evaluation:

1. Specified the ITS strategies to be included in each of the multimodal alternatives;
2. Defined the ITS strategies to a level of detail necessary to support estimates of travel benefits and costs;

3. Drew upon other ITS projects, studies, and published sources to identify anticipated ranges of performance for the proposed ITS strategies; and
4. Aggregated the proposed ITS strategies into logical packages for study.

Upon completion of alternatives refinement, the study team developed a consistent methodology to quantify the ITS travel benefits which was then applied to the final set of MIS alternatives. The evaluation process allowed the study team to demonstrate “order of magnitude” variations among the multimodal alternatives based on a comprehensive set of performance criteria. The following procedures outline the key steps used to incorporate ITS into the study evaluation:

(A) Selected measures of effectiveness that could be applied to all transportation modes and types of improvements. Included measures of effectiveness that highlighted the performance of ITS strategies.

(B) Collected field traffic and roadway geometry data.

(C) Used traditional travel demand forecasting models to predict corridor demand.

(D) Applied “industry-standard” techniques to validate travel demand, estimate modal shifts, and develop peak hour volumes necessary to support conceptual design assumptions.

(E) Developed an integrated “macroscopic” traffic operations modeling framework to test the performance of ITS strategies as well as traditional roadway capacity/design improvements and management strategies.

(F) Established the sequence of computational procedures for the traffic operations modeling framework.

(G) Analyzed and tested successive layers of ITS improvements before deciding which strategies should be carried forward into final evaluation.

(H) Developed cost estimates for the ITS strategies.

(I) Developed and presented final evaluation results for the MIS alternatives.

Lessons Learned

The consultant team and the study participants went through a learning process on the I-64 study. This has led to the development of a list of suggestions and ideas on how best to approach ITS and corridor planning. These suggestions largely reflect methods that worked well for us on the study and resulted in a better product. However, the list also includes ideas on how we would do things differently, if given the opportunity. Some of the “lessons learned” deal with the study approach and how to work with the different study participants. Yet others are suggestions on how to resolve technical issues which are likely to arise.

1) Use one study process to evaluate all proposed transportation improvements, including ITS.

2) Build relationships with study participants.

3) Understand the major decisions that are part of the study process. Communicate upcoming decisions to the study participants.

4) Do not be afraid of your critics. Bring them into the study process. Be willing to make changes, it may lead to a better product.

5) Be willing to undertake new or controversial ITS projects. Carry forward only those ITS projects that have a reasonable chance of being implemented.

6) Present ITS technical information to the study participants incrementally.

7) Only develop the technical information that is needed to support the decisions at hand. Focus on significant changes and differences.

8) Expand the array of performance measures to incorporate ITS in the evaluation of alternatives.

9) Perform a "reality check" on the ITS performance measures and methods.

10) In order to capture ITS benefits, consider different traffic operations modeling techniques than those used to design roadway improvements.

11) Quantify the benefits and costs of the ITS improvements. Decision-makers want to see this information.

12) Where information is missing, make assumptions. Back all study assumptions. Acknowledge uncertainty.

13) Rely on experts in the ITS field to help set assumptions and verify results.

14) Adjust study assumptions, as appropriate, to match level of uncertainty.

15) Understand that educating participants and decision-makers about ITS is an important part of the study effort.

16) Help provide the transition to successful implementation.

Final Thoughts

The integrated planning approach used in the I-64 study to incorporate ITS analysis is not limited to major investment studies. The same principles can be applied to most any type of traditional planning study.

Adding ITS forced us to look at benefits and performance measures that traditional planning studies would otherwise ignore. However, these measures added considerable insight into the relative effectiveness of ITS with respect to new transportation infrastructure, traditional management strategies, and other conventional improvement options. In the I-64 study, we noted tangible improvements in the performance of the transportation system as a result of the ITS strategies. This study finding provided additional incentive to move forward with the ITS projects.

Integrating ITS and Traditional Planning – Lessons Learned
I-64 Corridor Major Investment Study

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1.0 Introduction

This paper describes some of the planning techniques used to evaluate intelligent transportation systems (ITS) improvements as part of a major investment study conducted on behalf of the Virginia Department of Transportation (VDOT) for the I-64 corridor in the Commonwealth of Virginia.

Since every project is different, it is our goal to pass along information that is useful and relevant to other projects that involve ITS elements. Whereas we use the I-64 major investment study as one possible approach to integrating ITS and traditional planning processes, our focus is on planning concepts that could be applied to other, similar projects. Based on our experience and study findings, we strongly believe that ITS has a role to play in the transportation planning process.

2.0 I-64 Planning Study

The I-64 Corridor Study is a two-year planning study which examined the need for intelligent transportation system improvements as well as capital-intensive transportation improvements such as added highway lanes, high occupancy vehicle lanes (HOV), and high speed rail for a 75-mile corridor in southeast Virginia.

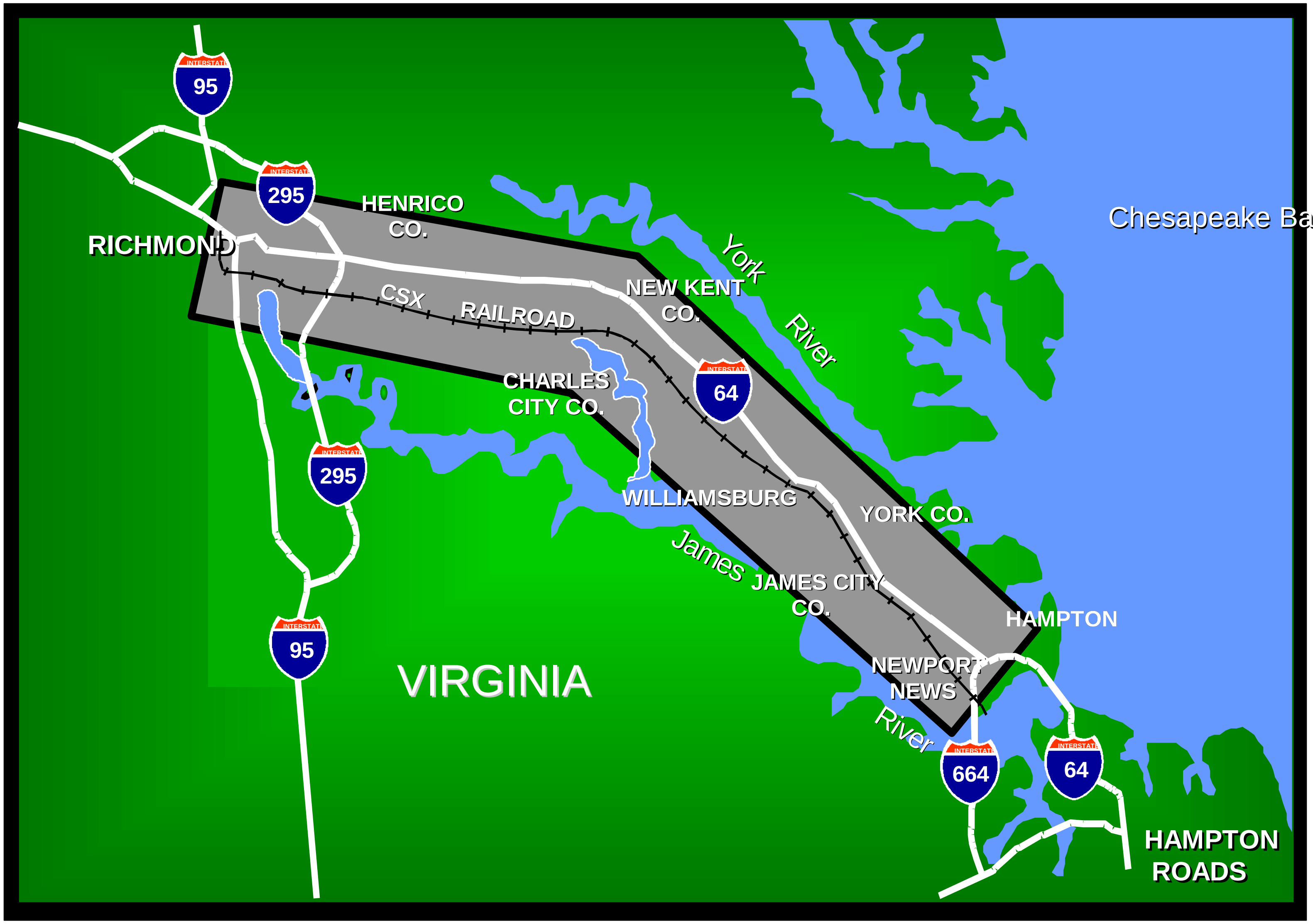
2.1 I-64 Corridor

As shown on Figure 1 on the following page, the I-64 corridor connects two major metropolitan areas in Virginia - Richmond and the Eastern Peninsula in Hampton Roads. The 75-mile travel corridor is especially critical to Hampton Roads metropolitan area. As a result of both regional land use patterns and geographical constraints, the I-64 corridor functions as the primary transportation link between southeast Virginia and the rest of the state.

The I-64 study focused on two principal transportation facilities within the travel corridor - Interstate 64 and the CSX Transportation (CSXT) rail line.

Interstate 64 serves a variety of trip purposes, both regional and local. For example, within the urbanized areas of the corridor, motorists use I-64 every day for local trips like traveling to work or to school. Trucks use I-64 as well to transport goods to and from Hampton Roads' seaports, military bases, and other commercial and industrial establishments. I-64 is also the primary route for tourists traveling to Williamsburg, the Virginia Beach Oceanfront, and the Outer Banks of North Carolina from other parts of the United States. These activities add up to an estimated 440,000 person trips per day on the Interstate alone.

STUDY CORRIDOR
FIGURE 1



The CSX Transportation rail line is an active freight corridor, hauling mostly coal for shipment overseas. The rail corridor is presently used by Amtrak for passenger rail service serving Richmond, Williamsburg, and Newport News. In addition, the CSXT rail line is an important potential link in a future high speed rail system currently under development for the Commonwealth of Virginia.

In addition to high speed rail, Virginia is aggressively pursuing a statewide program of ITS improvements as a means to better manage the existing transportation infrastructure, particularly the Interstate system. User services such as incident response and clearance, emergency management, and traffic control and management systems are in the process of being deployed in the Hampton Roads and Richmond metropolitan areas. The I-64 corridor straddles both of these metropolitan areas. Consequently, the I-64 study incorporated these regional ITS initiatives as well as statewide plans in the development and examination of future ITS improvements.

2.2 Purpose and Need

In transportation planning, the study's goals and objectives are largely driven by the problems and opportunities in the study area. This is equally true when examining the need for ITS improvements. The following discussion provides a brief overview of the planning issues in the I-64 corridor which shaped the development of transportation alternatives, evaluation criteria, and ultimately the study recommendations.

At present, traffic congestion on I-64 is most prevalent in the urbanized sections of the corridor - Richmond and the Eastern Peninsula - because of limited roadway capacity and high traffic volumes. Traffic conditions are also highly seasonal due to tourists and recreational travelers, with the greatest demand on I-64 occurring during the five-month period between May and September. For instance, traffic volumes are about 31% higher during these summer months.

By the Year 2015, travel demand on I-64 is anticipated to increase by about 62% compared to current travel conditions. This is due largely to two factors: (1) the pace and character of growth in the corridor, and (2) the dominant role that I-64 plays in the transportation system on the Peninsula.

Socio-economic projections show that the rate of growth is highest at the edges of the urbanized sections of the corridor, since the more developed areas are already built out. In the future, employment and residential patterns will be more dispersed. In essence, this is pushing up travel demand in the study area since motorists are traveling greater distances between origin and destination points. Moreover, a fair proportion of this new growth is projected to occur along I-64 or near routes which lead to I-64. At the same time, only a few major routes run parallel to I-64 in the corridor and no new routes are planned.

The single occupant vehicle is the dominant travel mode in the corridor study area, representing about 79% of the daily person trips on I-64. Land use patterns, inexpensive and plentiful parking, reasonable gasoline prices, scanty bus service, and lack of transportation alternatives such as carpool lanes and rail are all contributing factors to "drive alone" travel on the Peninsula.

Accident rates along several links of I-64 currently exceed the statewide average for an Interstate facility, particularly in spot locations. As traffic volumes increase, the number of accidents are projected to increase as well - by an estimated 70%.

Finally, I-64 is one of the few designated hurricane evacuation routes for Hampton Roads. Therefore, improvements which either increase capacity on I-64 or enhance the region's ability to manage traffic flow during a major storm event were an important consideration in the study.

2.3 Planning Context

The I-64 study was highly participatory in that it was conducted in close cooperation with representatives from the Federal Highway Administration (FHWA), the Virginia Department of Transportation, the Virginia Department of Rail and Public Transportation, two regional planning district commissions, two airports, three transit operators, nine municipalities, and various special interests such as the Williamsburg Foundation and CSX Transportation. The study team met with study participants on a bi-weekly basis throughout the two-year life of the study to discuss options and receive feedback at each stage in the analysis. In retrospect, these stakeholders were pivotal in shaping the study recommendations at key decision points - specifically, the study objectives, final set of alternatives, and the locally preferred alternative.

Despite varied interests among the jurisdictions, study participants were unified in their support of considering ITS improvements in the I-64 study. Prior to the major investment study, both Hampton Roads and Richmond had completed early deployment plans (EDPs) for their respective regions. Although Hampton Roads has made more visible progress towards implementation, both Hampton Roads and Richmond are currently involved in the design and deployment of ITS systems on the Interstate system in their areas. In addition, the Hampton Roads Metropolitan Planning Organization (MPO) has a standing ITS subcommittee made up of traffic engineers from VDOT and the localities to support the development of ITS in the region. Some of the members from this ITS subcommittee also served on the I-64 advisory group as representatives of their jurisdictions. Consequently, these members were already familiar with and highly supportive of ITS concepts.

The Hampton Roads Planning District Commission (HRPDC), in particular, was a vocal advocate of including ITS in the I-64 study. The reasoning behind this viewpoint was partly philosophical - as a rule, HRPDC promoted the use of advanced technologies and other management strategies as a means of deriving the greatest utility from the transportation system at the lowest possible cost. However, HRPDC's strong advocacy approach towards ITS was also based on pragmatic considerations. The I-64 study provided an opportunity to highlight ITS and to position the corridor for discretionary federal funds should these become available in the future.

On the whole, the localities that participated in the I-64 study were pro-growth and thus supportive of transportation improvements. However, these stakeholders were also sensitive to the potential visual impacts of certain transportation improvements such as new roadway lanes, added triple track, soundwalls and guard rail. As a result, there was a keen interest among some of the study participants to determine if the alternative modes (rail and bus) in combination with the ITS improvements would obviate the need for added roadway capacity.

3.0 I-64 Study Challenge

Much has been written about the obstacles that study managers face in incorporating ITS into their project evaluation and recommendations. Our situation was not unique. In order to truly integrate ITS into the I-64 major investment study, solutions had to be developed to answer the following concerns:

3.1 Reconciling Two Different Planning Approaches and Ways of Thinking – the Early Deployment Plan (EDP) and the Major Investment Study (MIS)

The EDP and the MIS evolved separately from two distinct planning doctrines. The EDP process is driven by an operational, systems deployment approach to planning. The systems planning perspective is necessary given that ITS projects consist of improvements to interconnected elements of the transportation system - for example, the collection and transfer of data, the development of communication networks, and the use of advanced technologies to achieve operational objectives. The EDP looks at what technological improvements might be beneficial and then develops functional packages of ITS strategies designed to fulfill specific needs.

On the other hand, the primary purpose of a major investment study is to support decisions on what major capital improvements should be included in a region’s long range transportation plan. An MIS uses a corridor planning approach in that major investment alternatives are evaluated based on their respective benefits, costs, and environmental impacts. The major investment study addresses a range of capital improvement projects such as freeway widenings, light rail systems, busways, or new highways and helps determine which, if any, of the alternative capital improvements are a worthwhile investment of public dollars. For this reason, benefit-cost analysis is an important component of the traditional planning process.

Both the EDP and the MIS result in recommendations for transportation improvements. However, the planning emphasis, geographic scope, range of alternatives considered, approach to analysis, and ways of shaping and presenting information are quite different. Even the language is different. As planners and engineers, once we have become accustomed to a certain way of thinking and communicating, we become vested in that approach.

Two different planning processes present a barrier to integrating ITS and traditional planning. At the outset of the I-64 major investment study, we elected to overcome this barrier by pursuing both the MIS and an EDP process for the I-64 corridor in parallel. Conducting two separate evaluations created several problems in the early stages of the study. We received a great deal of criticism from the study participants on the overall study approach and our initial ITS products to the extent we were having difficulty moving forward with the project.

3.2 Systems Perspective versus Corridor Perspective

As described above, ITS planning practices take a systems approach to problem-solving. Geographically, an EDP could easily encompass the entire metropolitan area as well as an individual corridor. There is no set rule. Moreover, transportation systems can be looked at individually or as subsets or as multiple systems. However, in order to be considered effective, ITS solutions should address the functionality of the systems under study. In addition, ITS transportation solutions are made up of both operational and physical networks. This means that the focus of an EDP is broad-based and, as a result, the technical analysis conducted under the EDP process is somewhat global in scope.

On the other hand, the major investment study is tasked with solving the transportation problems within a specific travel corridor or metropolitan subarea. The metropolitan transportation system is important, which is why linkages and connectivity are given such a high priority in the analysis. However, the regional transportation system is largely viewed as background. Transportation alternatives, made up of both physical and operational elements, are tested against the background condition to identify their travel benefits, costs, and environmental impacts. For instance, one of the first steps in the major investment study is to define the corridor study area in order to properly focus the technical analysis.

3.3 Short Term versus a Long Term Planning Horizon

Although there are exceptions to this rule, the planning horizon for a major investment study is longer compared to the EDP process. The major investment study is part of the metropolitan planning organization's long range planning process, which requires, at a minimum, a twenty year timeframe. This is because major capital projects take time to develop and implement. Some of the more complex projects can take several years to obtain all the appropriate approvals, environmental clearances, and necessary right-of-way. Oftentimes construction occurs in segments as funding is made available. Moreover, these projects represent a significant investment in the region's future transportation infrastructure. Once implemented, it is expected that the project will serve the community for a very long time – hopefully, well beyond the 20-year planning horizon.

The early deployment plan is usually conducted by the transportation system owner/operator and the EDP planning process is considered part of the management of the system. The EDP process can result in both short term and long term recommendations. However, the planning focus is largely geared towards implementing near-term solutions – typically in the five to seven year timeframe. This is not meant to imply that ITS planning is short-sighted. Once the recommended ITS systems have been implemented, a great deal of planning work is still ahead, such as making adjustments, expanding, or even building upon these initial deployments.

