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IMMEDIATELY APPLICABLE METHODS FOR EVALUATING ENVIRONMENTAL IMPACTS OF INTELLIGENT TRANSPORTATION SYSTEMS (ITS)

Tejas Mehta, Hani S. Mahmassani, and Chandra Bhat

CENTER FOR TRANSPORTATION RESEARCH
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16. Abstract

This report provides an overview of the various methodologies for assessing the impacts of Intelligent Transportation Systems (ITS) on the environment. The report also discusses the general ITS evaluation framework and the issues that are important in assessing environmental impacts of ITS. The report particularly focuses on Immediately Applicable (IA) methods. A description of the structure and the assessment methodologies of two of the most widely used IA tools is presented along with the limitations of these tools.

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by

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Hani S. Mahmassani, P.E. (Texas No. 57545)
Research Supervisor

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IMPLEMENTATION RECOMMENDATIONS

The methods presented in this report represent *best practice* tools that may be used to provide preliminary assessments of environmental benefits of ITS (Intelligent Transportation Systems) services in a network. While these methods are available and may be readily adapted to a particular situation, they also suffer potentially serious limitations via-a-vis their use for detailed assessments of ITS strategies. These limitations are discussed in the report.

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CHAPTER 1. INTRODUCTION

A Commonwealth Department of Transport and Regional Services (DOTRS) study (Ref 1) defines Intelligent Transportation Systems (ITS) as "a broad field encompassing a range of new and emerging technologies, such as computer systems, telecommunications, information technology, electronics, and sensor technology, built into transport applications to improve the performance, efficiency, and safety of all transport modes." ITS are evolving largely from demonstration projects to a mainstream set of options available to transportation agencies (Ref 2).

The ITS evaluation process has three important roles in the context of ITS deployment:

1. ITS evaluation serves as a means of conducting a comparative assessment of ITS deployments and the traditional capacity enhancing projects.
2. ITS evaluation provides an indication of the benefits that are likely to be realized as a result of the deployment of ITS, which can be used in conducting a feasibility analysis.
3. ITS evaluation assists in identifying the appropriate ITS technology from a wide range of ITS deployment options.

The Clean Air Act Amendment of 1990 requires that transportation plans, programs, and projects conform to the purpose of State Implementation Plans (SIPs) for the attainment of the National Ambient Air Quality Standards (NAAQS). Intelligent Transportation Systems are being considered as a strategy for reducing environmental emissions by improving the efficiency of the transportation systems (Ref 3). In this context, the importance of a systematic framework and methodology to quantify the environmental impacts of relevant ITS technologies becomes evident.

This report provides a brief overview of the important components of the National ITS architecture, which are the issues that make ITS evaluation different from evaluation of conventional transportation methods. There is a wide range of approaches found in ITS research literature for quantifying the environmental impacts of ITS technologies.

This report discusses the framework and assessment methodologies of some of these approaches. An outline of a procedure for analyzing incident related impacts of transportation improvements is presented. This procedure can be adapted for evaluation of a number of ITS strategies.

Some of the most widely used sketch planning or immediately applicable (IA) methods are described. The structure and the impact assessment methodology of these tools and their limitations are also presented.

CHAPTER 2. ITS EVALUATION FRAMEWORK

The National ITS Architecture

The National ITS Architecture (Ref 4) provides a common framework for planning, defining, and integrating intelligent transportation systems. It is a mature product that reflects the contributions of a broad cross section of the ITS community (transportation practitioners, systems engineers, system developers, technology specialists, consultants, etc.) over a five-year period. The architecture defines:

1. The functions (e.g., gathering traffic information or requesting a route) that could be performed by an ITS implementation
2. The physical entities or subsystems where these functions reside (e.g., the roadside or the vehicle)
3. The flow of information that connects these functions and physical subsystems together into an integrated system

The National ITS Architecture is based on the concept of *user services*. User services describe what the system will do for the user (Ref 4). These user services are logically grouped into seven user service bundles for convenience. Another useful concept within the National ITS Architecture is the concept of *market packages*.

Market packages identify the pieces of the National ITS Architecture that are required to implement a service. As such, they are directly grounded in the definition of the architecture. Most market packages are made up of equipment packages that consist of two or more subsystems. Market packages are designed to address specific transportation problems and needs and can be related to the user services and their more detailed requirements (Ref 4). Table 2.1 below shows the 31 user services that are mentioned in the National ITS Architecture. These services are grouped in seven user service bundles.