However, compared to MIS-type studies, ITS planning is more iterative and continuous. Operational conditions associated with our roadways, highways, railways, transit systems, and major ports are constantly shifting based on various factors such as system capacity, development patterns, economic activity, and transportation policies. In addition, the performance characteristics, availability, and costs of various advanced technologies tend to evolve rapidly over time. In other words, both the transportation problems and the potential ITS solutions are moving targets. Given these circumstances, specific recommendations beyond the five to seven year timeframe can easily become obsolete.

3.4 Individual ITS Projects are Small Compared to Major Capital Projects

The MIS is essentially an evaluative document. It compares different modes and levels of investment in order to select the optimal transportation solution. For example, in a major investment study, the performance of a busway is compared against added general purpose lanes or against a commuter rail system to decide which one should be selected. The comparative merits of major investment alternatives are usually large and relatively obvious.

ITS projects, if viewed individually, are smaller, less costly, and have a less discernible impact on the performance of the transportation system. A good example is pre-trip traveler strategies, where motorists or transit riders are informed of best routes, traffic incidents, areas of congestion, and/or transit schedules to help make their trip more convenient or more efficient. Motorists can avoid highly congested routes by taking a different route or by traveling at a different time. Because they have this information before initiating their trip, some people are able to save time or they may be more inclined to take public transportation.

By distributing trips in a more efficient manner, we can assume that pre-trip traveler strategies do improve the performance of the transportation network. However, even if it were possible to isolate and measure this particular travel benefit, the positive impact is very small. Moreover, these impacts are usually diffused in that they are spread throughout the overall transportation network at different times of day. When compared to the clearly defined travel benefits of a capital project such as an added roadway lane, these individual strategies appear weak and not a worthwhile alternative to added roadway capacity. In a common evaluation framework, this presents potential for bias against individual ITS strategies.

3.5 Average Peak Period Conditions versus Incident Management

Several of the potential benefits of ITS strategies result from providing travelers with information so that they can make better decisions. People's actions are dependent upon how much value they place on the information they receive and what they ultimately decide to do in response to this information. Oftentimes, this information is provided when motorists are "on the fly," so they can avoid a traffic accident or construction or other forms of unanticipated congestion. This means that evaluation of ITS strategies cannot exclusively assume typical, everyday circumstances or utilize a predictable timeframe such as peak hour.

This presents a challenge to study managers. Due to the human factor in travel decision-making, the anticipated benefits associated with ITS actions are difficult to characterize with any certainty. The independent trip making activities of several individuals are not easily tracked, particularly if your modeling tools rely on the use of traffic analysis zones that aggregate trips. Also, in traditional transportation planning, it is preferable to study the need for transportation improvements based on peak travel conditions, since this is when the highest stress is placed on the transportation system. If you can solve the mobility problems in the corridor during the peak hour, then you can generally assume that they are solved off-peak as well. Most traditional evaluation methods and procedures are based on this assumption.

In addition, transportation engineers and planners are accustomed to viewing transportation improvements based on the operating conditions of a transportation facility in the peak hour or during a typical work day. A great deal of value is placed on the levels of service during peak hour (roadway improvements) or average daily ridership (transit improvements).

3.6 Rapidly Evolving Pace of Advanced Technologies

Intelligent transportation systems involve the application of technologies to collect, process, analyze, and communicate information which is then acted upon. The pace at which these technologies are evolving has been exponential, particularly in recent years. Consequently, the operational capabilities, performance characteristics, and costs of these technologies are rapidly changing.

This affects ITS planning in several ways: (1) It leads to high expectations as to what ITS will be able to accomplish in future years. It then becomes a matter of debate among the study participants as to what ITS will bring in terms of travel benefits. (2) The overall performance of future ITS improvements is unpredictable. For example, some of the greatest barriers to implementation of ITS strategies are not due to the limitations of the technology. Rather, it is the institutional, liability, or policy implications of implementing those strategies which inhibit their effectiveness. (3) Proposed ITS strategies are difficult to define and to cost, since hardware and software elements are constantly shifting over time. And, (4) Study participants are reluctant to trust and commit to the proposed ITS recommendations, since they want to ensure that the improvements reflect “cutting edge” technologies and capabilities in the out years of project implementation. No one wants to invest in an ITS system that will soon be obsolete.

3.7 Lack of Information on ITS Deployments

With the I-64 study, our greatest challenge was a lack of information on the performance and costs of ITS strategies we were attempting to evaluate. There are several reasons for why this information is not available. First of all, there are not very many actual deployments of ITS systems that have been around long enough to generate consistent data. In some cases, the ITS concepts are so new that they have yet to be developed and systematically deployed under “real world” conditions. A good example of this is Automated Highway Systems and related ITS strategies. Moreover, specific ITS improvements are rarely deployed in a comprehensive manner, the same way, every time. Each region tailors its ITS deployments to meet their specific needs and objectives. Most of the time, individual ITS strategies are deployed along with other ITS strategies or physical improvements. This makes it difficult to isolate the benefits attributable to the individual strategies. In addition, ITS strategies operate under different conditions and at different times, which yield variable results. Finally, once these ITS strategies are in place, actual evaluation data on their costs and performance is typically sketchy.

The same lack of information applies to ITS planning and simulation studies. Although some do exist, comprehensive, in-depth studies are few and far between. As with actual ITS deployments, these studies vary greatly, which places limitations on how the results from these studies can be applied in other situations such as the I-64 major investment study. In addition, the ITS field does not yet have a solid foundation of accepted guidelines, methods, and standards which help provide a basis for technical analysis and project evaluation.

It is likely that as ITS continues to develop as a field, there will be many more deployments and evaluation studies to draw from in future years. However, the scarcity of performance and cost information on ITS strategies did present some immediate problems for the I-64 study. The level of uncertainty with the ITS improvements undermined the confidence that could be placed on the ITS travel benefits, particularly when compared against the traditional build improvements where a great deal of historical data is available.

3.8 Constrained Study Funds

Another very real limitation to analyzing ITS strategies in the I-64 study was the amount of study funds that could be devoted exclusively to the ITS tasks. The I-64 study was typical of a major investment study in that it considered and evaluated an array of transportation modes to address the purpose and need in the 75-mile travel corridor. These modes included: general purpose lanes, high occupancy vehicle (HOV) lanes, HOT (high occupancy toll) lanes, new interchanges, interchange modifications, high speed rail, local bus service, express bus service, park-and-rides, and transportation demand strategies. In addition, the study performed several technical studies to produce necessary evaluative information on the proposed improvements: conceptual engineering, travel demand forecasting, rail operations modeling, cost estimates, environmental analyses, traffic operations studies, and financial analysis. On top of these activities was an extensive public involvement component as well as a $300,000 subcorridor study that was performed in the first ten months of the project.

In short, there were several competing demands for study resources. Since it was important that the technical analyses remain objective and unbiased across all modes and types of improvements, the level of planning effort was allocated accordingly. Consequently, less than 5% of the overall $2.2 million study budget could be directed to the ITS tasks to answer some of the unique questions raised by the ITS elements of the study. The bulk of the ITS evaluation analysis, specifically the travel benefits, was conducted using a multimodal evaluation framework. The budget constraints presented us with our second biggest challenge – to produce meaningful results given very limited resources.

3.9 Lack of a Single Travel Demand Forecasting Model for the Corridor Study Area

Almost all transportation planning studies use travel demand forecasting procedures to predict and measure travel benefits. These travel demand procedures are structured to model average travel conditions as opposed to individual travel behaviors and incidents. In a few rare cases, depending on how significant the investment decision is to the region, new models are built to support the major investment study analysis. In other cases, existing models can be enhanced to answer specific questions or to strengthen the quality of the analysis. However, most studies must rely on the planning tools available to them.

Such was the case for the I-64 major investment study. The I-64 corridor spans two metropolitan planning areas: Richmond and Hampton Roads. Each metropolitan area has its own regional travel demand forecasting model. The model for the Hampton Roads region contained a mode split element, whereas the model for the Richmond region did not. Neither model was capable of estimating demand for high speed rail travel. They also did not consider the effects of the regions' existing and proposed ITS systems or travel demand management programs. Finally, before we started the project, no model sets (i.e., data files, zones or networks) existed for the areas of the corridor that fell between the two metropolitan areas.

The lack of a single travel demand forecasting model which encompassed the entire 75-mile corridor presented the study team with several technical obstacles, not all of them related to the ITS improvements. Socio-economic data was missing for portions of the corridor. Regional trips were difficult to characterize, since one end of the corridor was considered to be an external station to the other end and vice versa. Study participants were acutely interested in examining the impacts that rail, bus, and ITS improvements would have on traffic using I-64.

Although perhaps a luxury, a mode split element which explicitly addressed these other modes within a single modeling framework would have been extremely useful to the study team. Five travel demand forecasting models were used for the I-64 study. All mode shift estimates had to be calculated manually using the various outputs from these models prior to integrating and assessing the proposed ITS improvements in the overall study analysis.

4.0 I-64 Study Approach

In addition to resolving these technical challenges posed by the ITS analysis, the study framework also needed to provide for the evaluation of different transportation modes and facilities within the I-64 travel corridor. Therefore, an important, initial step in the I-64 major investment study was to develop a planning approach that included intelligent transportation systems as part of the overall study process.

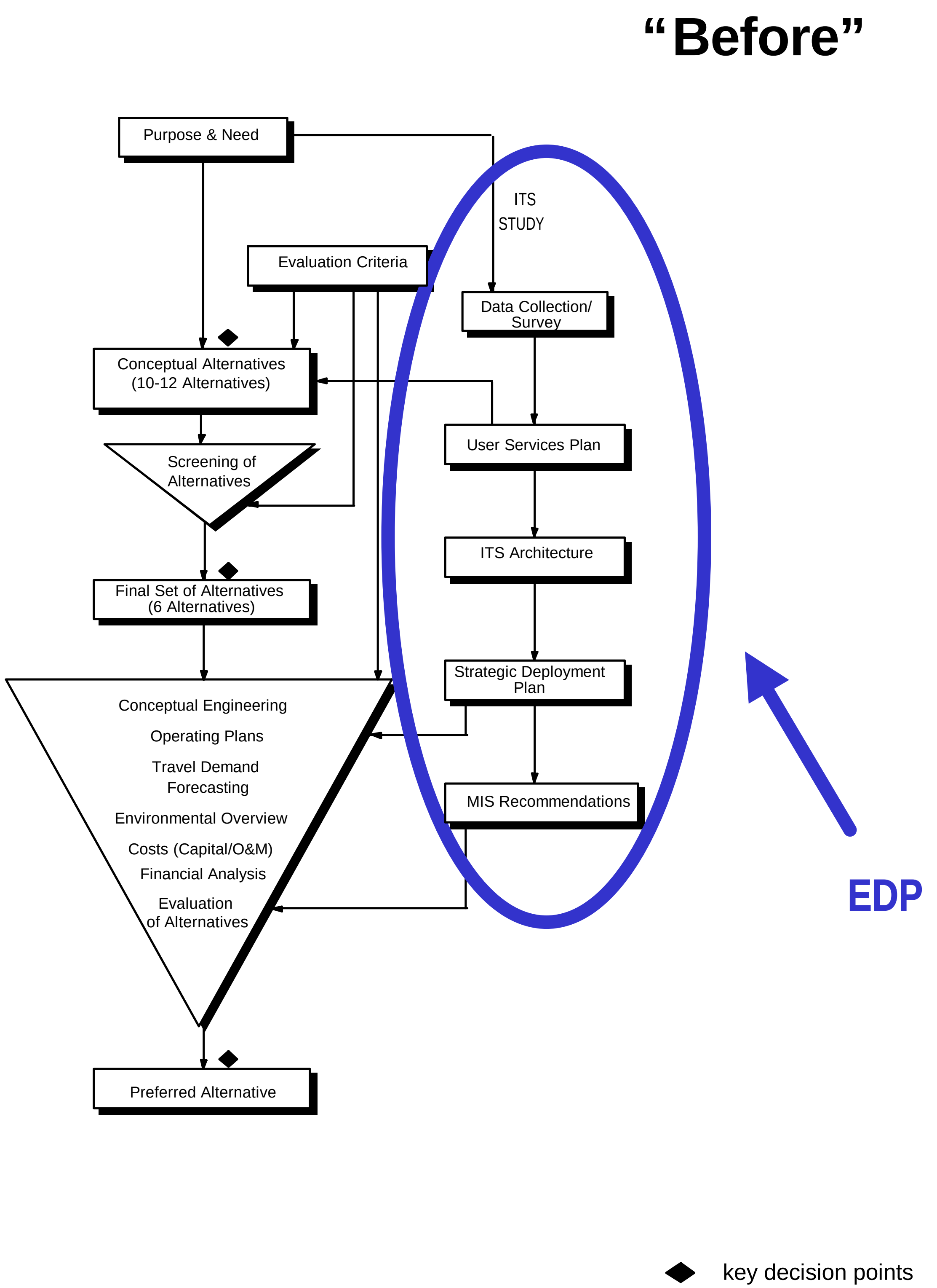
4.1 Planning Approach

Some months prior to the start date for the I-64 major investment study, VDOT, at the behest of HRPDC staff, directed the project team to include ITS in the scope of work for the planning study. Since EDPs had already been established for the Hampton Roads and Richmond metropolitan areas which covered the urbanized sections of the I-64 corridor, it was VDOT's original intention to develop a corridor-wide EDP for I-64. The I-64 EDP would build upon the previous ITS recommendations identified in the regional EDPs as well as guide the development of specific ITS recommendations for I-64. The scope of work for the I-64 study was drafted assuming two planning processes running in parallel: (1) the major investment study and (2) the early deployment plan. Information and recommendations would be coordinated at key points in the study to provide for the efficient use of study funds.

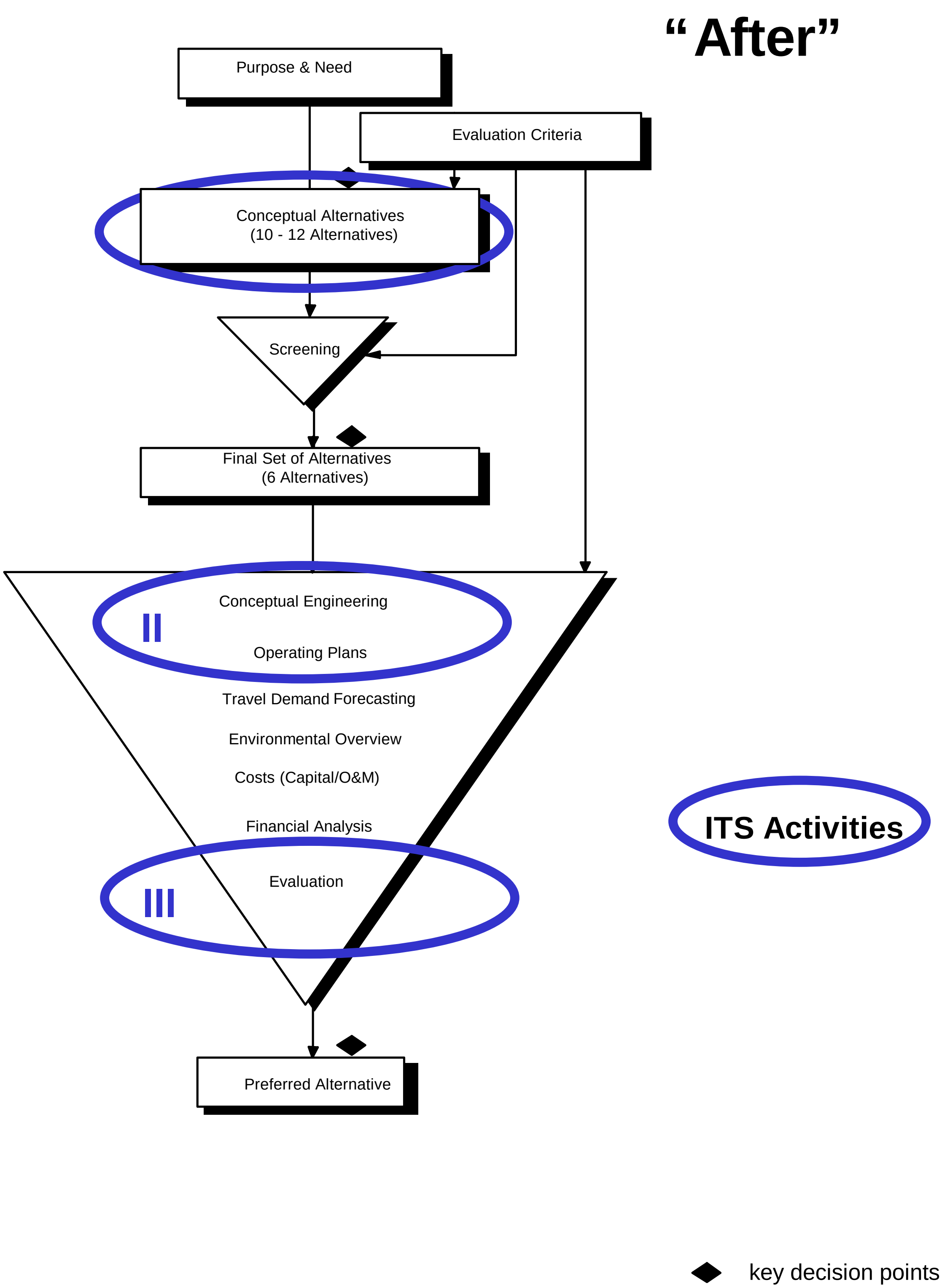
However, soon after project kick-off, it quickly became clear that certain stakeholders were opposed to following two separate planning processes within the same study. These stakeholders did not believe that the analysis and evaluation of ITS would result in meaningful findings unless it was fully integrated with the MIS work already underway. Furthermore, study participants wanted to be able to compare potential ITS improvements with any capital improvements under consideration. Progress on the I-64 study was further complicated by the negative feedback the study team was receiving from VDOT and some of the study participants on the early ITS deliverables.

In direct response to these criticisms, the I-64 study was rescoped to formally include the evaluation of ITS in the MIS decision-making framework. Figure 2 shows a "before" picture of the I-64 study flowchart with the two parallel processes, whereas Figure 3 depicts the "after" picture of the study structure once ITS was incorporated into the overall study. Although ITS was included in almost all aspects of the study, the circled tasks in Figure 3 indicate the MIS tasks where ITS planning activities figure significantly in the study process: (I) development of conceptual alternatives; (II) alternatives refinement (i.e., conceptual engineering and operating plans); and (III) study evaluation.

Study Flow Chart
FIGURE 2



Study Flow Chart
FIGURE 3



4.2 Alternatives Development

In the I-64 study, transportation alternatives were purposely developed to respond to the different travel markets, problems, and opportunities in the corridor. The proposed alternatives were multimodal, reflected a range of improvements, and were developed based on added layers of investment. The study team established this approach to alternatives development for several reasons: based on early public input, it was highly likely that the recommended alternative would consist of some combination of modal elements; it eliminated unnecessary competition among study participants regarding favored transportation modes during the study analysis; and it provided decision-makers with a spectrum of choices ranging from doing nothing as represented by the No Build Alternative to a Maximum Build Alternative, designed to solve most of the transportation problems observed in the corridor. The multimodal approach greatly complicated the technical analysis tasks. However, it also reinforced study procedures necessary for a balanced and objective evaluation across all transportation modes.

ITS elements were proposed for all of the conceptual alternatives. Levels of ITS improvements were developed for each of the alternatives in order to meet specific objectives established early in the study during the purpose and need task. For example, ITS measures were included as:

- low cost operational improvements in the Transportation Systems Management Alternative;
- specific elements necessary to support the operation of the High Occupancy Toll (HOT) Lane Alternative; and
- management strategies designed to leverage traditional capital investments in the various build alternatives.

The conceptual alternatives underwent a six-week screening evaluation, whereby an initial set of ten alternatives was narrowed to a final set of six alternatives. For example, during the screening evaluation, the HOT Lane Alternative was eliminated due to lack of support among the study participants and recent public sensitivities to toll projects in Richmond.

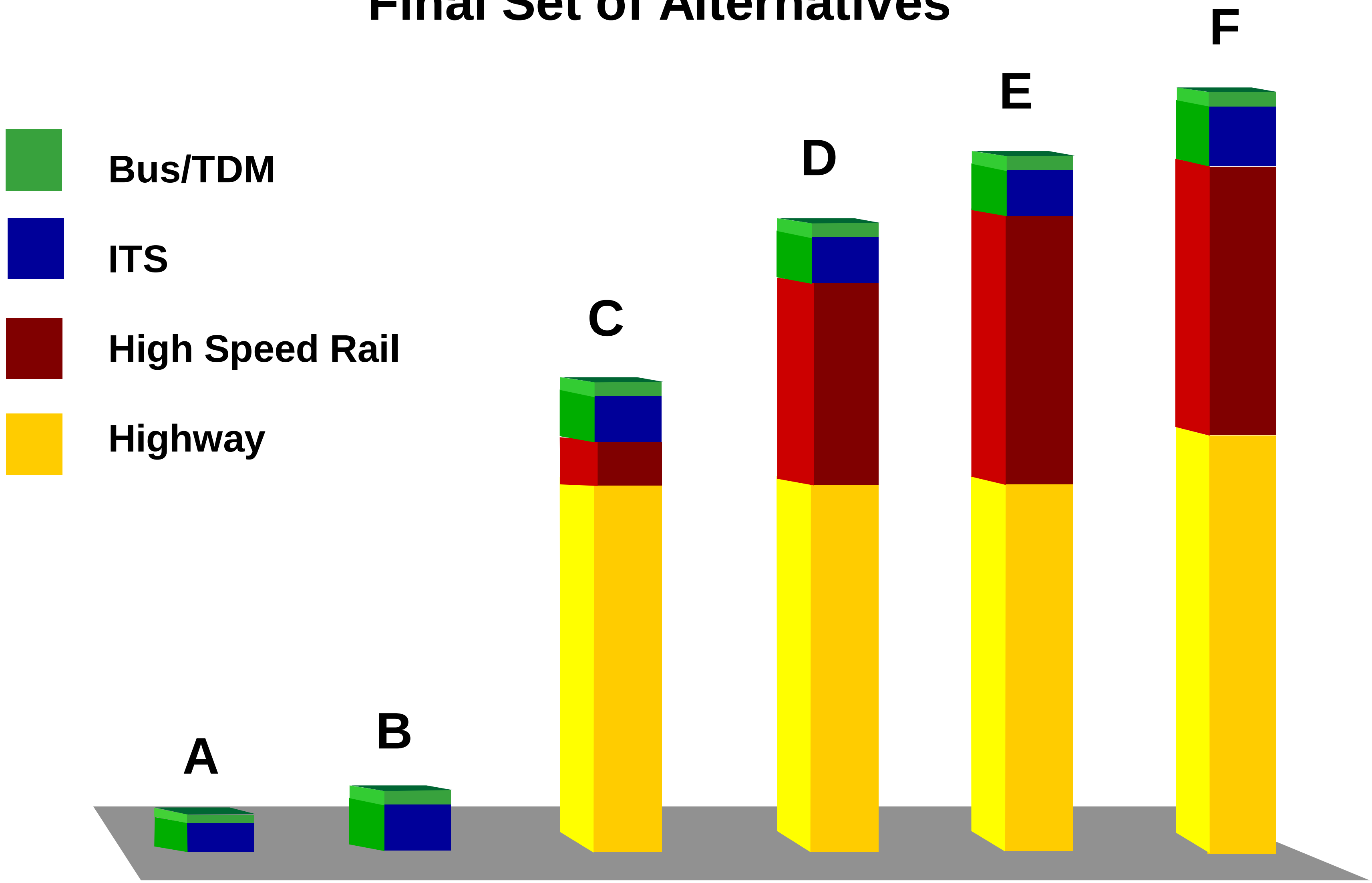
The final set of six alternatives consisted of the following:

A - No Build Alternative
B - Transportation Systems Management (TSM) Alternative
C - High Occupancy Vehicle (HOV) Highway/Low Rail Alternative
D - Medium Highway/Medium Rail Alternative
E - Medium Highway/High Rail Alternative
F - Maximum Highway/High Rail Alternative

Figure 4 illustrates the modal elements and corresponding layers of investment which comprise the final set of MIS alternatives. Note that Figure 4 is intended to show the multimodal concept employed in the development of alternatives and is not meant to represent specific estimates of capital or operating costs for the alternatives.

Multimodal Approach
FIGURE 4

Final Set of Alternatives



4.3 Refinement of Alternatives

Once the final set of six alternatives was approved by the Richmond and Hampton Roads MPOs, the study team undertook four major tasks which focused exclusively on ITS planning activities necessary for the overall project evaluation.

(A) Specified the ITS strategies to be included in each of the MIS Alternatives.

The objective of this task was to achieve consensus among the study participants regarding which ITS strategies would be considered for the I-64 corridor and how those strategies would be packaged into the final set of six alternatives. This process was largely defined by VDOT's current and planned efforts for implementing ITS throughout the state. For example, the statewide "Smart Travel Business Plan," developed by VDOT in 1997, provided a blueprint for all ITS improvements anticipated to be in place on the I-64 corridor by the Year 2015. The "Smart Travel Business Plan" presented a very aggressive approach towards implementing ITS systems over a ten-year period. This resulted in a long list of ITS strategies for the No Build Alternative since the state was assuming that these ITS measures would already have been deployed prior to the MIS planning horizon year.

On the other hand, some ITS strategies that have the potential to provide benefits to the I-64 corridor were not proposed as part of the "Smart Travel Business Plan." These ITS improvements were corridor-specific and included strategies such as: ramp metering with HOV queue bypass lanes; end of queue warning systems; variable speed limits; freeway incident traffic management systems with route diversion; advanced signal timing systems; and transit route deviation. These ITS measures represented discretionary actions for I-64 irrespective of the improvements listed in VDOT's "Smart Traveler Business Plan." Since these ITS strategies most directly addressed the criteria used to develop the Transportation Systems Management (TSM) Alternative, they were incorporated into Alternative B.

Finally, it was recommended that ITS improvements also be included in the build alternatives for testing and evaluation. The study team expected that the ITS improvements would likely increase the transportation performance of the build alternatives at a relatively small additional cost and would thus be a strong candidate element for the preferred alternative. Also, if the regions elected to make a substantial capital investment on I-64, then it would be prudent to implement the communications infrastructure required to support advanced technologies along the corridor in conjunction with any construction activity.

Figure 5 lists the ITS strategies for each of the MIS alternatives. Note the layering approach used for ITS in the alternatives. All ITS strategies listed under the "existing" conditions were included in the No Build Alternative; the No Build ITS strategies were then included in the TSM Alternative; and so forth.

(B) Defined the ITS strategies to a level of detail necessary to support estimates of travel benefits and costs.

The next step in the alternatives refinement phase was to define the ITS strategies to a level of detail necessary to support estimates of travel benefits and costs. This meant developing an understanding and description of how the different ITS measures would operate on I-64;

ITS Strategies
FIGURE 5

I-64 MIS Alternatives	ITS Elements
Existing Conditions	Incident Response and Clearance Emergency Management Traffic Control and Management Pre-Trip Travel Information En-Route Travel Information
No Build Alternative	All "Existing Conditions" ITS improvements Traffic Control and Management: - Data Collection w/Advanced Comm. & Processing - Transportation Management Systems Asset Management Public Transportation Management: - Transit Management Systems Pre-Trip Travel Information (expanded) En-Route Travel Information (expanded) and Route Guidance Electronic Payment Emergency Notification and Personal Security Commercial Vehicle Operations: - Administrative Processes & Electronic Clearance - Roadside Safety Inspections - Intermodal Connectivity Collision Avoidance Safety Readiness
TSM Alternative	All "No Build" ITS improvements Traffic Control and Management: - Variable Speed Limit w/ End of Queue Warning System - Advanced Signal System Timing with Freeway Incident Traffic Management and Route Diversion - Ramp Metering Public Transportation Management: - Transit Route Deviation
Build Alternatives	All "TSM" ITS improvements

establishing market penetration assumptions regarding private initiatives such as in-vehicle location and collision avoidance devices; and identifying the necessary software and hardware components for each ITS strategy. Any legislative or institutional issues anticipated to hinder or enhance the effectiveness of the individual ITS strategies were also listed and described. Particular care was given to how these strategies would function on the I-64 corridor and what types of data collection and communication systems would need to be in place to support their operation.

This information was critical in discussions with study participants about ITS. For instance, the study team needed to be able to “paint a picture” as to how the ITS measures would work and what they were meant to achieve since few “real world” examples of ITS exist in Richmond and Hampton Roads for advisory group members to draw upon. In other words, decision-makers needed to be able to visualize and understand the ITS strategy in order to give reliable input to the study team on how the ITS strategies should be evaluated and which ITS improvements should be considered further. For example, with the ramp metering strategy, the localities wanted to know which interchanges would be metered, what their hours of operation would be, what devices would be in place to prevent ramp queues from overflowing onto the local street network, and whether or not the meter timing would be so restrictive as to discourage local trips from accessing the Interstate. Even though many of these are design-level, operational decisions which will ultimately be determined much later in the project development, it was necessary to set certain assumptions regarding some of these questions as part of the study process.

Relatively detailed descriptions of the operational and physical characteristics of the ITS strategies were needed to develop estimates on benefits and costs. For example, the variable speed limit ITS strategy could operate as an advisory measure or the speed limit could be strictly enforced. This assumption had a direct bearing on the benefits would could be expected to result from its implementation. If the speed limit is advisory, then the effectiveness of the travel benefit is modest. If regulatory, then the study team could be more aggressive with the benefit calculations. Assumptions regarding variable speed limits also had to be made as part of the costing effort. For instance, if variable message signs are posted every half-mile the cost is higher than if they are posted every mile.

(C) Drew upon other ITS projects, studies, and published sources.

As noted earlier in the discussion, high levels of uncertainty regarding ITS coupled with limited study funds presented a significant challenge for the study. Consequently, the study team drew very heavily from the actual experiences of other jurisdictions and from evaluation findings realized in other ITS studies.

Once the ITS strategies were identified and accepted by the stakeholders, the study team undertook a major research effort to gather information on the proposed strategies. Several data collection methods were employed: database research, review of published sources, contacts with ITS professionals, internet searches, and, in some cases, follow up telephone calls to jurisdictions which have implemented or evaluated specific ITS strategies.

The purpose of the research effort was to accomplish the following:

- identify those jurisdictions which have implemented ITS projects or have conducted evaluations on ITS projects similar to the I-64 ITS strategies;
- determine the physical and operational characteristics of the identified ITS projects;
- record and analyze their observed benefits (both quantitative and qualitative);
- note specific environmental conditions (i.e., physical, operational, institutional, political) present in the respective jurisdictions which could influence the performance of the ITS projects.

Results from the research effort were then summarized and analyzed for each ITS strategy under consideration in the I-64 study. Figures 6 and 7 show the results of this task. In some cases such as ramp metering and advanced communication and processing measures, several data points were available for analysis. With new or evolving ITS concepts, such as variable speed limits and end of queue warning systems, the source data was limited.

Travel benefits reported by other studies and jurisdictions generally fell into the following categories: travel time reductions, accident reductions, delay reductions, transit ridership increases, improved productivity, reduced administrative burden, and increased convenience for travelers. Potential evaluation results associated with each ITS strategy from other sources were analyzed based on their observed similarities and differences with the I-64 corridor. The study team then applied professional judgment to estimate the levels of benefits which could be expected if these ITS strategies were to be implemented in the I-64 corridor. These findings and assessments were reviewed with other ITS professionals as well as members of the I-64 advisory group and adjusted accordingly. See the columns entitled “I-64 Assumptions” on Figures 6 and 7.

(D) Aggregated proposed ITS strategies into logical packages for study.

The next and last task of the alternatives refinement process with regard to the ITS planning activities was to group “like” ITS strategies into logical packages for study evaluation. Viewed individually, the ITS travel benefits are small compared to other more capital-intensive improvements. However, when integrated into a package of improvements, the ITS strategies show a more discernible impact to transportation system performance.

In addition, this packaging concept recognizes that certain ITS strategies work better in combination with other ITS improvements. For example, en-route travel information strategies combined with route guidance devices combined, in turn, with advanced communications and processing systems results in a synergetic effect since the effectiveness the package exceeds the sum of the parts. In other cases, the travel benefits attributable to combined ITS strategies are redundant. This means that the positive impact of combined ITS strategies is not necessarily additive. For example, if three different ITS strategies each report a 20 percent reduction in accidents, does the combination of all three result in a 60 percent reduction or should it be less? Therefore, it is important to explicitly acknowledge redundancies and inter-relationships among the ITS improvements when combining ITS strategies to form logical packages.

No Build Alternative – ITS Evaluation Summary
FIGURE 6

				Level 1 Packaging	Level 2 Packaging	Level 3 Packaging
ITS Strategy	**Application of ITS Strategy**	**Advantages/Disadvantages**	**Examples From Other Jurisdictions**	**I-64 Assumption Level 1**	**I-64 Assumption Level 2**	**I-64 Assumption Level 3**
Transportation Management Systems (TMS)	• Incident and traffic mgmt. • Upgrade existing systems • Implement new systems	• Improve traffic management capabilities • Minimize incident impacts	10-45% travel time decrease 5-65% delay decrease 35% total accident decrease 15% injury accident decrease 30% secondary accident decrease 40% weather accident decrease 20% effective capacity increase	10-20% travel time decrease 5-10% delay decrease 10-15% total accident reduction	10-20% travel time decrease 5-10% delay decrease 10-15% total accident reduction	10-30% travel time decrease 10-20% delay reduction 1-3% increase in transit ridership 20-25% reduction in total accidents Reduced administration Increased convenience Improved productivity
Data Collection with Advanced Communication and Processing	• Collect data to evaluate conditions • Transmit data to TMS • 100 percent coverage	• Improve incident management • Improve responses to traffic conditions • Installation and maintenance of in-pavement detectors requires cutting road surface				
Asset Management	• Maintenance management • Construction, weather • Fleet mgmt. • Computer Aided Dispatch • Automated inventory monitoring • Weather and pavement monitoring	• Minimize maintenance and construction delays • Enhance safety and efficiency				
Transit Management	• Vehicle tracking • Transit information	• Improves schedule adherence	1 % ridership increase	1% ridership increase Increase convenience	1% ridership increase Increase convenience	
Pre-Trip Travel Information	• Information Service Providers • Available at home, office, and public locations	• Travelers avoid congestion • More even distribution of traffic	11-35% travel time reduction for responding vehicles 2-7% travel time reduction for non-responding vehicles	3-11% travel time reduction	5-15% travel time reduction	
En-Route Travel Information	• Upgrade and expand existing (HAR, VMS, etc.) • In-Vehicle Information	• Travelers avoid congestion • More even distribution of traffic	8-11% travel time reduction for responding vehicles 1-2% travel time reduction for non-responding vehicles	5-10% travel time reduction Increased convenience		
Route Guidance	• In-vehicle guidance • Turn-by-turn directions • 10 percent public sector • 10 percent market penetration	• Travelers avoid congestion • More even distribution of traffic • Reduces wrong turns and driver confusion	5-15% travel time reduction 13-16% travel time reduction for equipped vehicles 1-2% travel time reduction for unequipped vehicles	1-2% travel time reduction Increase convenience		
Electronic Payment (Smart Cards)	• Common fare media • Store personal information • 100 percent market penetration	• Reduces admin. costs • Increase operating efficiency • Eliminate need for cash, tokens, etc.	2-5% increase in trips	1-3% increase in trips Reduced admin. Increase convenience	1-3% increase in ridership Reduce admin. Increase convenience	
Emergency Notification and Personal Security (Mayday)	• Transmit identity and location when collision occurs • 10 percent public sector • 20 percent market penetration	• Reduce emergency vehicle response time • Issue of priority to mayday calls in cellular network	75% delay reduction 5% delay reduction	5-15% reduction in accident-caused delay	5-15% reduction in accident-caused delay	
Administrative Processes & Electronic Clearance (Automated Commercial Vehicle Administrative Processes)	• Automated processes • Electronic record keeping and financial transactions • 60 percent public sector	• Improve safety and efficiency of freight movement	Qualitative Benefits Only	Reduce admin. Improve productivity	Reduce admin. Improve productivity	
Intermodal Connectivity	• Predict and schedule freight transfers • Track shipments • Electronic databases • Public sector responsibility	• Increase efficiency of freight movement				
Roadside Safety Inspections (Advanced Roadside Safety Inspect.)	• Electronic screening • Diagnostic testing • Public sector responsibility	• Quicker and more thorough inspections • Reduce delay to commercial vehicles	Qualitative Benefits Only	Improve productivity		
Collision Avoidance	• Standard on all new vehicles • Devices installed in/on vehicles • Costs assumed by motorists	• Reduce severity of accidents • Reduce effect of accidents on network • Tort liability concern	51% reduction rear-end collisions 47% reduction lane change/merge collisions 40% reduction total collisions 33% reduction total collisions	15-20% reduction in total accidents	20-25% reduction in total accidents	
Safety Readiness (Driver and Vehicle Condition Monitoring)	• Identify potential accident causing conditions • Driver and vehicle condition monitoring • Standard on all new vehicles • Onboard devices • 5 percent public sector	• Reduce number of accidents • Reduce effect of accidents on network	Strategy under development and not yet deployed	5 - 10 % reduction in total accidents		

TSM Alternative – ITS Evaluation Summary

FIGURE 7

ITS Strategy	Application of ITS Strategy	Advantages/Disadvantages	Examples From Other Jurisdications	I-64 Assumption
Variable Speed Limit System with End of Queue Warning System (unenforced/enforced)	• Advisory/regulatory speed limit provided in response to conditions • Warns of stopped vehicles downstream	• Reduce collisions • Reduce delay resulting from collisions • Regulatory is more effective, but requires legislation and enforcement	30% injury accident reduction (London) 25% damage-only accident reduction (London) 30 - 50% total accident reduction (Germany)	5 - 25 % total accident reduction
Advanced Signal Timing System/Diversions	• Used on diversion routes • Only during major freeway incidents or hurricane evacuations	• Reduces congestion • Requires detectors on arterials	8 % travel time reduction (Toronto) 32% travel time reduction (TRRL research - England) 17 % delay reduction (Toronto) 38.3 % delay reduction (Aberdeen, Scotland) 58% delay reduction (TRRL research - England)	2 - 6% travel time reduction 5 - 15 % non-recurring delay reduction
Ramp Metering	• Controls rate of vehicles entering freeway • Timed so as not to discourage local trips • HOV bypass • LOS D or worse during peak periods	• Reduces overall system delay • Maximizes throughput • Requires enforcement for compliance • Geometric improvements for storage capacity and acceleration distance	37 % travel time reduction (Denver) 48 % travel time reduction (Seattle) 61 % travel time reduction (Portland) 24 % peak period accident reduction (St. Paul) 27 % peak period accident reduction (Minneapolis) 43 % peak period accident reduction (Portland) 50 % total accident reduction (Detroit) 50% rear-end & sideswipe accident reduction (Denver) 15 % accident frequency decrease (Long Island) 38 % peak period accident rate reduction (Minneapolis/St. Paul) 39 % accident rate reduction (Seattle) 2 % recapture of lost roadway capacity (Long Island) 7.9% recapture of lost roadway capacity (Austin)	15 - 20 % travel time reduction 24 % accident reduction 5 - 7% recapture of lost roadway capacity
Transit Route Deviation	• ADA service • Detours from fixed route upon request by rider and approval by dispatcher • Detours within predefined range of fixed route • Vehicle tracking	• Increases flexibility and responsiveness of buses to attract transit riders • Reduces single vehicle trips • Can not operate on completely fixed schedule	20% formerly drove to work (Potomac & Rappahannock Transportation Commission) 20% formerly drove to shop (Potomac & Rappahannock Transportation Commission)	1% transit ridership increase

The packaging procedure was employed three times with the ITS strategies identified for the No Build Alternative. See Level 1, Level 2, and Level 3 packages of ITS strategies shown on Figure 8. (As a reminder, the No Build Alternative includes those ITS strategies which are expected be in place by the Year 2015 - the planning horizon year for the study.) The study team determined that it was necessary to predict the impact that ITS strategies would have in the future year analysis condition as part of the ITS analysis tasks, since the benefits of these future ITS improvements were not captured in the traditional travel demand forecasts for Year 2015.