Table 2.1 User Services for the National ITS Architecture

Source: *The National ITS Architecture* (Ref 4)

User Service Bundle	User Service
Travel and Traffic Management	Pre-trip Travel Information; En-route Driver Information; Route Guidance; Ride Matching and Reservation; Traveler Services Information; Traffic Control; Incident Management; Travel Demand Management; Emissions Testing and Mitigation; Highway-Rail Intersection
Public Transportation Management	Public Transportation Management; En-route Transit Information; Personalized Public Transit; Public Travel Security
Electronic Payment	Electronic Payment Services
Commercial Vehicle Operations	Commercial Vehicle Electronic Clearance; Automated Roadside Safety Inspection; Onboard Safety Monitoring; Commercial Vehicle Administrative Processes; Hazardous Material Incident Response; Commercial Fleet Management
Emergency Management	Emergency Notification and Personal Security; Emergency Vehicle Management;
Advanced Vehicle Safety Systems	Longitudinal Collision Avoidance; Lateral Collision Avoidance; Intersection Collision Avoidance; Vision Enhancement for Crash Avoidance; Safety Readiness; Pre-Crash Restraint Deployment; Automated Vehicle Operation
Information Management	Archived Data Function

ITS Evaluation Frameworks

Most studies found in the ITS research literature (Refs 2, 5) indicate that there have been two principal approaches to ITS benefits evaluation: a goal-oriented approach and the economic analysis approach. A study conducted at the University of Wisconsin (Ref 2) describes these approaches as:

Goal Oriented Approach

In this approach, the starting point is to define the goals and objectives, and then the focus is on whether the end product achieves its original goals. In the context of environmental benefit assessment, the appropriate goal is to reduce the energy and environmental costs associated with traffic congestion. Such an approach is likely to be used at the local or district level for project selection and identification.

Economic Analysis Approach

This approach focuses on whether the investments in ITS that are required to achieve a particular set of goals are economically beneficial and on how the rate of return on investments compares to that of other projects. This approach is therefore better suited for use at a statewide level for project selection.

The study (Ref 2) further points out that the approaches are closely related and that the frameworks used for both approaches incorporate elements of the other approach. The difference appears to be that economic benefit is one of several components of the overall evaluation in the goal-oriented approach, while it is the sole or most important measure in the economic analysis evaluation. The main thing to note is that the two approaches are complementary and not mutually exclusive.

The goal oriented approach is used in many ITS evaluation frameworks that are found in the ITS research literature (Refs 6, 7). The National ITS Program Plan (Ref 8) jointly developed by US DOT and ITS America presents six goals for the National ITS Program. The three relevant goals with regard to air quality evaluation are shown here with further objectives:

1. Reduce energy and environmental costs associated with traffic congestion
2. Reduce harmful emissions per unit of travel
3. Reduce energy consumption per unit of travel

The ITS Joint Program Office (JPO) of the United States Department of Transportation (USDOT) advocates the use of what is termed "a few good measures," which are robust enough to represent the goals and objectives of the entire ITS program, yet few enough to be affordable in tracking the ITS program on a yearly basis (Ref 9). These "few good measures" include:

1. Crashes
2. Fatalities
3. Travel time
4. Throughput
5. User satisfaction or acceptance
6. Cost

ITS Evaluation Guidelines

The ITS Joint Program Office (JPO) of the United States Department of Transportation (USDOT) has issued an ITS Evaluation Resource Guide, (Ref 10) which breaks down the evaluation process into six steps:

1. Form the evaluation team
2. Develop the evaluation strategy
3. Develop the evaluation plan
4. Develop one or more test plans
5. Collect and analyze data and information
6. Prepare the final report

Types of ITS Evaluation

A study of applications of ITS evaluation guidelines conducted at the University of Virginia (Ref 11) has identified the two types of ITS evaluations described below.

Formative evaluation is performed concurrently with the ITS deployment. This type of evaluation is aimed at providing useful short-term feedback during the deployment process so that the objectives and goals of the project are met.

Summative evaluation is performed after the ITS deployment. It is aimed at analyzing the deployment and identifying the lessons from the deployment, which may serve as valuable inputs to the decision making process for subsequent ITS deployment projects.

The study (Ref 11) further provides a matrix of suggested measures of effectiveness based on ITS evaluation guidelines and the review of literature. The portion of the matrix relevant to energy and environment is given in Table 2.2 below.

Table 2.2 Measures of Effectiveness Sensitive to Energy and Environment

Adapted from *Integrating Intelligent Transportation Systems within the Transportation Planning Process: An Interim Handbook* (Ref 12)

Goal Area	Measures of Effectiveness	Traveler Information	Traffic Management	Commercial Vehicles
Energy	vehicle emission	X	X	X
and	noise pollution		X	
Environment	fuel consumption	X	X	X

CHAPTER 3. METHODS OF ASSESSING ENVIRONMENTAL IMPACTS OF ITS

Introduction

Methodologies for assessing air quality impacts of transportation control strategies typically involve two major steps. The first major step is to estimate the emission-producing activities that can be attributed to mobile source activities such as vehicle miles/hrs traveled, and refueling, etc. The next step is to estimate the emissions of various pollutants as a result of these activities using a suitable modeling approach.

There have been a number of approaches in the ITS research literature (Ref 13) for each of these steps. Emission-producing activities (EPA) can be simulated using either the conventional travel demand and traffic simulation models, commonly referred to as *static* models or more recently as *dynamic* simulation models. The estimation of the produced emissions may be performed using the *emissions factors* based models such as EPA's MOBILE series of models that are most widely used, or using modal emissions models that explicitly capture the impact of vehicle operating modes on emissions.

The approaches to ITS evaluation that have been adopted in practice and reported in the ITS research literature exhibit a lot of variation. The approaches range from highly detailed micro-simulation based models to spreadsheet-based sketch-planning tools. The suitability of using one approach over the other for both steps is largely governed by the purpose for which the emissions estimates are required and by the resources available to perform the analysis. For determining the true impact on the system and on society, a high degree of representational detail and correspondingly elaborate network-based methodology is required in the evaluation approach. On the other hand, a sketch-planning tool may suffice for prioritizing ITS projects or for tracking annual progress towards goals. The availability of data is also an important consideration when selecting the appropriate tool for ITS evaluation (Ref 2).

Based on the review of the literature and the methodological development conducted as part of the present study, the methods for evaluating the air quality impacts made by ITS can be viewed at the following three levels:

Level 1

This level, which defines much of the current state of practice in emissions estimation, involves using outputs from the four-step transportation planning process and static traffic assignment models. The emissions estimation is performed by using emission factor models, e.g., EPA's MOBILE series of models or CARB's EMFAC for California. This approach is suitable for the purposes of preparing emissions inventory for a geographical region or for forecasting emissions for long-term strategic planning purposes. The *static* models used produce average travel times, speeds, and delays experienced in the network as the main indicators of performance. Generally, these models are not sufficiently responsive nor sensitive to the kind of operational changes introduced by ITS measures.

Level 2

In this case, dynamic simulation-assignment models like DYNASMART may be used to estimate the emission-producing activities. In dynamic modeling, more refined and operationally meaningful indicators of traffic performance include queues and speeds on links for every simulation interval. This approach is therefore responsive to Intelligent Transportation System measures and provides an important improvement over using a *static* model for the purpose of air quality assessment of ITS. The output from the dynamic model can then be used with the emission factor based models, but this is done at sufficiently small intervals to capture the impact of ITS technologies. Shazbak (Ref 14) performed a comparative analysis of air quality impact assessment in the Greater Beirut Area (GBA) using both *dynamic* and *static* models.

Level 3

Dynamic models may be interfaced with *modal* emissions models that explicitly capture the impact of vehicle operating modes on emissions instead of using average values. This approach therefore provides a very fine degree of resolution, both in terms of estimating emission-producing activities, as well as estimating the emissions generated as a result of these activities. There is a fair amount of research presently underway, both in the US and in Europe, which focuses on developing and validating such *modal* emission models. An earlier research report prepared under this project (Ref 13) discusses some of these modal emission models. The general framework for combining, planning, and simulation methods is shown in Figure 3.1.

Induced Demand

One of the main concerns with ITS strategies is *induced demand.* One concern is that improved traffic operations and reduced travel times may lower the road users' perceived costs of vehicle travel and consequently induce additional vehicle traffic. This argument is based on the theory of induced growth in vehicle travel, which hypothesizes that an increase in the capacity of a specific corridor or road network will attract increased levels of vehicle traffic (Ref 15).

Dia et al (Ref 3) have presented a methodology for modeling the environmental impacts of ITS, including the impacts of induced demand. The framework used in their methodology integrates the traditional four-step travel demand models with microscopic traffic simulation models and modal emissions models. The methodology includes the following feedback loops (Ref 17):

1. *Feedback from traffic assignment to trip generation.* This feedback loop is designed to capture the long-term effects of additional ITS-generated capacity on regional land use and trip making.
2. *Feedback from traffic assignment to trip distribution.* This loop is designed to provide speed sensitive travel times for trip distribution, and secondly to capture long-term changes in origin or destination due to ITS-generated capacity.
3. *Feedback from simulation models to traffic assignment.* This feedback loop provides more accurate travel time and congested speed estimates for each traffic assignment.

The framework for these loops is shown in Figure 3.1.