At each level, selected ITS strategies which exhibited similar operational and performance characteristics were combined and assumptions regarding the expected travel benefits were then refined. A reality check was also performed at each level. As stated above, this packaging procedure was conducted three times to establish the final set of performance values for the entire ITS element of the No Build Alternative. (See Figure 6, far right column.)

4.4 Alternatives Evaluation

As indicated earlier in the discussion, the travel demand forecasting models available for use in the I-64 study did not account for ITS improvements. Consequently, the study team developed a consistent methodology to quantify ITS travel benefits which was then applied to the final set of MIS alternatives. The evaluation process allowed the study team to demonstrate “order of magnitude” variations among the multimodal alternatives based on a comprehensive set of performance criteria. The following sections describe the key steps in the development of the evaluation framework for the I-64 major investment study.

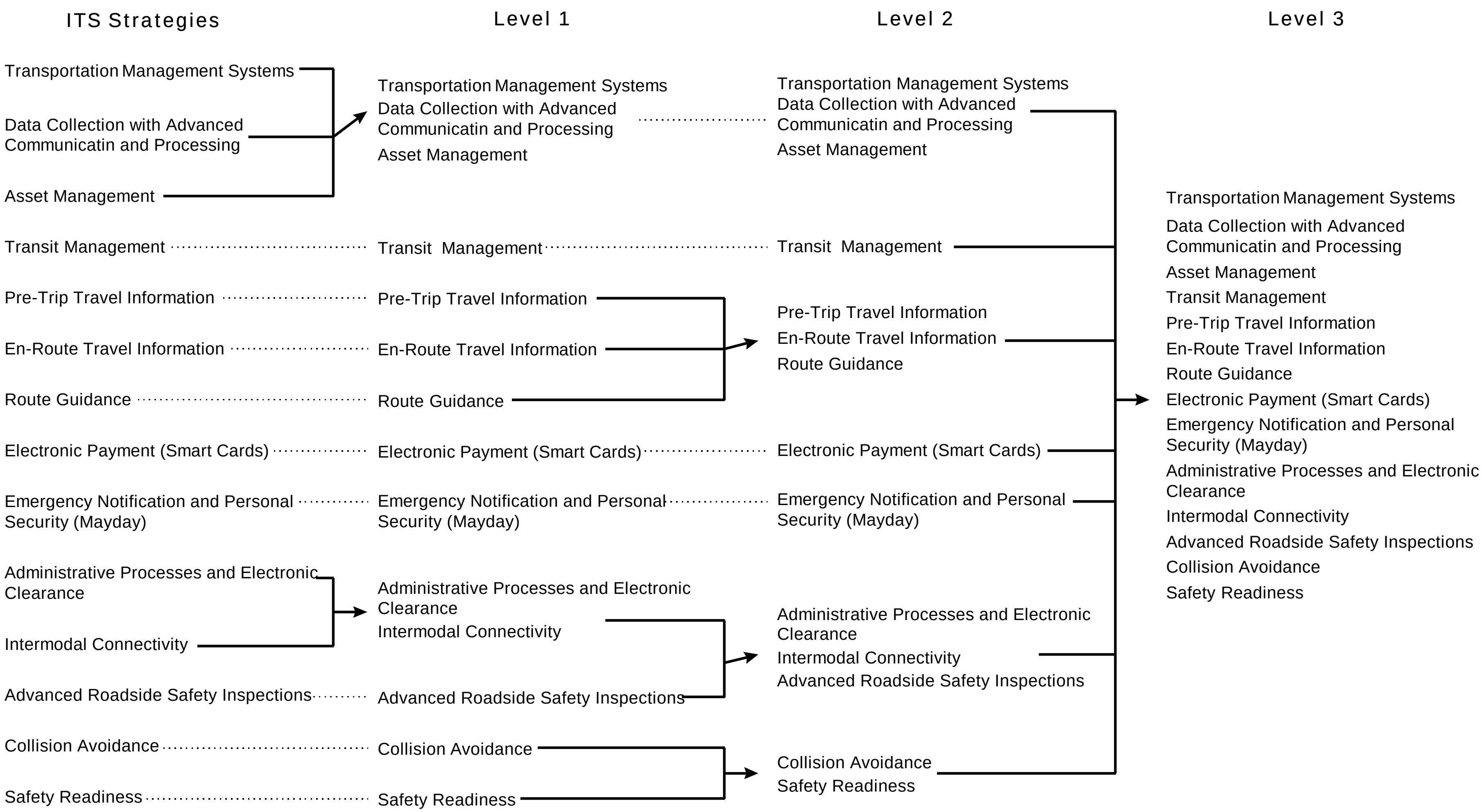
(A) Selected measures of effectiveness that could be applied to all transportation modes and types of improvements. Included measures of effectiveness that highlighted the performance of ITS strategies.

Since the six final alternatives for the I-64 MIS were multimodal, we needed a uniform basis of comparison among modes (i.e., the same measuring stick for all types of improvements). In addition, the measures of effectiveness needed to tie back to the purpose and need identified earlier in the study. This enabled the project team to evaluate how well each of the proposed alternatives solved the transportation problems in the corridor.

Consequently, we discovered early on that it is important to determine what measures of effectiveness would be needed to address the purpose and need of the study before conducting detailed technical studies and subsequent evaluation tasks. This step ensures that the analysis results are relevant to the decision-making process. On the other hand, it’s also a good idea to look at whether it is possible to obtain certain performance measures from available modeling processes and whether you are able to produce the data in a format required by these specific modeling procedures. Furthermore, the array of measures of effectiveness used in the overall study evaluation should include performance measures that show the benefits of ITS strategies, since traditional measures such as peak hour levels of service do not adequately capture these ITS effects.

Upon completion of the research effort which identified which benefits might be expected from implementing the proposed ITS improvements based upon the experience of others, the claimed benefits must be related to performance measures that can be produced by the traffic

Levels of No Build ITS Strategies
FIGURE 8



operations analytical modeling framework used for the study. For instance, some measures could not be quantified or could not be represented in the available modeling tools. Examples of these measures included reductions in administrative costs or increases in productivity and user convenience.

Given the above considerations, the following primary performance measures were chosen to capture transportation benefits attributable to ITS improvements proposed in the I-64 MIS:

- Capacity Enhancement
- Accident Reduction
- Recurring Delay Reduction
- Non-recurring Delay Reduction
- Demand Reduction (or Diversion of Trips to Alternate Modes)
- Peak Period and Peak Hour Travel Time

Additional measures of effectiveness were selected to pick up benefits attributable to capital improvements, multimodal strategies and other considerations. These included:

- Person Ridership (transit and freeway boardings)
- Person Travel (person miles on each travel mode)
- Quality of Service (level of service on the freeway)
- Hurricane Evacuation (critical evacuation capacity)

Furthermore, the model provided estimates of how changes in primary performance measures would affect secondary measures such as:

- Excess Fuel Consumption
- Excess Emissions of CO, HC and NOx
- Excess Vehicle Operating Costs
- Accident Impact Costs
- Excess Person Time Costs (due to delay)

In short, the I-64 study used multiple measures to capture the full array of potential travel benefits associated with the multimodal alternatives. The overall evaluation framework was structured to show the relative strengths of the alternatives in light of the various study objectives to guide the selection of a preferred alternative for the corridor.

For the I-64 MIS, another important step in the technical evaluation was that the benefits of all ITS strategies identified as a result of the research effort (see Figures 6 and 7) had to be translated into effects for the five primary measures used in the multimodal evaluation. This task was accomplished using the professional judgment of the study team based on their familiarity with the operational modeling tools available for the study analysis.

This activity was complicated by the nature in which ITS benefits were reported in the other studies. For example, some studies reported either a reduction in delay, or travel time, or both. Since the available modeling tools required estimates of delay reductions, travel time benefits had to be converted to delay benefits. Also, the modeling structure used in the I-64 study already incorporated certain relationships among the primary measures. Most significantly, the estimate of non-recurring delay is sensitive to a reduction in accidents. Therefore, where both accident and non-recurring delay reductions were reported in the research findings, only the accident reduction information was used. Otherwise the model would have double counted non-recurring delay reductions.

One key performance concept used in many studies, including the I-64 MIS, is the benefit-cost ratio. This placed special requirements on how the measures of effectiveness for the study were estimated. First, any measure perceived as a benefit or a burden eventually had to be quantified monetarily. Second, since all capital, operating and maintenance costs are annualized, the monetary benefits and burdens had to be annualized as well. This meant that the performance measures had to be assessed on an annual basis and not strictly on a weekday or peak hour basis. It also introduced other complications in that we had to account for seasonal variations in weekday traffic and seasonal variations in weekend traffic separately to produce representative annualized measures of effectiveness for the corridor.

Also, some measures of effectiveness required for decision making in the I-64 MIS did not play a part in the benefit-cost calculations. In addition to certain measures such as level of service, redundant measures were excluded from the cost-effectiveness calculations. For example, daily delay incorporates the impacts of added peak hour travel time. Both measures were presented in the evaluation findings, but only the former was used in the annualized benefit-cost calculations - again, to avoid double-counting.

Figure 9 shows the end result of this analytical process and how the performance of ITS strategies obtained in the research effort was further modified by the study team to reflect the primary measures of effectiveness used in the multimodal evaluation for the study. The reduction or enhancement percentages shown in the columns of Figure 9 were then applied to specific modeling processes used to predict each measure of effectiveness. These modeling processes were integrated to form an overall modeling framework that estimated the primary and secondary measures of effectiveness summarized above.

(B) Collected field traffic and roadway geometry data.

At the specific request of the study sponsor, the project team conducted an extensive traffic data collection effort throughout the corridor, including: two-day 13-hour mainline traffic volume and vehicle classification counts in several locations; 48-hour pneumatic tube counts on all ramp roadways and on each crossroad; mainline vehicle occupancy counts at two locations, and floating car travel speed studies on the most-congested urban sections. These 1996 counts were supplemented by other counts on the mainline from VDOT and counts used in the Hampton Roads Congestion Management System. This exhaustive data collection effort is not typical most other major investment studies. However, the up-to-date, comprehensive traffic data set was extremely useful in the I-64 study.

Using this data, it was possible to combine limited mainline volumes with all ramp volumes to produce 1996 daily and peak hour volumes on all sections of I-64, all ramp roadways, and on the crossroads north and south of the corridor. This data provided the basis for establishing K-factors (percent of daily traffic during peak hours) and D-factors (directional splits on the mainline), which were used to predict future peak hour volumes from daily traffic forecasts produced by the demand forecasting models. The vehicle occupancy data was also used to establish future occupancy patterns given daily carpool forecasts from the forecasting models.

Benefits of ITS Strategies to Operations on I-64
FIGURE 9

ITS Elements	ITS Benefits to the I-64 Freeway						
	Freeway Demand Reduction	Freeway Capacity Enhancement	Recurring Delay Reduction	Non Recurring Delay Reduction	Accident Reduction	Peak Period Travel Time Reduction	Peak Hour Travel Time Reduction
No Build Alternative							
Incident Management & Clearance	-	-	-	25%	2%	-	-
Traffic Control & Management:							
- Data Collection w/ Advanced Communication & Processing	-	-	-	14%	3%	-	-
- Transportation Management Systems	benefits included outside of this modeling process						
Asset Management	no corridor benefits						
Public Transportation Management:							
- Transit Management Systems	0.5%	-	-	-	-	-	-
Pre-Trip & En-Route Travel Information and Route Guidance	-	-	4%	6%	-	5%	10%
Electronic Payment	not applicable						
Emergency Notification & Personal Security	benefits included with advanced communications & processing						
Commercial Vehicle Operations:							
- Administrative Processes & Electronic Clearance	no corridor benefits						
- Roadside Safety Inspections	-	-	-	-	2%	-	-
- Intermodal Connectivity	no corridor benefits						
Collision Avoidance	-	-	-	-	18%	-	-
Safety Readiness	benefits included with incident management & clearance						
TSM Alternative							
All No Build ITS Improvements	0.5%	-	4%	45%	25%	5%	10%
Traffic Control & Management:							
- Variable Speed Limit w/ End of Queue Warning Systems	-	-	-	-	25%	-	-
- Advanced Signal Systems/FITM	-	-	-	10%	-	-	-
- Ramp Metering	-	5%	20%	-	10%	25%	30%
Public Transportation Management:	-	-	-	-	-	-	-
- Transit Route Deviation	0.5%	-	-	-	-	-	-
All Build Alternatives							
All TSM ITS Improvements	1%	5%	24%	55%	60%	30%	40%

Not only did these counts help us understand current traffic patterns, they also significantly contributed to validation of the travel demand forecasts. The Hampton Roads and Richmond travel demand forecasting models were calibrated against traffic volume data in the year 1990. These models were then used to project traffic volumes in the year 2015. It would normally be expected that by 1996, the portion of traffic growth occurring on the corridor should fall about one quarter of the way between the 1990 volume and the 2015 forecast. However, we found that 1996 volumes had grown significantly faster in some locations. Therefore, rather than using the 2015 traffic forecasts straight from the models, we used the annual growth rates predicted by the model on each roadway segment between 1990 to 2015 to project 1996 volumes to 2015. This was important because without the validation, some of the 2015 forecasts were not much higher than the volumes we counted in 1996. In effect, this allowed the project team to tailor the modeling output to specific travel and growth characteristics on the I-64 corridor, thereby sharpening the study results.

The study team also collected data on existing through and turn lane configurations, interchange forms, traffic control devices, posted speed limits, and surrounding land uses at each interchange. This information helped to establish a baseline from which conceptual roadway and traffic control improvements could be developed to address future deficiencies.

(C) Used traditional travel demand forecasting models to predict corridor demand.

Travel demand forecasting models are used to predict future travel demand levels on roadways and transit systems based on a forecast of future land use activity. These travel demand projections are necessary to evaluate different transportation system improvements that would help accommodate the demand. Transportation system improvements could include different categories of roadways or different modes of transit such as bus or rail. The demand forecasts help establish how much capacity is required to accommodate the demand by predicting how many travelers are likely to use any new transportation facilities tested using the model. Travel demand forecasts also serve as inputs to the traffic operations analysis conducted in subsequent phases of the study.

As noted earlier, the I-64 MIS applied results from five different demand forecasting models to produce projected traffic volumes and transit ridership levels for the corridor. The reasons we needed five models were: 1) the demand models for Hampton Roads and Richmond covered only a portion of the I-64 corridor, 2) there was a section in the middle (New Kent County) that was not covered by either model, 3) one of the models did not have transit forecasting capabilities, and 4) none of the urban models could forecast intercity rail travel.

Figure 10 shows which models were used to cover different sections of the corridor and/or the different transportation elements which made up the multimodal alternatives. Note that two models were used for Richmond. The current Richmond demand forecasting model, which is fully calibrated, does not have a transit forecasting capability. However, a new, not-yet-approved model that includes transit was in the final stages of development. We used the transit forecasting capability of the new model since it was the only model available for this purpose at the time.

Sources of Travel Demand Forecasts
FIGURE 10

Travel Demand Elements by Section of I-64	Source of Demand Forecasts				
	Hampton Roads Travel Demand Forecasting Model	New Kent County Manual Demand Forecast	Current Richmond Travel Demand Forecasting Model	Draft New Richmond Travel Demand Forecasting Model	Southeast US Intercity Rail Demand Model
Hampton Roads Section					
I-64 Mainline SOV	XXX				
I-64 Mainline HOV	XXX				
I-64 Cross Roads	XXX				
Local Bus	XXX				
Express Bus	XXX				
CSX Rail					XXX
New Kent County Section					
I-64 Mainline SOV	XXX	XXX	XXX		
I-64 Mainline HOV	XXX	XXX	XXX		
I-64 Cross Roads		XXX			
Local Bus				XXX	
Express Bus				XXX	
CSX Rail					XXX
Richmond Section					
I-64 Mainline SOV			XXX		
I-64 Mainline HOV			XXX		
I-64 Cross Roads			XXX		
Local Bus				XXX	
Express Bus				XXX	
CSX Rail					XXX

(D) Applied "industry-standard" techniques to validate travel demand, estimate modal shifts, and develop peak hour volumes necessary to support conceptual design assumptions.