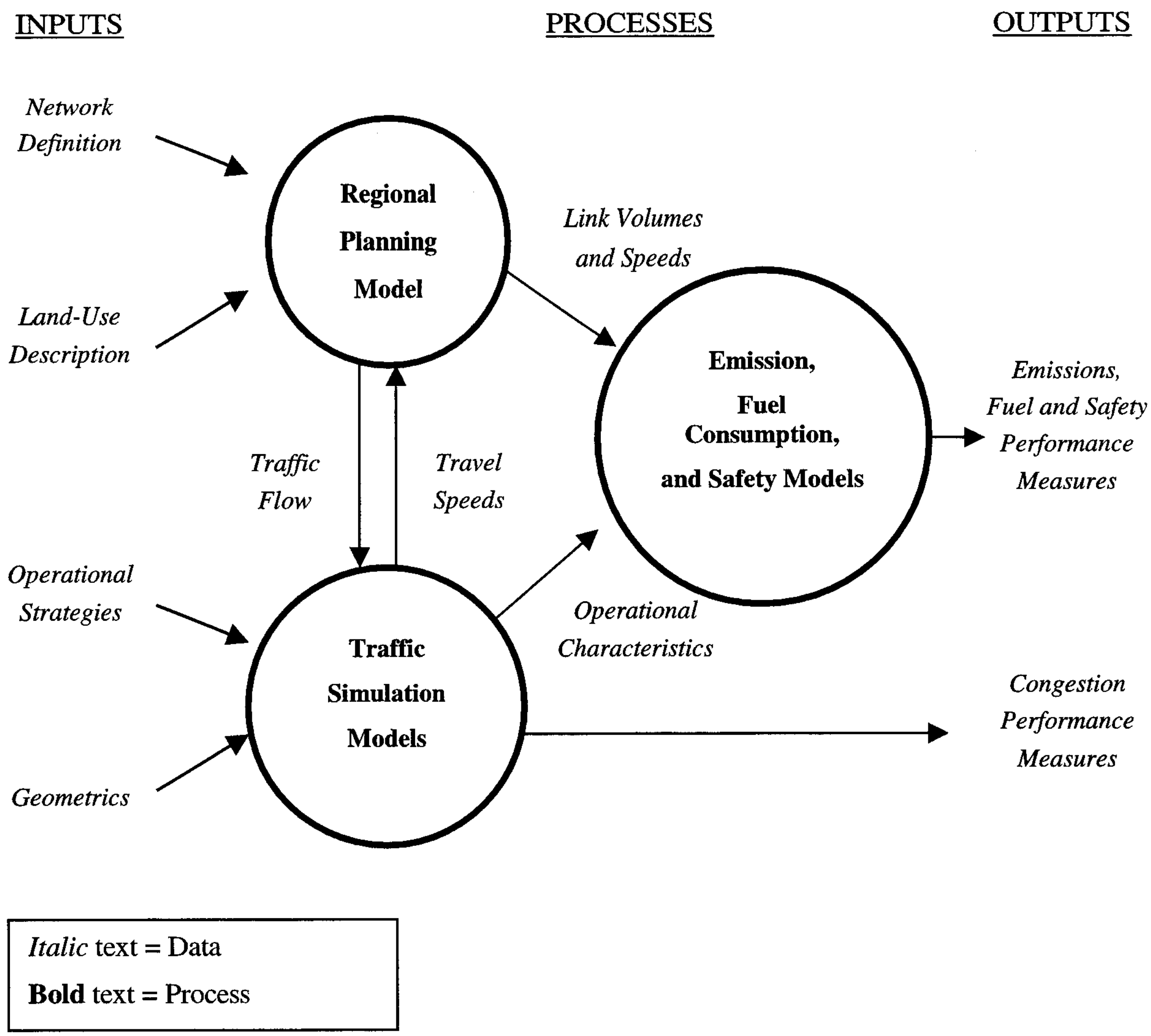

Figure 3.1 ITS Modeling Framework

Source: *Intelligent Transportation Systems Impact Assessment Framework: Final Report* (Ref 6)

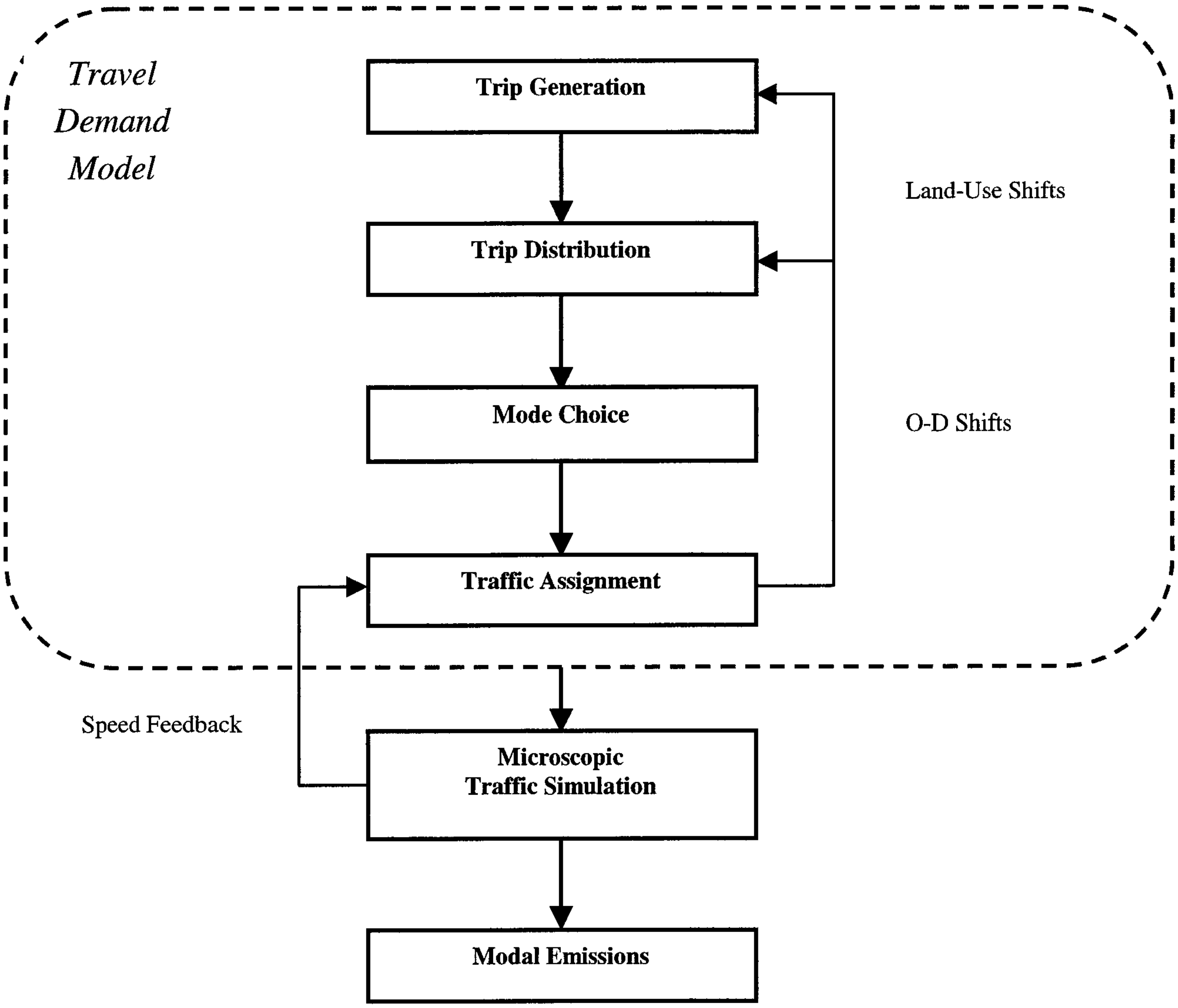

Figure 3.2 Generic Framework for Integrating Travel Demand, Traffic Simulation and Emissions Models

Source*: Assessing the Emissions and Fuel Consumption Impacts of Intelligent Transportation Systems (ITS*) (Ref 17)

Sketch Planning Methods

ITS strategies differ from conventional strategies considered in the transportation planning process in that ITS strategies are targeted toward improving the efficiency of the existing transportation systems and are therefore operation and information oriented. Furthermore, the impacts of most ITS strategies are localized. These factors make it extremely difficult to develop sketch planning methods that do not require elaborate analytical procedures and simulation runs. There is very little information available in the ITS research literature on sketch planning methods for assessing environmental benefits of ITS.

One of the AREAS where ITS strategies have significant potential is in reducing the nonrecurring delay in incident situations. A study by Cambridge Systematics (Ref 18) has developed step-by-step procedures for calculating travel time without queuing. The research team obtained a series of equations by fitting a curve with these variables as the dependent variables and with variables such as the ratio of the Average Annual Daily Traffic to Capacity, (AADT/C) incident rate, accident rate, and duration factor as the independent variables. These equations have been developed for both freeways and signalized arterials for the following scenarios:

1. A.M. peak direction, daily traffic
2. A.M. peak direction peak period traffic
3. P.M. peak direction, daily traffic
4. P.M. peak direction peak period traffic
5. Both directions, daily traffic (accident delay equations only)
6. Both directions, peak period traffic

The equations therefore allow the analyst the flexibility of deciding whether to perform the analysis on a daily basis or on a peak period basis, as well as whether to perform directional analysis. The choice depends on factors like the availability of data, the purpose of the analysis, and the ITS application being analyzed.

The queuing factors account for the actual delay due to queues, while the nonqueuing factor is basically the inverse of the speed for that segment and is therefore not pure delay.

The nonqueuing delay for a segment can be calculated by subtracting the time required to traverse the segment at the *free flow* speed from the time required to traverse the segment at the computed speed.

Cambridge Systematics User's Guide (Ref 18) provides a detailed explanation of the variables used in the analysis, the default values for these variables, and of all the equations used for calculating the queuing and non queuing factors. The report also provides a tutorial for analyzing a number of scenarios.

A brief description of the main input variables and the important elements of the procedure are described in the following section.