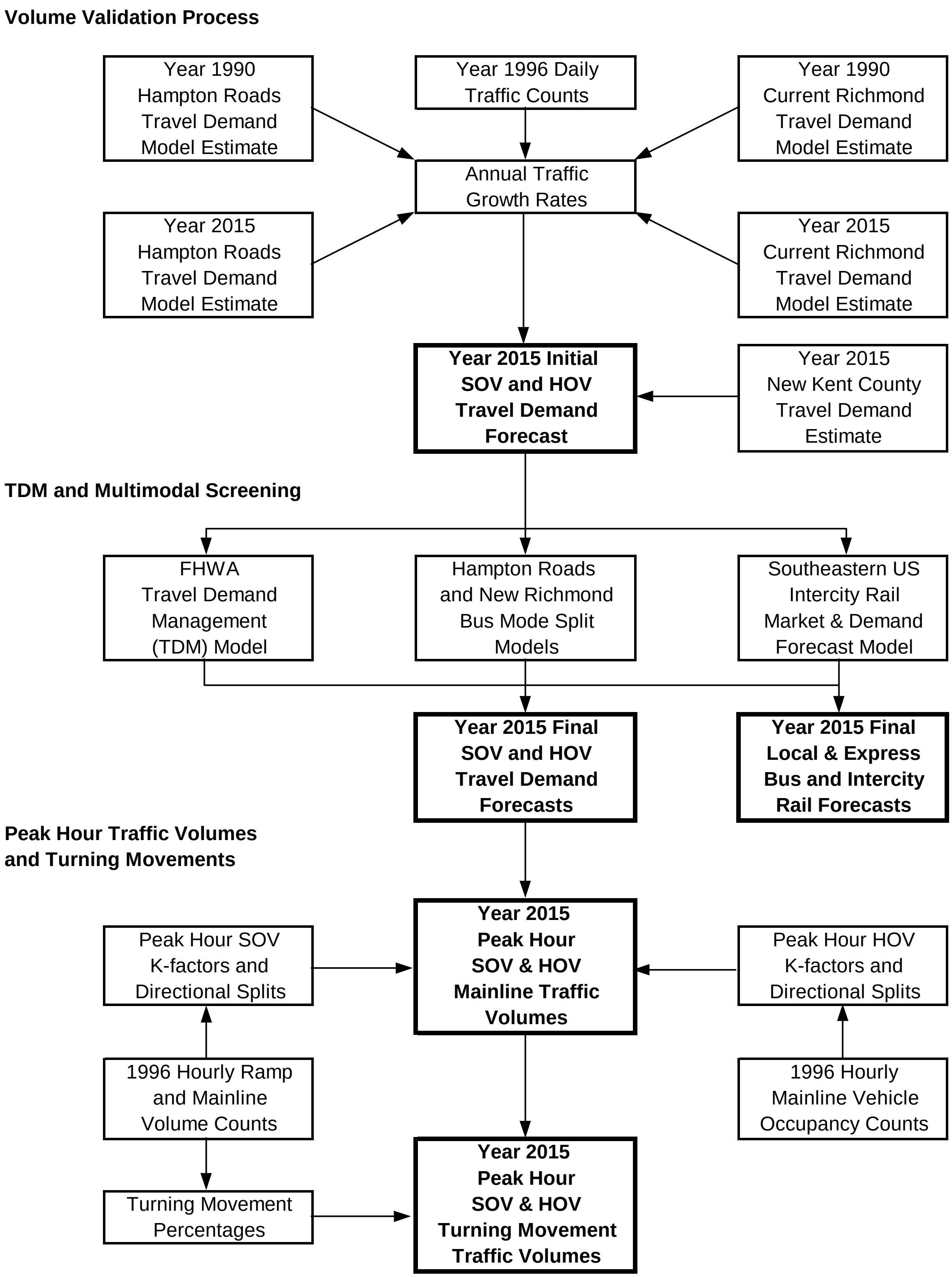
The flow chart in Figure 11 illustrates the processes used to combine the results from the five demand forecasting models and the TDM model to produce traffic and transit forecasts for the corridor. The top third of Figure 11 depicts the process of combining and validating the highway forecasts for the three sections of the corridor. Year 1990 and 2015 forecasts from the Richmond and Hampton Roads models were used to determine annual traffic growth rates on segments of I-64 within the boundaries of each model. In order to validate the model against the most-recent available traffic count data, these growth rates were used to project 1996 traffic counts on each segment to the year 2015, rather than using the 2015 forecasts straight from the model. Forecasts for segments of I-64 in New Kent County were interpolated using external station volumes from the Richmond and Hampton Roads models at either end, and crossroad forecasts developed manually for interchanges in New Kent County. The interpolation and manual forecasts were necessary because neither the Richmond nor the Hampton Roads models covered New Kent County.

The initial highway forecasts for the entire study area were then modified through a screening process to account for the impact of bus and rail transit services and travel demand management measures. The Southeastern US Intercity Rail model was used to forecast rail ridership levels on the CSX rail corridor parallel to I-64. The Hampton Roads and the draft new Richmond demand forecasting models were used to forecast ridership on new express bus services along the corridor. FHWA's travel demand management (TDM) model was used to predict demand reductions on I-64 in response to proposed TDM measures.

Demand reductions due to TDM and projected rail and transit person trips due to added investments associated with the proposed alternatives were equated to a reduction in vehicle trips on I-64. These trips were deducted from the initial highway forecasts to produce the final daily highway forecasts. The end result of this rather complex accounting process was to consistently track person trips along the corridor by mode of travel and to ensure consistency between travel demand levels in each alternative. This was important to ensure rail, bus or HOV person trips increases were offset by single occupant vehicle person trip decreases for those areas/transportation modes which were not covered by the mode choice component of the forecasting models for the two urban areas. Without this conservation of person trips, it becomes difficult to show the benefits of multimodal improvement options such as carpool lanes, buses or rail transit.

The daily highway volumes and transit ridership levels provided the basis for the multimodal analysis of alternatives, evaluation of ITS strategies and development of costs and benefit-cost ratios for the six final alternatives. Peak hour volumes were also needed to support conceptual design decisions regarding mainline lane configurations, weaving sections, ramp junctions, interchange forms and the need for collector-distributor roads. These conceptual designs were developed to provide a basis for project cost estimates and environmental impact assessments for the overall study. Traffic volumes were developed using the 1996 traffic counts as a basis for K-factors, directional splits, vehicle occupancy stratification and turning movement percentages. AM, noon and PM peak hour volumes were developed as inputs to the highway capacity analysis to support the conceptual highway design assumptions.

Validation and Screening of Travel Demand Forecasts and Development of Peak Hour SOV and HOV Volumes
FIGURE 11



(E) Developed an integrated "macroscopic" traffic operations modeling framework to test the performance of ITS strategies as well as traditional roadway capacity/design improvements and management strategies.

Travel demand models are designed to predict demand levels on different transportation facilities. However, these models do not adequately quantify how well these facilities will perform under the projected demand levels. Therefore, it is necessary to use various traffic and transit operations models, which relate transportation demand to supply and management strategies, to predict how each facility will perform. These operations models provide estimates of performance measures used to compare different alternative improvements and management or ITS strategies.

The analytical models used to estimate performance measures for the study are classified as macroscopic traffic operations models. Several specific models were assembled into a modeling framework for use in the I-64 MIS. This framework is significantly different from other traffic operations models such as FRESIM or TRANSYT-7F in that it can directly produce annualized estimates of the primary and secondary performance measures based on macroscopic algorithms with relatively minimal data requirements and processing time.

The individual models in the framework operate at the roadway link level. Therefore, the effects of "nodal" operational problems occurring at intersections, ramp junctions and weaving sections are not directly modeled. This global approach is appropriate for this level of analysis since the planning decisions to be made involve corridor-level investments and system improvements as opposed to localized, spot improvements along the corridor.

The integrated modeling framework was constructed from scratch using available research and selected macroscopic models. This technical approach was necessary since no other model with the necessary characteristics was available at the time of the study. The reader should note there are two new models currently under development that are likely to handle what the I-64 traffic operations modeling framework was set up to accomplish. These include the Integrated ITS Deployment Analysis System (IDAS) and the Surface Transportation Efficiency Analysis Model (STEAM). The former is in the early stages of development. The latter is currently available, but with only limited documentation.

The following sections describe the sources for individual models used to estimate primary performance measures in the overall modeling framework:

Roadway Capacity and Level of Service

Estimates of roadway section capacities and free flow speeds were based on procedures from the most-recent Highway Capacity Manual. Estimates of 24-hour level of service profiles were based on equations that estimate the portion of daily traffic using a roadway according to specific threshold levels of volume to capacity ratios. These equations were obtained from the study "Roadway Usage Patterns: Urban Case Studies" prepared for FHWA in June 1994. The equations were evaluated for each v/c ratio separating different levels of service based on v/c break-points reported in the Highway Capacity Manual. The equations are a function of the daily traffic volume, the hourly section capacity, and the v/c ratio of interest.

Recurring Congestion

Estimates of 24-hour, peak period and peak hour recurring delay were based on equations developed for the HPMS modeling process from the study "Speed Determination Models for the Highway Performance Monitoring System" prepared for FHWA in October 1993, and the subsequent study "Development of Diurnal Traffic Distribution and Daily, Peak and Off-Peak Vehicle Speed Estimation Procedures for Air Quality Planning" prepared for FHWA in April 1996. These models predict daily, peak period and peak hour recurring delay for typical weekend and weekday traffic patterns as a function of daily traffic volume, hourly section capacity and effective traffic signal spacing. The results from these delay models can also be used to estimate average travel speeds for daily, peak period, and peak hour conditions.

Accidents and Accident Rates

Accident rates for the I-64 study were based on a non-linear regression equation that is sensitive to the traffic loading level on each roadway link. This model was developed as a function of the annual average daily traffic to peak hour section capacity (AADT/C) ratio using five years of historical accident data on all sections of I-64 between interchanges. Rather than assuming constant accident rates as a function of vehicle miles traveled, this relationship accounts for the increase in accident activity that occurs as roadways become more congested. Another source for accident rates is the HPMS modeling process. Accident rates for different roadway classes can be found in the report "Incorporating Traffic Crash and Incident Information into the Highway Performance Monitoring System Analytical Process" prepared for FHWA in September 1996. This document provides accident rate estimation procedures for different roadway classes and can accommodate certain more-detailed geometric features within each class as well as the effects of congestion for some classes of roadway.

Incidents and Non-Recurring Congestion

Non-recurring congestion was estimated based on a one-year period worth of accidents and incidents (note that accidents are one type of incident). Incident activity was estimated corridor-wide as a function of total corridor accidents using incident-accident relationships from the "Incident Management Study" prepared for the Trucking Research Institute and the ATA Foundation, Inc. in June 1990. Incidents were classified as accidents, disablements or other. Corridor-level incidents were then distributed to individual segments of I-64 based on a combination of vehicle miles traveled (VMT) and vehicle hours traveled (VHT) on each segment. The resulting distribution of accidents and other incidents were then segregated into different levels of severity including on-shoulder, single lane blocking and multi lane blocking.

These incidents were then screened to eliminate those that would not produce non-recurring delays. For example, a shoulder incident would not produce delays unless the remaining roadway capacity is less than the current demand while the incident is present. The previously-mentioned v/c ratio equations, used to predict 24-hour level of service profiles, were used for this screening in conjunction with the number of lanes in each direction. For example, freeways with only two lanes in each direction are vulnerable to delay impacts from a greater portion of incidents than freeways with more than two lanes in each direction. This screening process resulted in a final group of incidents, stratified by type and severity, that produce non-recurring delay. The delay per incident was then estimated based on ranges reported in the

"Incident Management Study". The delay per incident was a function of the type of incident, the severity, and the degree of loading on each roadway segment modeled.

Note: This macroscopic non-recurring congestion modeling process was developed for this study using available research from several sources. It was considered to be the best available approach at the time. However, current research related to the HPMS modeling process is working to develop simplified non-recurring delay equations that are a function of roadway loading level (AADT/C), accident rate, and average incident clearance time. The final report describing this research should be available during the last quarter of 1998.

Secondary Performance Measures

Secondary performance measures included excess fuel consumption, emissions and vehicle operating costs due to freeway congestion, and accident and person delay impacts. These measures are categorized as secondary because they are all a function of the primary measures.

Excess fuel and emissions rates per vehicle hour of delay were estimated using macroscopic fuel consumption and emissions rates imbedded in the FREQ freeway simulation model. Multiplying the rate per mile by the speed converts it to a rate per hour of vehicle travel. The difference between consumption and emissions rates between a normal speed of 55 mph and a congested speed of 20 mph was computed. The resulting rates are an estimate of excess fuel consumption or pollutant emissions per vehicle hour of delay. Though considerable detail could be added to improve the accuracy this fuel and emissions modeling process, the additional information that would be obtained as a result of the added technical detail was beyond what was necessary for the evaluation task in the I-64 study.

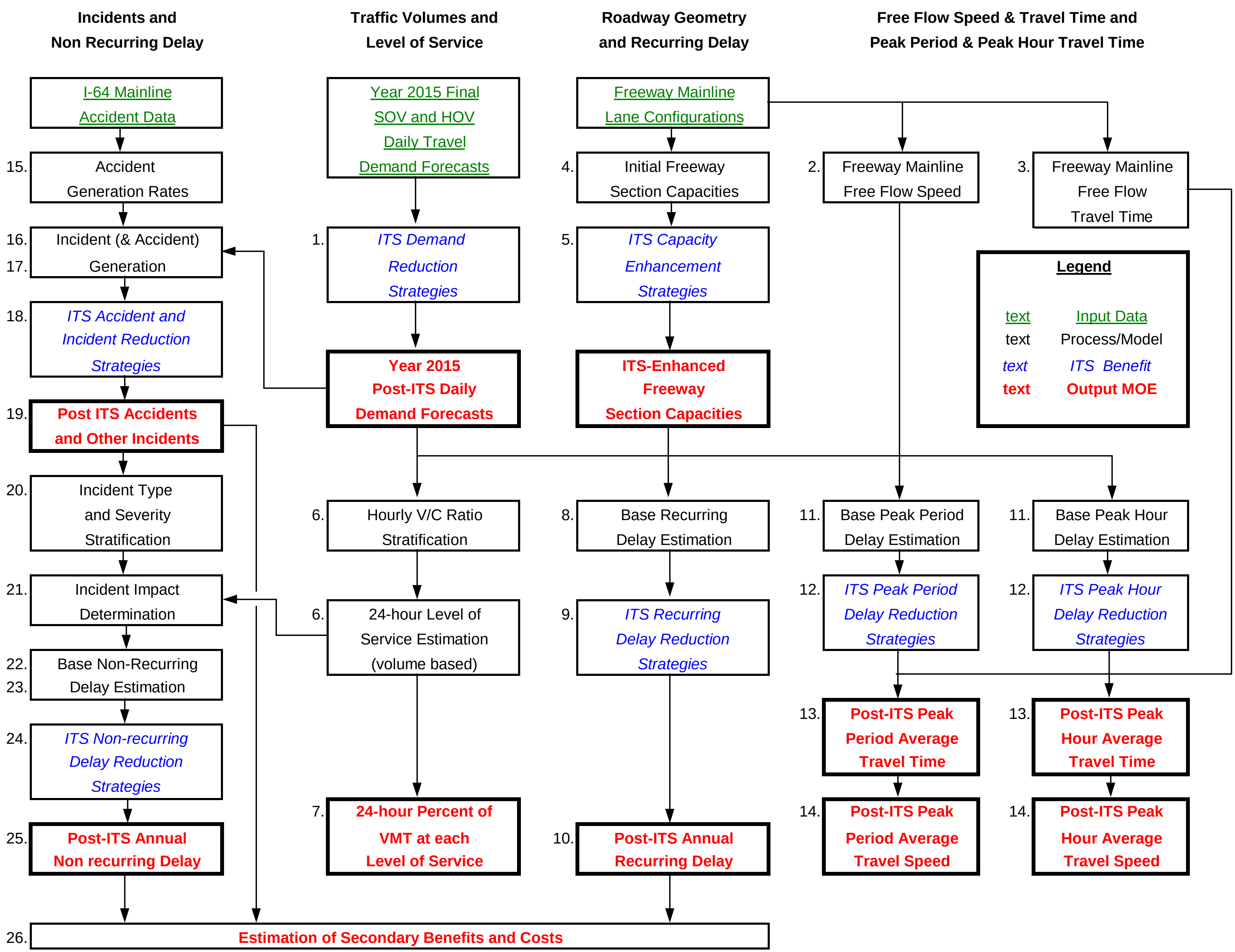
Excess vehicle operating costs were based on figures from the 1992 FTA publication "Characteristics of Urban Transportation Systems". Accident costs were stratified by severity. Projected future accident severity distributions were based on five years of accident data on I-64. Accident costs by severity type were based on an October 1991 FHWA study entitled "The Cost of Highway Crashes". Person delays were estimated by multiplying vehicle hours of delay by an average corridor vehicle occupancy. The delay unit costs were obtained from the 1992 FTA publication "Characteristics of Urban Transportation Systems".

(F) Established the sequence of computational procedures for the traffic operations modeling framework.

Figure 12 illustrates the flow of calculations in the traffic operations modeling framework. The first column is the process of quantifying accident and incident activity and estimating non-recurring delay. The second column begins with traffic demand volumes and ends with quality of service estimates. The third column begins with section capacity estimates and ends with recurring delay calculations. The fourth and fifth columns calculate free flow speed, and peak period and peak hour travel time, speed and delay.

In essence, an ITS "before" picture is established for each of the primary performance measures. The ITS improvements are then applied (based on the anticipated benefits as

Traffic Operations, Incident and ITS Benefits Modeling Macroscopic Analytical Framework
FIGURE 12



previously defined in Figure 9) at interim stages in the operations modeling process to develop an ITS "after" picture.

In Figure 12, elements of the flow chart in underlined type represent the input data whereas the bold faced type elements indicate the primary performance measures that are an output of the operations modeling process. The elements with italicized type indicate where the benefits of ITS strategies are accounted for in the modeling framework.

Figure 13 provides additional detail on the computational steps used in the operations modeling framework. Each step is referenced on the flow chart. Unless otherwise noted, calculations are performed for each segment of freeway in the study area.

(G) Analyzed and tested successive layers of ITS improvements before deciding which strategies should be carried forward into final evaluation.

A unique aspect of the I-64 MIS was that study participants were given the opportunity to determine whether a particular group of controversial ITS strategies would be incorporated into the TSM and build alternatives for the study. In order to support this decision-making process as well as to assist in the understanding of ITS benefits versus roadway improvement or other management strategies, packages of ITS strategies were tested in cumulative manner using the transportation performance modeling framework outlined in Figures 12 and 13.

ITS strategies assumed to occur under the No Build Alternative were packaged together since these improvements are expected to be in place by the Year 2015 as a result of statewide ITS plans adopted by VDOT. See Figure 5 for a complete list of the No Build ITS strategies. These No Build ITS strategies are considered part of the TSM Alternative as well as the four build alternatives.