Input Variables

The input variables are AADT/C ratio, free flow speed, incident rate factor, duration factor, shoulder factor, and accident rate factor. These variables are explained below:

1. *AADT/C*. This is the measure of congestion in the network. The value of AADT/C rarely exceeds 14.0 for existing facilities and under no conditions should exceed 18.0. If it exceeds 18.0, then both AADT and capacity should be checked for accuracy.
2. *Incident Rate Factor*. Incident factor is computed using the following equation: *Incident Rate Factor = Facility Incident Rate/Default Incident Rate*
The incident rate includes all forms of incidents, including minor incidents.
3. *Accident Rate Factor*. Accident rate factor essentially measures the deviation of facility specific rate from the default accident rate that is imbedded in the overall incident rate: *Accident Rate Factor = (Facility Accident Rate/Default Accident Rate) – 1.0.* If information is not available on all types of incidents that are to be included in the incident rate, then the analyst has the option of using the default incident rates. It is to be noted that accidents are a subset of the total incidents, so to avoid double counting, either the total incident rate or the accident rate should be adjusted for accidents. The default accident and incident rates are given in Table 3.1.

4. *Duration Factor*. The duration factor is computed using the following:

   Duration Factor = (target mean incident duration)/38.0

   where

   38.0 minutes is the overall weighted average duration of all incidents for the default case.

5. *Shoulder Factor*. Shoulder width impacts incident delay by the way of its ability to shelter disabled vehicles. Shoulder factors are computed as a function of shoulder width for the right and left shoulders individually using the values given in Table 3.2. The shoulder factor for use in the equations is then ShldFac = {SF (left) + SF (right)}/2

6. *Percent of Annual VMT in the Peak Period*. This input variable is needed if peak period is used as the period of analysis. The peak period is defined as weekdays between the hours 6:00 A.M. to 10:00 A.M. and 3:00 P.M. to 7:00 P.M. If locally defined values are unavailable, the defaults in Table 3.3 may be used.

Table 3.1 Default Accident and Incident Rates by AADT/C

Source: *Sketch Planning Methods for Incident-Related Impacts-User's Guide* (Ref 18), Table 2.7

AADT/C	Accident Rate (per MVMT)	Total Incident Rate (per MVMT)
1	1.066	9.611
2	1.069	9.614
3	1.075	9.620
4	1.086	9.631
5	1.105	9.650
6	1.132	9.677
7	1.172	9.717
8	1.220	9.765
9	1.275	9.820
10	1.345	9.890
11	1.414	9.959
12	1.518	10.063
13	1.583	10.128
14	1.657	10.202
15	1.709	10.254
16	1.760	10.305
17	1.810	10.355
18	1.853	10.398

Table 3.2 Shoulder Factors for Left and Right Shoulders

Source: *Sketch Planning Methods for Incident-Related Impacts-User's Guide* (Ref 18)

Shoulder Width	Shoulder Factor (Left and Right)
<= 3 ft	0.0
4-5 ft	0.5
6+ft	1.0

Table 3.3 VMT Proportions for Freeways

(Both Directions Combined)

Source: *Sketch Planning Methods for Incident-Related Impacts-User's Guide* (Ref 18), Table 3.2

AADT/C	Percent of Traffic in Peak Hour	Percent of Traffic in Peak Period
1	0.0787	0.3844
2	0.0786	.03844
3	0.0788	0.3847
4	0.0789	0.3852
5	0.0789	0.3845
6	0.0784	0.3842
7	0.0787	0.3844
8	0.0768	0.3830
9	0.0745	0.3814
10	0.0718	0.3777
11	0.0619	0.3720
12	0.0620	0.3644
13	0.0602	0.3497
14	0.0579	0.3339
15	0.0557	0.3188
16	0.0533	0.3045
17	0.0509	0.2925
18	0.0489	0.2823

Application Guidelines

The Cambridge Systematics user's manual (Ref 18) provides a detailed step-by-step guide to the procedure for analyzing the incident related impacts. A brief summary of the procedure is presented here:

Step 1: Determine if directional analysis is needed based on factors like geometry, directional traffic volumes and presence of bottlenecks.

Step 2: Identify recurring bottlenecks: Recurring bottlenecks can occur whenever AADT/C values exceed 8.0. It is possible to have many successive segments with AADT/C ratio greater than 8.0, yet designate only one of them as the *controlling bottleneck*, as only one will control traffic flow.

Step 3: Based on AADT/C ratios, define the links to be used in that analysis.

Step 4: Set input parameters using the procedures discussed above. Additional information is available in the user's manual (Ref 17).

Step 5: For each link, calculate travel time without queuing (H_u), and calculate delay due to incidents (H_i) using appropriate equations. Calculate VMT by multiplying the link length with the average annual traffic for the period of analysis.

Step 6: Adjust H_i to account for the accident rate for the facility if the accident rate for the facility is known.

Step 7: For each link, calculate delay due to recurring queues (H_r), using the appropriate equation. Number of Vehicles (V_r) is presented as the average annual traffic for the link for the period of analysis.

Step 8. Calculate baseline Vehicle Hours of Travel (VHT) for the entire corridor.

$$\text{Total VHT} = \sum_{l}\left(\left(H_{u(l)} + H_{i(l)}\right) * VMT\right) + \sum_{b} H_{r(b)} * V_{r(b)}$$

where l refers to individual links and b refers to recurring bottlenecks.

If desired, the user can also track the proportion of VHT due to incidents (VHTi), recurring bottlenecks (VHTr), and uncongested travel (VHTu) by extracting from the terms in the equation above. For any given Link:

VHTu = Hu * VMT

VHTi = Hi * VMT

VHTr = Hr * Vr

The delay incurred by vehicles for unqueued factors can be found by computing VHT under ideal or *desired* speeds for the segment (e.g., VHT at the free flow speed, VHTffs) and subtracting it from VHTu.

Then,

Total vehicle-hours of delay = VHTi + VHTr + (VHTu - VHTffs)

Analyzing the Impact of ITS Strategies

The deployment of many ITS strategies are likely to have an effect on the input variables and hence on the delay estimated using the procedure described above. The Cambridge Systematics user's manual (Ref 18) has provided an indication of the input parameters that are likely to get affected by a number of transportation improvement strategies. The user's manual also contains a number of ITS strategies. An overview of Cambridge Systematics user's manual's assessment of the effect of ITS strategies on the input variables is presented here:

Closed Circuit Television (CCTV) Surveillance. This technology is mainly used for incident verification. The main effect of this strategy will be the reduction of incident duration. It may also reduce secondary accidents due to shorter durations of primary accidents.

Automated Incident Detection. This is likely to result in a decrease in incident duration.

Computer-Aided Dispatch. This is an automated control of incident response strategies. The effect is likely to be the reduction in the total incident duration.

Ramp Metering. Ramp metering generally results in an increase in capacity and a corresponding decrease in delay on the freeway. It may, however, result in additional delay on the adjacent arterials because of spillbacks. Ramp metering may also reduce accident potential.

En Route Traveler Information. Traveler information systems are likely to work in a way similar to demand management strategies, and this will mean a reduction in Average Annual Daily Traffic (AADT).

CHAPTER 4. SKETCH PLANNING TOOLS FOR ITS EVALUATION

Introduction

Immediately Applicable (IA) or sketch-planning methods are simplified procedures that provide an early-stage indication of the impacts of deployment of various ITS strategies. The sketch planning tools may be a set of look-up tables, spreadsheet based models, or stand-alone applications that analyze ITS strategies. Two of the considerations taken in developing these IA methods are ease of application and compatibility with the existing transportation planning methods.

The Florida ITS planning guidelines (Ref 19) list two such sketch planning tools for forecasting the impacts: SCRITS (SCReening for ITS) and IDAS (Intelligent Transportation System Deployment Analysis System). The impact assessment methodology of SCRITS, IDAS, and some other IA methods is discussed in the subsequent sections.

Screening Analysis for ITS (SCRITS)

The user's manual for SCRITS (SCReening analysis for ITS) (Ref 20) describes SCRITS as a "spreadsheet analysis tool for estimating the user benefits of ITS, developed in response to the need for simplified estimates in the early stages of ITS related planning, in the context of either a focused ITS analysis, a corridor/sub-area transportation study, or a regional planning analysis."

The SCRITS user's manual (Ref 20) further describes the guiding principles used in the development of SCRITS:

1. *Compatibility with Existing Tools.* The results of SCRITS analysis should be compatible with the transportation analyses conducted using other types of tools such as travel demand models or simulation applications. This requires the user to provide baseline data form other local sources.
2. *Spatial Adaptability.* The analysis should be adaptable to regional, corridor, facility, and sub-area scales. SCRITS was designed with the flexibility for the

user to specify the geographic/facility coverage, but the analyst must provide the baseline data that is consistent with the areas' facilities being analyzed.

3. *Time Frame for Impact Assessment.* The analyses produce impact assessment on a daily basis. Peak hour and peak period analyses are limited to ramp-metering, which is an ITS strategy that targets peak periods. The estimates are expandable to an annual basis to enable calculations of economic benefits.
4. *Level of Accuracy.* A great deal of uncertainty still surrounds the effects of ITS applications. A number of assumptions therefore become inevitable for any ITS planning or evaluation method, despite its sophistication. SCRITS is no exception, and sensitivity analysis of the outputs to a range of input parameters is strongly recommended in the user manual.

Applications of SCRITS

The SCRITS user's manual (Ref 20) describes SCRITS as a sketch level or screening analysis tool that allows practitioners to obtain an initial indication of the possible benefits of various ITS applications. The SCRITS user's manual further lists the three primary uses of SCRITS:

1. Approximation of user benefits for the evaluation of transportation alternatives in corridor/sub-area studies, regional planning studies, and other types of transportation studies
2. Approximation of user benefits of ITS strategic planning
3. Sensitivity analysis of the benefits of ITS applications to certain input assumptions

The SCRITS user's manual (Ref 20) cautions the analyst against using SCRITS for applications for which it is not suited or ascribing to it more accuracy than it is intended to provide. SCRITS, being in a workbook format, lends itself to modifications such as adding additional features, or updating the look-up tables to make it suitable for analyzing particular ITS applications. SCRITS is self-documenting and allows the user to see the underlying formulas and data requirements. It also makes extensive use of the comment feature of MS-

Excel to illustrate additional details associated with a particular cell. The analyst is required to enter the appropriate information in the column labeled *user input* which is highlighted in red to distinguish it from the column that contains the calculated values.