On the other hand, the ITS strategies proposed for the TSM Alternative were considered to be discretionary actions in the I-64 MIS decision-making process. Again, see Figure 5. These strategies were viewed separately for ITS testing and analysis, since the study participants may elect to implement one, some, or all of these ITS improvements. Examples of the ITS strategies considered part of the TSM Alternative included:

- ramp metering along the entire corridor;
- enforced variable speed limits combined with end-of-queue warning systems designed to warn motorists of upcoming congestion shock waves and to slow the speed of traffic on approach to these shock waves;
- freeway incident traffic management (FITM) plans for the entire corridor implemented in conjunction with a comprehensive advanced traffic signal systems for alternate routes parallel and connecting to I-64;
- transit route deviation strategies which use communications and vehicle tracking technologies to allow a transit vehicle to deviate from its normal route to serve passengers off the route, provided that this does not overly affect the vehicle's schedule. (Readers familiar with the I-64 study will note that this ITS strategy was subsequently shifted to the No Build Alternative at the direction of the advisory group.)

Traffic Operations, Incident, and ITS Benefits Modeling
Macroscopic Analytical Framework - Computational Steps
FIGURE 13

1. Apply a percentage reduction in average daily travel demand due to ITS demand reduction strategies to forecast traffic volumes to produce post-ITS daily demand forecasts. ITS demand reduction strategies are those that improve effectiveness of TDM or transit ridership.

2. Given freeway lane configurations, lane widths, lateral clearance, percentage of trucks, type of terrain and number of lanes in each direction; estimate freeway mainline free flow speed based on HCM methods.

3. Estimate vehicle hours of normal travel time as vehicle miles of travel divided by free flow speed. Compute total vehicle hours normal travel time for full corridor. Annualize normal travel time assuming 250 weekdays and 115 holiday-weekend days per year.

4. Estimate initial average lane capacity from adjusted free flow speed based on HCM speed-capacity relationships. Compute total section capacity of general use lanes. Add HOV lane demand levels to section capacities to account for HOV lane capacity benefits.

5. Increase section capacities due to impact of ITS strategies, or operational improvements such as auxiliary lanes or collector-distributor roads.

6. Use hourly volume to capacity ratio stratification model to estimate percent of volume below v/c ratio cut-off of each level of service based on LOS cut-offs tabulated in the HCM. Subtract cumulative percentages to obtain volume of traffic at each level of service.

7. Multiply percentage of traffic at each level of service by freeway section volume and length to obtain VMT at each level of service. Compute VMT-weighted average level of service distribution for full corridor.

8. Use post-ITS daily demand forecast and post-ITS freeway section capacity to estimate vehicle hours of weekday and weekend recurring delay using HPMS equations.

9. Apply recurring delay reduction percentages due to ITS strategies to reduce total daily recurring delay.

10. Compute total vehicle hours recurring delay for full corridor. Annualize total recurring delay assuming 250 weekdays and 115 holiday-weekend days per year.

11. Use post-ITS daily demand forecast and post-ITS freeway section capacity to estimate average weekday recurring delay during peak period and peak hour using HPMS equations.

12. Apply recurring delay reduction percentages due to ITS strategies to reduce peak period and peak hour recurring delay.

13. Combine normal travel time and delay to estimate travel time per trip for peak period and peak hour, converted to minutes per trip.

Figure 13 Continued on Next Page

Figure 13 continued

These ITS strategy packages were then combined into scenarios as shown in Figure 14. This allowed study participants to note the progressive impacts of the various packages of ITS strategies in both the No Build Alternative and the TSM Alternative. The objective of this approach was twofold: (1) to elicit input from study participants on the ITS evaluation processes based on the study results; and (2) to provide study participants with an interim decision point so they could determine which of the discretionary ITS strategies should be rolled into the overall analysis for the TSM Alternative and eventually the build alternatives based upon their predicted travel benefits and system costs.

First, existing conditions were evaluated with no ITS strategies as a base condition. Then, in Scenarios 0 and 1, the No Build Alternative was evaluated with and without the No Build ITS strategies, respectively. The No Build ITS strategies were then tested on the TSM alternative in Scenario 2. Note that pre-ITS traffic conditions for the TSM Alternative differ slightly from those of the No Build Alternative due to modest demand reductions in traffic as a result of transportation improvements other than ITS which were included in the TSM Alternative.

Finally, the discretionary ITS strategies associated with the TSM Alternative were added into the analysis in successive layers in Scenarios 3, 4 and 5 to show how they would improve travel in the corridor. For example, Scenario 4 included all the No Build ITS strategies, ramp metering, variable speed limits and end-of-queue warning systems, but not advanced signal system systems, freeway incident traffic management plans, and transit route deviation strategies. This method allowed decision makers to determine the relative improvements attributable to each discretionary ITS action as well as view how these ITS strategies performed in combination with other ITS improvements.

Examples of the evaluation findings for the different ITS scenarios are shown in Figures 15 and 16. Despite some controversial projects such as ramp metering and alternative route diversion strategies, study participants chose to support all three optional ITS strategy packages. Consequently, all these ITS strategies were rolled into the build alternatives for the final MIS evaluation.

(H) Developed cost estimates for the ITS strategies.

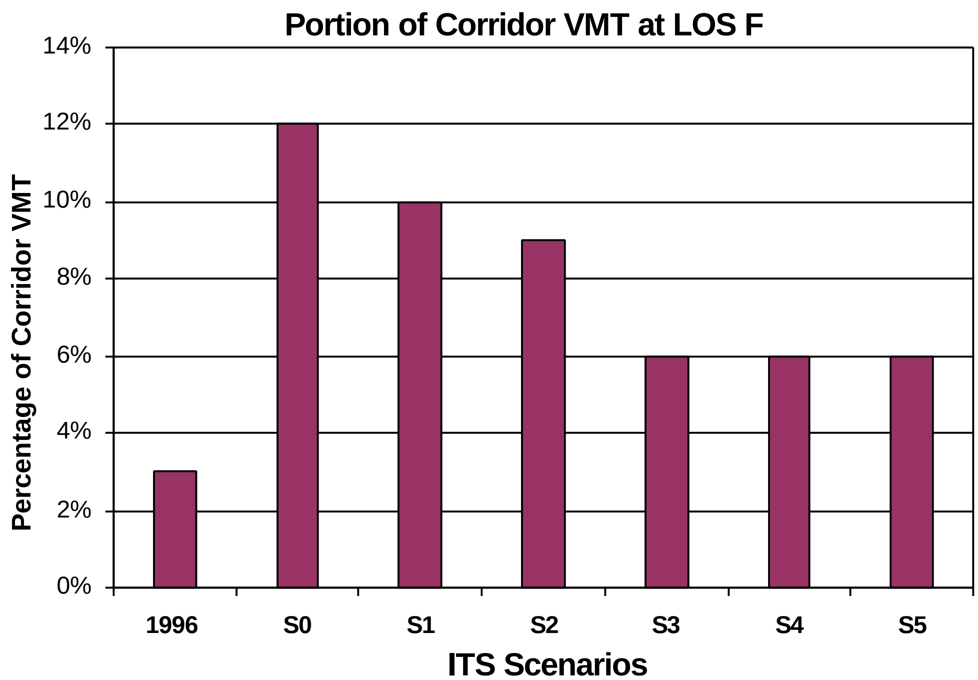
Compared to the procedures used to predict travel benefits, the costing effort for the ITS strategies was a relatively straight-forward process. As mentioned previously, the majority of the ITS improvements under consideration for the I-64 MIS were encompassed in the No Build Alternative. Capital costs were not developed for any of the No Build improvements since these transportation projects were assumed to be in place by the study planning horizon year and were, therefore, not subject to decision-making in the study. Rather, the costing effort focused on developing capital and O&M (operating and maintenance) costs for all the transportation improvements proposed in the TSM Alternative and in the four build alternatives, including ITS.

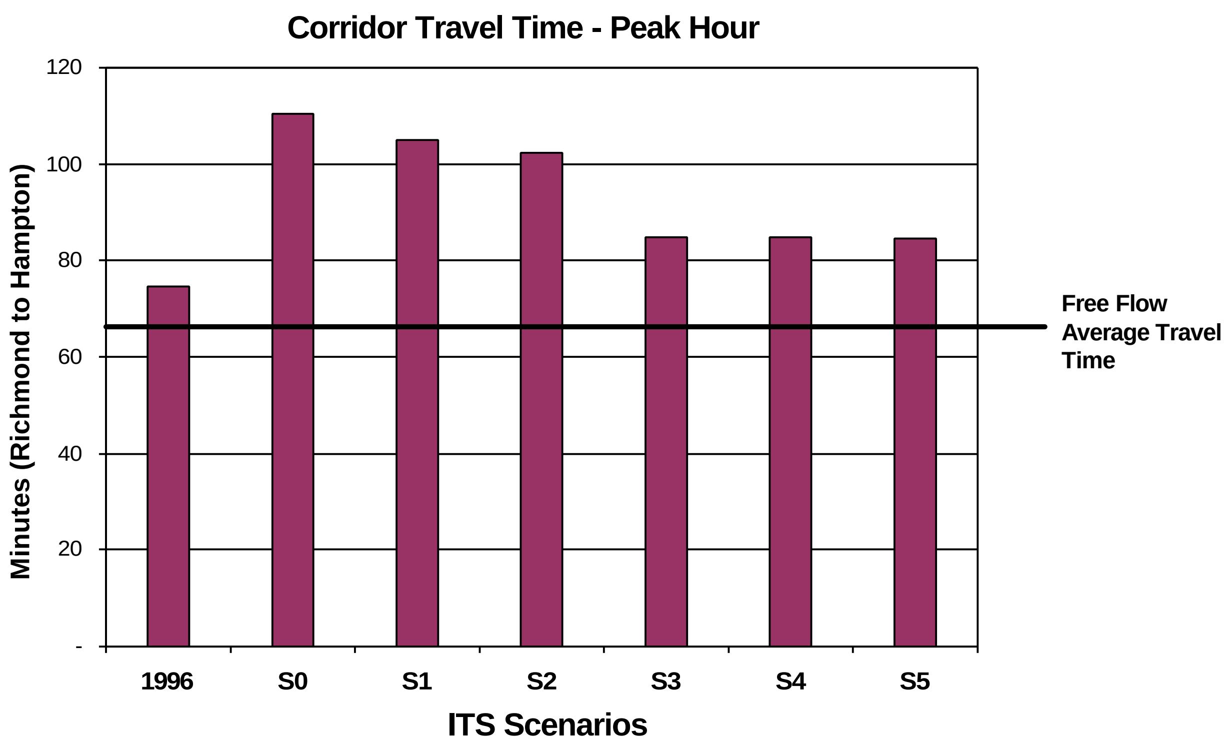
In some cases, such as the bus and rail modes, operating and maintenance costs were prepared for the No Build Alternative improvements. However, these “no build” O&M costs were largely developed to form a baseline number so that the incremental costs associated with the increases in service proposed for these modes could be accurately defined.

ITS Scenarios
FIGURE 14

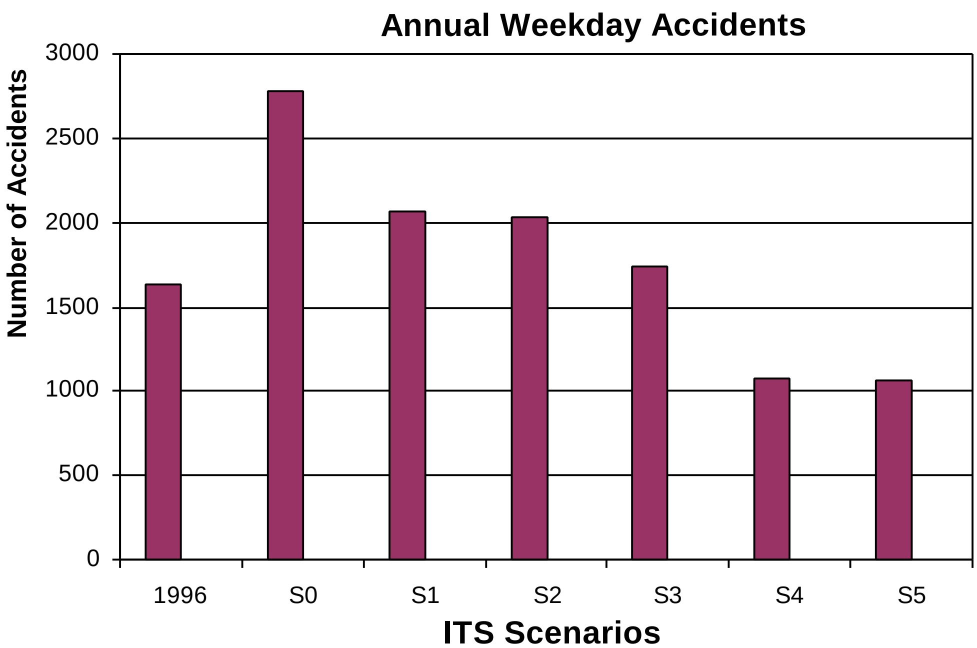
	No Build ITS Strategies	**Ramp Metering**	**Variable Speed Limit/End of Queue Warning Systems**	**Advanced Signal Systems/FITM Route Diversion/ Transit Deviation**
Existing Conditions 1996 Traffic				
Scenario 0 No Build Traffic				
Scenario 1 No Build Traffic	**X**			
Scenario 2 TSM Traffic	**X**			
Scenario 3 TSM Traffic	**X**	**X**		
Scenario 4 TSM Traffic	**X**	**X**	**X**	
Scenario 5 TSM Traffic	**X**	**X**	**X**	**X**

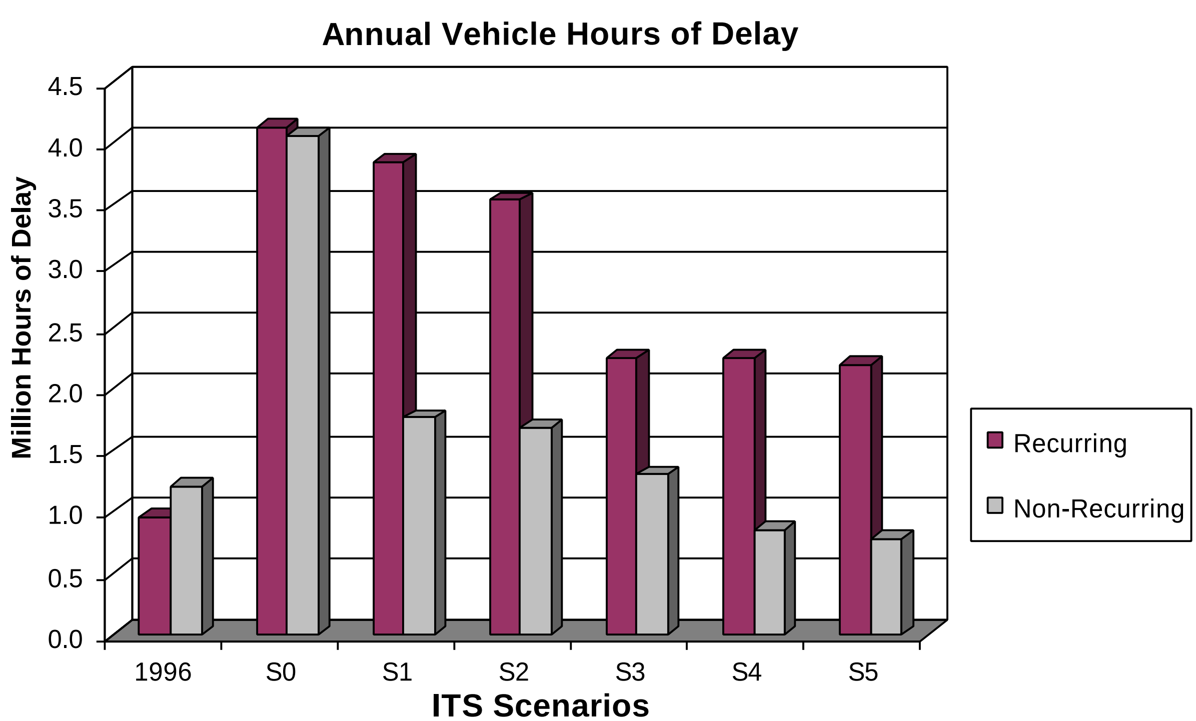
Evaluation Findings - ITS Scenarios
FIGURE 15





Evaluation Findings Continued - ITS Scenarios
FIGURE 16





The study team did a great deal of research on the proposed ITS strategies during the benefits analysis phase of the study that greatly assisted with the costing effort. Much of the information which ultimately shaped the assumptions used in the cost estimates was obtained through this initial research.

The first and most important step to preparing the cost estimates for the ITS strategies was to develop a detailed picture of what physical elements were included in the ITS options and how these strategies would operate on I-64 in the Year 2015. In this task, assumptions were established regarding items such as types of technology (i.e., radar detection vs. sensor loops); form of enforcement (i.e., state police vs. camera); and level of coverage (i.e., entire corridor vs. urbanized segments) for the ITS strategies. Assumptions were also set defining the amount of ITS and communications infrastructure which would be in place in the two regions and along the I-64 corridor by the Year 2015. In some cases, the proposed ITS improvements required additional systems, in other cases, system upgrades or expansion.

Quantity estimates were then developed for each of the ITS strategies. For the capital cost estimates, quantities were compiled using unit measures such as directional miles or number of on ramps as guides. For operating and maintenance costs, number of man hours was the most common unit of measure. Fortunately, as part of their budgeting processes, public agencies often develop guidelines for personnel resources needed to operate and maintain various elements of the transportation system. For example, manpower requirements for operating and maintaining ramp metering systems were obtained by contacting Caltrans, District 7 (Los Angeles).

Unit costs were acquired for the various hardware and software elements based on actual cost experience of ITS projects recently deployed throughout the United States. For example, with regard to the advanced signal systems, cost assumptions were provided by consultant staff members who had worked on designing similar systems (RT-TRACS and SCOOT) in major metropolitan areas such as Northern Virginia, Chicago, and Toronto. Some items such as operations software systems were estimated on a lump sum basis. Where a great deal of local coordination or operating systems integration was anticipated, lump sum costs were adjusted to reflect the liberal end of the cost scale (i.e., higher cost). Labor unit costs for O&M estimates were largely provided by VDOT based on local experience with contracting out ITS services. These unit costs were fully burdened in that they included both overhead and supporting direct expenses.

Total cost estimates were then prepared for both capital and O&M costs using a “cost build up” approach (quantities x unit costs). Capital cost estimates included “add on” items such as design, administrative functions, and contingencies. Preliminary estimates were then reviewed for reasonableness. In some cases, cost items were adjusted upwards to reflect higher levels of uncertainty.

Finally, annual costs were developed for the capital cost estimates using a life cycle costing method based on the expected usable life of the various ITS elements and a federally accepted discount rate (7%, Office of Management and Budget). Annual figures for both capital and O&M costs were needed to support the development of cost-effectiveness measures as part of the final evaluation task.

(I) Developed and presented final evaluation results.

Once approved, the ITS strategies were formally integrated into the evaluation analysis for the final set of MIS alternatives. See Figure 17 which shows an example of some of the final results for the six alternatives. The positive impacts of the ITS strategies are immediately apparent in Alternative B, the TSM Alternative. Though each build alternative reduced congestion on the corridor by adding various levels of freeway lane capacity which served to reduce the impact of ITS benefits, the ITS strategies still played a significant role in reducing non-recurring delay and reducing the number of accidents along the corridor.

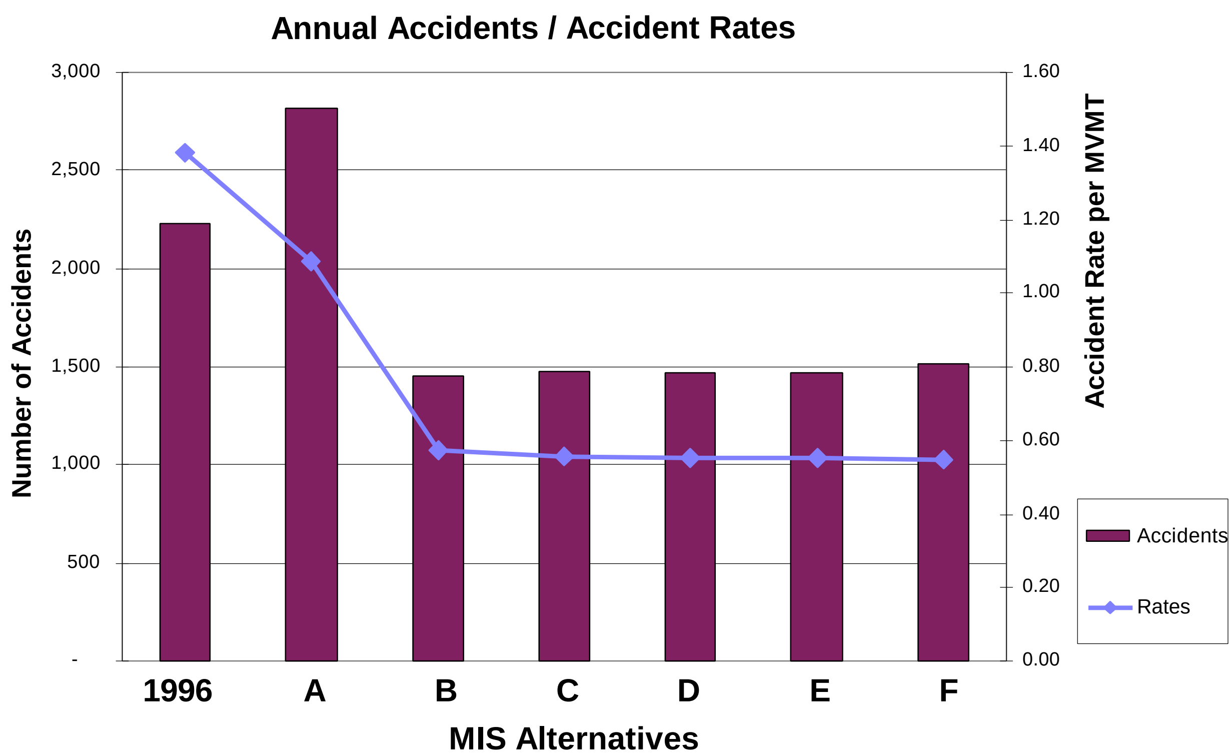
The reader will note that the evaluation findings shifted somewhat between the time that the ITS strategies were initially tested (i.e. ITS scenarios) and when the modeling procedures were re-run for the final set of alternatives (i.e., MIS alternatives). This was primarily due to adjustments in annualization factors which were necessary in latter phases of the study in order to prepare the cost-effectiveness indices. Benefits had to be balanced against costs using the same time period - a 365-day year.

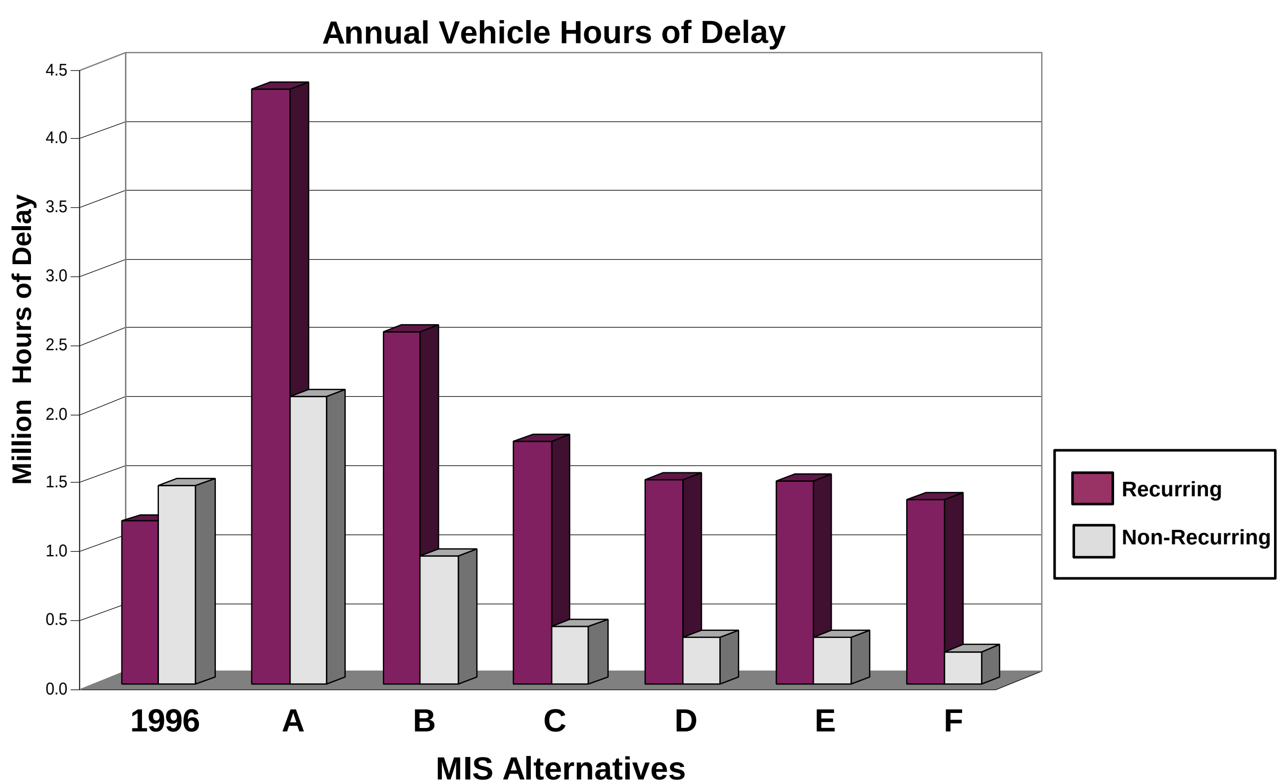
Figure 18 provides one example of a cost-effectiveness comparison that was developed for the final set of alternatives in the study. Costs represent the added cost of implementing the proposed transportation improvements compared to the "no build" condition. The costs are shown as an annual figure in current year dollars. The cost estimates include capital, operating, and maintenance costs for all the transportation elements (i.e., highway, rail, bus, and ITS) contained in each MIS alternative. Note that the build alternatives (Alternatives C - F) include high levels of capital investment which is why the annual costs of these four alternatives are higher compared to the No Build and TSM Alternatives (Alternatives A and B, respectively.)

The benefits shown in Figure 18 are a monetary measure of the benefits which accrue to travelers on I-64 as a result of implementing the proposed transportation improvements over a one-year period. As with costs, the benefits represent the incremental improvement over the no build condition. These monetized benefits are calculated assuming current year dollars and are derived from the secondary performance measures described earlier in Section 4.4 (E).

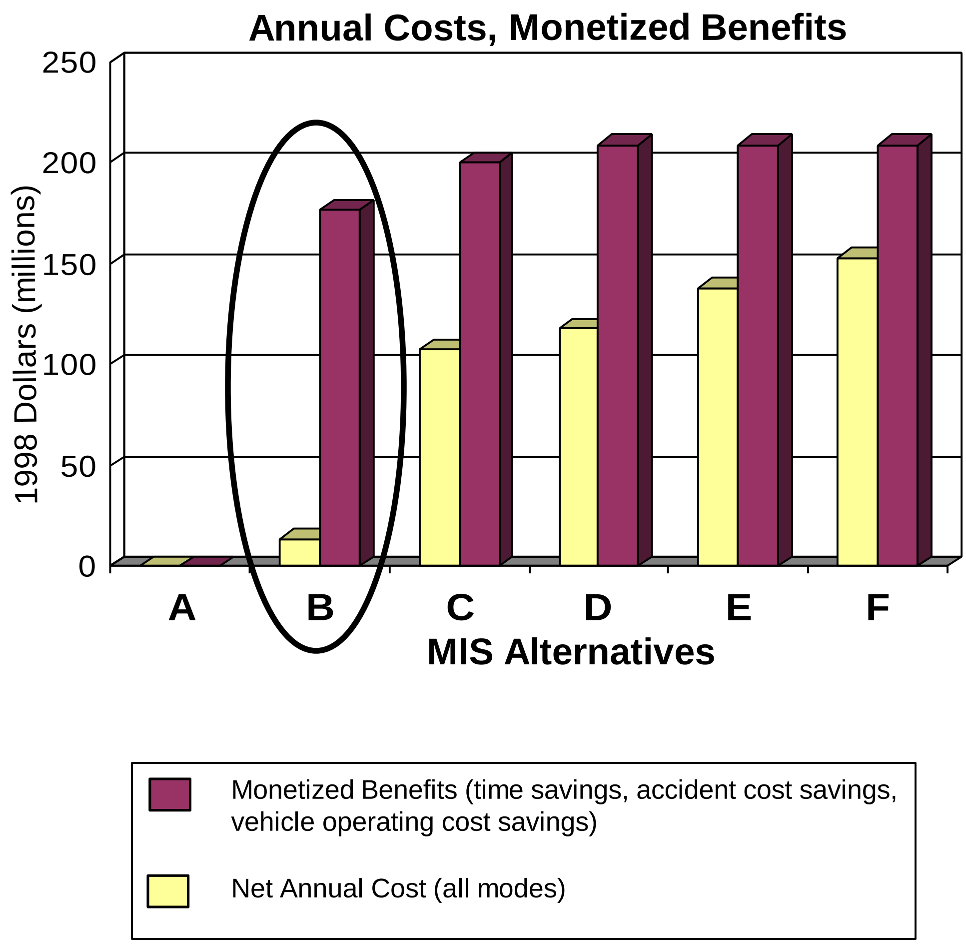
Most traditional planning studies do not include these types of monetary benefits in the cost-effectiveness evaluation tasks as a general rule. However, this cost-benefit comparison was extremely useful in highlighting the effectiveness of the ITS strategies in the I-64 MIS. Embedded in Figure 18 are three key messages: (1) the benefits justify the investment of public dollars for all the alternatives; (2) the TSM Alternative is, by far, the most cost-effective choice (see Alternative B which is circled in Figure 18); and (3) not only does ITS pay for itself (Alternative B), but it pays for all the other transportation improvements as well (Alternatives C - F).

Evaluation Results - MIS Alternatives
FIGURE 17





Cost Effectiveness - ITS Strategies
FIGURE 18



5.0 Lessons Learned

The consultant team and the study participants went through a learning process on the I-64 study. This has led to the development of a list of suggestions and ideas on how best to approach ITS and corridor planning. These suggestions largely reflect methods that worked well for us on the study and resulted in a better product. However, the list also includes ideas on how we would do things differently, if given the opportunity. Some of the "lessons learned" deal with the study approach and how to work with the different study participants. Yet others are suggestions on how to resolve technical issues which are likely to come up.

1) Use one study process to evaluate all proposed transportation improvements, including ITS.

Although this first recommendation seems obvious, it is worth mentioning here. It is important to develop a single, integrated approach as the basis for the written scope of work for the project. The I-64 study generally followed the decision-making structure of a major investment study, with modifications in technical processes to accommodate ITS. However, there is no "one best way." The integrated study approach should be tailored to address the transportation problems in the study area and should be designed to provide evaluative information that meets the study objectives and answers the decisions at hand. An integrated planning approach is applicable not only to corridor level studies, but is recommended for area-wide studies as well.

With the I-64 study, we discovered that the study participants and the local decision-makers did not care that much about the differences between the EDP process and the MIS process. It was actually the study team (i.e., the consultants and VDOT) which was having the greatest difficulty in communicating with each other about which ITS improvements should be studied and how to go about it.

An integrated planning approach was very important to the I-64 study since we were able to bring ITS into a single decision-making process. Once the ITS elements were included, it was easier for us to coordinate tasks; we were able to consolidate study resources (i.e., budget efficiency); it enabled the study team to treat all proposed improvements equally; and finally, study participants were more likely to buy into the proposed ITS improvements since they were part of the process used to develop and recommend them.

An integrated approach was also highly relevant to the final recommendations which resulted in the study. For example, we learned that the ITS improvements contributed greatly to performance of transportation system. Whereas ITS strategies could not rectify the capacity deficiencies in the corridor, the I-64 study showed that these improvements would go a long way towards solving some of the transportation problems in the corridor until future construction could take place.

2) Build relationships with study participants.

In order to address some of the uncertainties inherent in evaluating ITS, the study team worked extensively with the advisory members on the project. We were fortunate in that almost all members of these two groups were supportive of the ITS elements of the study. As mentioned earlier, several of the members of the advisory group had worked with ITS concepts before as part of the EDPs prepared for their metropolitan planning areas or within the course of their professional lives. This was helpful to the project team since the study participants already understood the uncertainty associated with analyzing the ITS strategies and the lack of "real world" ITS information.

As a result, we were able to take a team approach towards solving some of the unique challenges presented by the ITS components of the study. In other words, the advisory members were constructive and helpful, rather than critical. The study participants helped shape which ITS improvements would be studied; sharpened our assumptions on how the ITS improvements would work best; and gave us feedback on anticipated benefits and costs based on common sense, other similar projects, or what they knew about the study area.

3) Understand the major decisions that are part of the study process. Communicate upcoming decisions to the study participants.

Because of our limited budget and the need to keep on schedule, it was essential to have agreement from our advisory members on one step before we proceeded to the next step. As a project team, we had to set many assumptions regarding how the proposed ITS strategies would work, what the benefits would be, and how much they would cost. The advisory members verified each set of major assumptions. The study team simply couldn't afford to devote study resources down nonproductive paths of analysis or to redo the analysis if the advisory group questioned the ITS evaluation results due to opposition to assumptions that affected the modeling input values. This meant that we had to think through all the major decision-points on the study and then fully engage the key stakeholders at the critical stages.

It is the study manager's responsibility to carefully define the role of the advisory members so they understand how their feedback affects future decisions in the study. It is recommended that the project team meet with study participants regularly and frequently. It is also recommended that "game rules" for communicating with study participants be established and respected throughout the study process. For example, in the I-64 study we distributed agendas well ahead of each meeting to advisory members so they knew what topics were going to be discussed. At the beginning of each meeting we told them what information was going to be presented; what decisions we were going to ask them to weigh in on; and how the information would then be used. At the conclusion of each meeting and in the meeting minutes, we reminded them what they had decided. We allowed a comment period after each meeting. At times we even told stakeholders to be sure about their decision because we wouldn't be able allow them to change their minds later once we got too deep into the analysis.

4) Do not be afraid of your critics. Bring them into the study process. Be willing to make changes, it may lead to a better product.

Our greatest critics at the beginning of the study turned out to be some of greatest supporters toward the end of the study. The key was listening and responding to our stakeholders early on in the project. This allowed us to make changes in our approach and in our analytical techniques while there was still room in the budget and schedule to accommodate major shifts in direction.

In response to input from our study team and advisory group members, we made three noteworthy adjustments which strengthened the study recommendations: (1) integrated ITS planning activities into the overall major investment study; (2) added an ITS strategy to the analysis (use of parallel arterials as alternative diversion routes to I-64); (3) placed more effort on identifying and analyzing ITS improvements within the context of the I-64 corridor rather than on developing and testing generic ITS solutions.

However, don't concede too quickly. On occasion, the study team should give certain suggestions added thought and initiate further discussion prior to making significant changes even if it means schedule delays. For example, on the I-64 study we made an early decision at the request of an important stakeholder that greatly influenced the direction of the study - the large array of ITS improvements which were defined as part of the No Build Alternative. (The No Build Alternative represents future conditions in the corridor assuming no new transportation improvements beyond what is already planned to occur. In a major investment study, the No Build Alternative provides a baseline for comparing the relative merits of the other alternatives.) Prior to initiation of the I-64 study, VDOT had already done extensive planning to determine what ITS improvements they were committed to developing throughout the Commonwealth. It was their hope and expectation that all of these ITS improvements would be in place by the Year 2015 - the planning horizon year for the I-64 MIS. As the State had already committed to the improvements, it is possible some participants did not want the study to reopen consideration of whether or not these ITS strategies should be implemented on I-64. As a result, the level of scrutiny and discussion of these No Build ITS strategies was cursory, since study team directed their efforts towards producing information on those additional improvements which were subject to decision-making on the corridor. In hindsight, a compromise solution could have easily been reached. Selected ITS strategies could have been examined without locking either the State or the localities into specific commitments regarding phasing or implementation.

5) Be willing to undertake new or controversial ITS projects. Carry forward only those ITS projects that have a reasonable chance of being implemented.

The I-64 study considered a number of new and potentially controversial ITS projects. For instance, two of the ITS strategies - ramp metering and use of parallel arterials as alternate diversion routes for I-64 traffic - were not at all popular with some of the localities in the corridor. We also proposed a high occupancy toll (HOT) lane concept in the initial set of alternatives. Although the study team received some very close questioning from members of the public and other stakeholders on these and other improvements, in retrospect, it was well worth the effort.

First of all, we learned that if the study team fails to take the initiative or bring forth information on controversial strategies, then these improvements have little chance of being implemented no matter what their potential benefits might be. In general, study participants are usually interested in allowing the discussion to take place, knowing that they are making an informed decision if they elect to discard the controversial strategy later on in the study. This was true of the HOT lane alternative. This alternative was formally eliminated during the screening phase of the project, mostly because of general public opposition to tolls in the Richmond region and only lukewarm support among the advisory group members.

Also, you cannot know how valuable an ITS strategy might be until you see the evaluative data; it might be worthwhile to try to make it work. This was certainly the case with the ramp metering improvement. We were able to show strong benefits with ramp metering and despite some initial opposition, this improvement along with the route diversion strategies were ultimately recommended for inclusion in the preferred alternative.

Finally, although there was great interest on the part of some of the advisory committee members, the study team was reluctant to pursue an Automated Highway System (AHS) alternative. Based on discussions with ITS professionals in this field, the study team did not feel the AHS concept was sufficiently developed to be considered a reasonable alternative by the 2015 planning horizon. Consequently the AHS alternative was eliminated very early in the study during a technical advisory meeting, mostly at the request of both VDOT and members of the consultant team.

6) Present ITS technical information to the study participants incrementally.

In order to obtain meaningful feedback from study participants, it is advisable to present the technical information on the ITS evaluation in manageable blocks at key decision-points in the study. With regard to the I-64 study, we were only partially successful in accomplishing this objective. On a few occasions, we were pressed for time and didn't allow for full discussion on some of the more complex ITS concepts since we had large amounts of material on other aspects of the study which had to be covered during the same meeting period. The advisory group members recognized this and elected not to ask questions when they knew we wanted to keep moving through the agenda to stay on schedule. We did learn to pare down the amount of data that we presented to the group during subsequent meetings.

We also learned that we could not expect the stakeholders to digest long and highly detailed technical reports. This manner of communication was quickly dropped in favor of brief presentations. It then fell to the study team to highlight the ITS information that might be important during the verbal discussion. It was also up to us to keep the discussions relevant, short, and interesting.

We presented a large amount of ITS information to the advisory group members: study flow chart; how ITS fit into the conceptual alternatives; refined ITS descriptions (physical and operational components); evaluation methodology for ITS; assumptions and inputs for the ITS evaluation; measures of effectiveness; policy and technical implications associated with implementing the ITS improvements; preliminary ITS findings on travel benefits; ITS capital, operating and maintenance cost estimates; and final evaluation findings. It is doubtful we would have received the high-level cooperation or "buy in" on the ITS evaluation from stakeholders if we waited until we had already completed the analysis to begin to discuss ITS.

7) Only develop the technical information that is needed to support the decisions at hand. Focus on significant changes and differences.

Planning studies are often conducted in an environment where the study schedule and budget are relatively fixed. This, in turn, places practical limitations on the scope and level of effort for the technical work at the outset of the study. On any major planning study, the study manager must determine how to allocate limited resources wisely, particularly within a context of competing interests.

As a rule, the bulk of the technical effort should be directed to producing the evaluative information which is required to support decision-making on the study. In other words, concentrate your planning effort on developing the information you think you will need to answer the key questions which are likely to arise. In some cases, a high level of detail is necessary to discriminate among transportation choices. In other cases it is not. With larger planning studies, it is best to focus first on significant changes in the overall performance of the transportation system as a result of different ITS actions. As these major decisions are made, then more detailed analysis can be performed later to shape specific ITS improvements.

In the I-64 study, we needed to answer the following questions: Does the ITS strategy improve travel conditions for motorists on I-64? and, if so, by how much? How does the ITS improvement compare to doing nothing in the corridor? How does the ITS strategy compare to major capacity improvements to the Interstate? What are the ITS benefits relative to their costs?

Consequently, the evaluative methods used to quantify operational improvements on I-64 did not attempt to capture changes in individual travel behavior. Rather, the bulk of the technical effort was geared to define and measure “order of magnitude” differences among the transportation alternatives. Early in the study, it was determined that a macro-level operational analysis would be most suitable to produce these evaluative results.

On the other hand, detailed microsimulation techniques that measure individual travel shifts and then aggregate those impacts to produce ranges of effect across the overall transportation system may be more appropriate for some types of ITS-related planning studies. However, much depends on the scope of the study, available budget, planning horizon, and anticipated level of uncertainty. For example, the temporal nature of demand volumes combined with unknowns associated with future technologies, trip patterns, and transportation network changes may lead to such a high amount of variability in the performance measures that the quantifiable effects of individual travel behaviors are overshadowed.

8) Expand the array of performance measures to incorporate ITS in the evaluation of alternatives.

Evaluating the benefits of ITS measures in conjunction with conventional transportation management techniques and major investment options requires a more widespread array of measures of effectiveness than an evaluation that does not consider ITS. This affects the analytical requirements for the study in several ways.

First, it is not enough to consider only peak hour demand patterns nor only the weekday travel patterns in the analysis. Peak hour travel conditions often extend to multi-hour peak periods, and congestion can often occur due to seasonal or special event traffic. This includes shopping and recreational tourist traffic. During certain periods of the year, congestion due to these other trip types can become as significant as that of traditional commuter peak period traffic. Also, non-recurring congestion due to incidents can occur at any time of the day.

Second, ITS is designed to enhance the effectiveness of traffic management measures that extend beyond the scope of dealing with recurring congestion. Therefore, measures of effectiveness are needed to directly assess non-recurring congestion as well as accident experience which has a secondary impact on non-recurring congestion. Traditional major investment options rely upon safety improvements such as added capacity or changes in roadway design as the sole means of reducing accident experience. When ITS measures are considered, numerous in-vehicle technologies have the potential to achieve a significant reduction in accident experience that roadway safety improvements may not be able to achieve.

It is suggested at least one measure of effectiveness be selected to represent each primary aspect of transportation system performance. These primary aspects include demand, supply, service quality, congestion and safety. There are also secondary aspects of transportation system performance. These include energy consumption; environmental, social and economic impacts; and costs.

9) Perform a "reality check" on the ITS performance measures and methods.

Measures of effectiveness selected to evaluate ITS strategies and other capital improvement and management measures should acknowledge the baseline ideal condition. Many ITS strategies are intended to optimize transportation network efficiency, but not necessarily to improve efficiency beyond the ideal operating characteristics each facility was designed to accommodate. Therefore, any performance criteria included in the evaluation must be measured with respect to the ideal condition. For example, if a particular ITS strategy claims a 30 percent reduction in travel time, this benefit cannot be generalized without a frame of reference to understand the ideal conditions that the benefit was measured from. If a roadway experiences delays that increase travel time by 20 percent, assuming a 30 percent reduction would result in a travel time 10 percent less than the ideal travel time. In this case, delay would be a better measure, since delay reductions will not result in travel times better than the ideal.

Also, ITS strategies are often assumed to increase capacity when in reality there needs to be a distinction between strategies that can increase capacity above the "ideal", and those that merely recover capacity lost due to incidents, congested traffic flow, or other network effects. For example, incident management programs recover lost capacity by clearing incidents more quickly, while automated highway and/or automated vehicle technologies have the potential to achieve flow rates higher than the traditional ideal capacity achieved without these ITS technologies.

10) In order to capture ITS benefits, consider different traffic operations modeling techniques than those used to design roadway improvements.

Since the benefits of ITS normally accrue at the system level rather than at specific locations, analytical techniques need to provide system-level estimates of all major performance measures rather than spot-specific detail on limited performance measures. Also, the analytical techniques applied should produce performance measures representative of all time periods throughout the year, including seasonal variations. This is different from what is required for analyzing highway design improvements.

For the I-64 study, highway improvement options were analyzed using a macroscopic freeway operations model based on Highway Capacity Manual techniques (FRESYS) to develop conceptual design assumptions for the build alternatives. Though the I-64 study did not focus extensive analysis on cross road and arterial street operations, the appropriate macroscopic models for analyzing these types of facilities would include HCM techniques or macroscopic integrated models like TRANSYT-7F, the PASSER family, or similar network models.

Due to several practical limitations, the study team determined that it was not appropriate to apply microsimulation models throughout the 75-mile corridor to estimate the necessary performance measures. However, microsimulation could provide useful design-support information in spot locations where mezzoscopic or macroscopic models can not differentiate the operational impacts of various design options. In these situations, FHWA's FRESIM model was used to refine the design recommendations or answer specific design questions posed by study participants.

11) Quantify the benefits and costs of the ITS improvements. Decision-makers want to see this information.

It is necessary to quantify benefits and costs, because this information is critical to understanding how ITS performs compared to other proposed improvements or to the "no build" condition. Cost-benefit information on the ITS improvements was cited by our study participants as being one of the most useful contributions of the I-64 study. About 90% of the ITS planning effort on the study was geared to accomplish this objective.

With the I-64 MIS, the transportation alternatives were made up of combinations of modal elements such as added highway lanes, HOV lanes, bus, and rail improvements. As mentioned previously, the alternatives also included different levels of ITS improvements. In order to properly compare and evaluate the multimodal alternatives, the study team aggregated the evaluation findings associated with the different transportation elements included in each alternative. The only way that this could be done was to use quantitative measures so that similar units, such as hours of delay or current year dollars, could be summed for each alternative and then compared.

Quantitative data on both costs and benefits is highly desirable even when evaluating modally homogeneous transportation alternatives as it provides a consistent "measuring stick" to show order of magnitude differences among the alternatives. This type of information is also easier to present since it is possible to use tables and graphs to quickly communicate key findings and concepts. Moreover, these methods lend credibility to study findings.

Qualitative information on ITS strategies, such as added convenience to the user or greater efficiencies in administrative processes, is equally valid and should also be developed to supplement the quantitative data. In most cases, it is not possible to fully quantify all potential benefits and impacts associated with ITS strategies. For example, with the I-64 study, we did not have the detailed traffic data necessary to measure what the positive impact would be to travelers using parallel arterials if advanced signal systems were to be implemented or to account for the added time delay to local motorists at the on ramps due to ramp metering. Although these impacts were not quantified in the travel analysis, these factors were important and relevant to the evaluative discussions in the study.

12) Where information is missing, make assumptions. Back all study assumptions. Acknowledge uncertainty.

As mentioned earlier, one the greatest challenges that study managers face in analyzing ITS as part of traditional planning studies is the lack of knowledge on developing technologies. In the I-64 study, we partially resolved this problem by gathering what information that we could on the ITS strategies under consideration. Where information was lacking on the ITS strategies, we collected data from recognized sources on related or similar ITS strategies. However, despite these data collection efforts, we still faced several unknowns regarding the operational parameters, costs, and performance of the proposed ITS improvements.

The study team addressed the gaps in knowledge about ITS by setting assumptions throughout the course of the study. Where possible, study participants were included in this process. Critical assumptions which could potentially shape the outcome of the evaluation results were explicitly discussed and then adjusted as necessary.

In developing study assumptions, a few guidelines are recommended. First, the study team should be fairly aggressive in establishing the analytical procedures and then setting assumptions. The quality of input is higher when decision-makers have something they can react to. Secondly, it is essential to back all study assumptions using factors such as performance of similar technologies, local experience with ITS-related projects, knowledge of transportation issues in the corridor study area, accepted unit costs, professional judgment, logic, and common sense. Third, once established and agreed upon, all key assumptions regarding ITS should be recorded and then included in the study documentation. Finally, the uncertainty associated with the ITS assumptions should be formally acknowledged in the verbal discussions with study participants and also documented.

We discovered that our advisory group members had a relatively high tolerance for the unknowns associated with the ITS evaluation process as long as they understood the methods used to produce the information and the some of the uncertainties involved with the study results. Also, since study participants were involved in establishing the ITS assumptions, there was general agreement on the value of the ITS evaluative findings in the overall study.

13) Rely on experts in the ITS field to help set assumptions and verify results.

It is beneficial to step outside the immediate study process to verify both ITS assumptions and interim evaluation results. This entails discussing the ITS elements of the study with other ITS planning professionals to obtain an objective opinion and to benefit from a broader array of ITS resources.

In the I-64 study, this task was accomplished in a number of different ways. ITS assumptions were largely verified through telephone discussions or meetings with ITS technical advisors associated with the consulting firms on the study. Some of these staff members are acknowledged experts in their field or have direct experience with implementing similar ITS projects or technologies nationwide. These discussions involved topics such as: viability of emerging technologies, identification of appropriate technologies for the I-64 corridor, potential deployment strategies, and capital and operating cost assumptions.

As part of the ITS operations modeling effort, the study team drew upon FHWA compendiums of study results pertaining to ITS benefits. A good example is “Intelligent Transportation Systems - Real World Benefits,” published by FHWA in January 1998 (FHWA - JPO - 98 - 018).

To obtain information or to affirm key study assumptions, the study team contacted VDOT staff responsible for leading the Commonwealth's ITS planning efforts as well as VDOT staff in charge of implementing ITS strategies in the corridor study area.

Presentations on the I-64 ITS study results were conducted with the ITS subcommittee for the Hampton Roads region. This enabled the study team to receive feedback from the localities who would ultimately be involved in the design and the implementation of the ITS recommendations resulting from the study. As opportunities arose during the study, presentations were also made to attendees at regional and national ITS conferences in order to receive comments and suggestions on the study approach and preliminary findings.

If additional study resources are available, it is recommended that an ITS peer review committee be established to review the study procedures and to examine the ITS evaluation results and cost estimates. For best results, peer review members should be acknowledged experts in their field; well-versed in ITS systems and/or evaluative planning studies; and drawn from a geographic cross section of metropolitan areas.

14) Adjust study assumptions and findings to match level of uncertainty.

Under some circumstances, it is advisable to develop a range of potential travel benefits for a performance measure to cover the gamut of possible applications and background conditions. For example, the application of variable speed limits with end-of-queue warning systems on the I-64 corridor could reduce the incidence of collisions somewhere between 5% and 25% depending upon environmental conditions or how vigorously the measure is enforced. The same procedure can be used with costs. In general, the span of the range should reflect the level of uncertainty associated with the estimate. The greater the uncertainty, the more variability one would expect for that performance measure; hence, a wider range.

The identification of ranges of travel performance measures and costs estimates works well, particularly in the early stages of the study. During the technical discussions, this provides a means of acknowledging the effects of different parameters and conditions associated with implementing ITS. However, eventually you will need to settle on one representative data point from your range to serve as the final input to the study evaluation analysis and findings.

Although it is tempting to fall back upon using the midpoint of the range, the study manager should carefully consider the type of benefit or cost and the level of uncertainty involved. If the level of uncertainty is low, then the study manager can feel relatively confident with a median data value. Conversely, if the level of uncertainty is high then it is appropriate to look towards the edges of the data range.

Much also depends upon the style of the study manager and the planning environment. In general, with costs, it is best to go high. This, in part, compensates for the tendency of cost estimates to increase as the project is further defined during subsequent stages of project development - more design details are known and can thus be costed. Also, once a cost estimate is publicized, the public tends to react negatively if the project cost increases significantly beyond the planning estimate. On the other hand, with travel benefits, select from the lower end of your range. This reflects a conservative estimate of the potential performance of the ITS strategy. When undergoing close questioning by the public and local decision-makers regarding the claimed ITS travel benefits, a conservative estimate is typically more credible.

Though we did not have the time or study budget on the I-64 MIS, a risk management analytical process could have been used to quantify the levels of uncertainty associated with the ITS improvements to select the appropriate values for each data range. One might consider applying this approach if the study funds permit it.

15) Understand that educating participants and decision-makers about ITS is an important part of the study effort.

Corridor planning studies such as the I-64 provide a public forum where the merits of ITS can be highlighted and discussed. Although this alone is not sufficient reason to include ITS in traditional planning studies, these opportunities should be seized when they present themselves.

In addition, the public and local decision-makers need to be able to grasp what is involved with the ITS strategies, how they operate, and what the strategies are supposed to achieve before these individuals can be expected to comprehend the ITS evaluation results and give relevant feedback regarding the ITS improvements that should be included in the final study recommendation.

This means that the study team, particularly the study manager, should understand that educating the public and decision-makers about ITS is an important part of the study effort. Consequently, study presentations, media materials, and technical summaries should be developed with this in mind.

First of all, it is important to illustrate the ITS improvements using concepts that your target audience can relate to and understand. For technical audiences highly familiar with ITS, it is sufficient and probably beneficial to use accepted ITS terms and categories (or hierarchies) when listing the proposed improvements so as not to create confusion among study team members and participants.

On the other hand, these very specific ITS terms may not hold the same meaning or may not include enough descriptive detail when communicating with the general public. Under these circumstances, it is recommended that the study team begin with examples of existing ITS improvements that people may already be familiar with in their day to day travel. In the Hampton Roads region, examples of ITS include CCTV devices, highway advisory radio (HAR), variable speed limits and warning systems on the bridge-tunnels, and route diversion information presented via variable message signs upstream of major decision points or construction zones.

Once the basic elements of these ITS improvements are understood, then it is easier to illustrate ITS using more general concepts such as vehicle detection, communication, and systems management. For new or advanced technologies, it is advisable to describe the proposed improvements based on what they are designed to bring to the transportation system or what the proposed ITS strategy means to the individual motorist rather than presenting a list of its physical and operational components.

When presenting ITS evaluation results, it is often necessary to take the time to reacquaint study participants with the ITS strategies under study. Special conditions or circumstances which impact the effectiveness of the proposed ITS improvements or their costs should also be noted and explained. During the presentations, it is helpful to point out what elements of the ITS improvements are contributing significantly to the study results and why. Finally, graphics and pictures should be used wherever possible in the study materials to communicate key points quickly. Unfortunately, most local decision-makers do not have the time nor the patience to absorb the detailed background information which is often necessary to fully grasp the ITS elements of any one study.

16) Help provide the transition to successful implementation.

A significant advantage of including ITS into a corridor study such as a major investment study is that, if selected, the proposed ITS strategies would then be included in the region's long range plan as part of the locally preferred alternative adopted by the metropolitan planning organization. This step is important in order to garner the funding and political support needed for eventual implementation of the ITS improvements.

The study team can assist with this process by raising public awareness about ITS and the potential benefits that the ITS improvements are expected to bring to the transportation system. During the numerous briefings and public presentations which typically precede the selection and adoption of the locally preferred alternative, the effectiveness of the ITS elements should be highlighted as appropriate. In the I-64 MIS, we were able to demonstrate that ITS significantly improved the operation of I-64, particularly in terms of safety, level of service, and delay. In the overall evaluation results, the TSM Alternative which was mostly comprised of ITS improvements, performed very well compared to the No Build Alternative, and at a relatively low cost.

The study team can also help provide the transition to implementation of ITS by reaching out to the agencies and/or committees responsible for guiding the funding and development of ITS improvements in the region. Ideally, this outreach is occurring throughout the study process in order to give members of these groups the opportunity to help shape the ITS recommendations. Budget permitting, the study team can also work with these groups to identify next steps or to provide supplementary information on the proposed ITS strategies to support their project development efforts.

6.0 Final Thoughts

As of this writing, we are close to completion on the I-64 major investment study. Below, we have summarized some of the final conclusions the study team reached about ITS in the I-64 study:

- A large task budget is not required and highly detailed, micro-level analyses are not essential to produce meaningful results on ITS.

- Adding ITS forced us to look at benefits and performance measures that traditional planning studies would otherwise ignore. However, these measures added considerable insight into the relative effectiveness of ITS with respect to capital improvements, traditional management and multimodal strategies, and other conventional improvement options.

- We noted tangible improvements in the performance of the transportation system as a result of the ITS strategies, especially ramp metering. This study finding provided additional incentive to move forward with the ITS projects.

- ITS significantly enhances the effectiveness of traditional transportation management strategies and can extend the service life of existing facilities until improvements can be funded and constructed.

- The integrated planning approach used in the study to incorporate the ITS analysis elements is not limited to major investment studies. The same steps can be applied to most any type of traditional planning study.