SCRITS does not analyze the gamut of ITS *user services* but analyzes a set of 16 selected ITS applications. These 16 modules are (Ref 20):

Freeway Control Systems

1. Ramp metering

Traveler Information Systems

1. Freeway detection systems
2. Closed circuit TV
3. Highway advisory radio
4. Variable message signs
5. Pager or FM subcarrier-based ATIS
6. Traffic information kiosks
7. Internet traffic information

Transit Systems

1. Bus AVL system
2. Bus fare collection systems
3. Bus signal priority systems

CVO Systems

1. CVO kiosks
2. Weigh in motion systems

Other Systems

1. Railroad crossing systems
2. Electronic toll collection systems
3. Traffic signal systems

SCRITS Benefits Assessment Methodology

As mentioned earlier, environmental benefits assessment of ITS will generally require quantifying the vehicle activity parameters such as vehicle speeds, Vehicle Miles Traveled (VMT), Vehicle Hours Traveled (VHT). Once these parameters have been quantified, the emissions resulting from these activity parameters have to be estimated.

SCRITS uses a series of look-up tables to perform the analysis of both the activity parameters and the emission estimation. These look-up tables are based on a synthesis of a number of research efforts that were designed to analyze the impacts of various transportation related measures. Tables 4.1, 4.2, 4.3, and 4.4 below are used for environmental benefit assessment.

Table 4.1 Ratio of Non-Recurring VHT To Recurring VHT

Source*:* Adapted from *SCRITS Workbook* (Ref 21)

AADT/C	Presence of Shoulder (0 = no, 1 = yes)	Bottlenecks per Mile 0.67	1.00
1	0	0.0015	0.0015
2	0	0.0057	0.0057
3	0	0.0082	0.0082
4	0	0.0144	0.0144
5	0	0.0336	0.0336
6	0	0.0591	0.0591
7	0	0.1221	0.1222
8	0	0.1905	0.1928
9	0	0.2603	0.2781
10	0	0.309	0.3645
11	0	0.3412	0.4495
12	0	0.3685	0.5471
13	0	0.3743	0.6109
14	0	0.3501	0.6406
15	0	0.3042	0.6353
16	0	0.2668	0.6217
17	0	0.2322	0.5977
18	0	0.2102	0.5793
1	1	0.0008	0.0008
2	1	0.0015	0.0015
3	1	0.0026	0.0026
4	1	0.0036	0.0036
5	1	0.0075	0.0075
6	1	0.0129	0.0129
7	1	0.0243	0.0243
8	1	0.0409	0.0414
9	1	0.0629	0.0684
10	1	0.0701	0.0882
11	1	0.0917	0.1374
12	1	0.1045	0.1946
13	1	0.1101	0.2452
14	1	0.1	0.2688
15	1	0.0817	0.2617
16	1	0.0696	0.2526
17	1	0.0574	0.2303
18	1	0.0549	0.2311

Table 4.2 Speeds Associated with AWDT/C Ratios for Freeways

Source: *Estimating The Effects Of Urban Transportation Alternatives* (Ref 22)

AWDT/C	Speed	AWDT/C	Speed	AWDT/C	Speed	AWDT/C	Speed
1	59.68	5	58.23	9	54.58	13	35.3
1.1	59.65	5.1	58.19	9.1	54.25	13.1	34.80
1.2	59.62	5.2	58.14	9.2	53.91	13.2	34.30
1.3	59.59	5.3	58.10	9.3	53.58	13.3	33.80
1.4	59.56	5.4	58.06	9.4	53.24	13.4	33.30
1.5	59.53	5.5	58.02	9.5	52.91	13.5	32.81
1.6	59.49	5.6	57.97	9.6	52.58	13.6	32.31
1.7	59.46	5.7	57.93	9.7	52.24	13.7	31.81
1.8	59.43	5.8	57.89	9.8	51.91	13.8	31.31
1.9	59.40	5.9	57.84	9.9	51.57	13.9	30.81
2	59.37	6	57.8	10	51.24	14	30.31
2.1	59.34	6.1	57.75	10.1	50.78	14.1	29.88
2.2	59.30	6.2	57.70	10.2	50.32	14.2	29.44
2.3	59.27	6.3	57.64	10.3	49.85	14.3	29.01
2.4	59.23	6.4	57.59	10.4	49.39	14.4	28.57
2.5	59.20	6.5	57.54	10.5	48.93	14.5	28.14
2.6	59.16	6.6	57.49	10.6	48.47	14.6	27.70
2.7	59.13	6.7	57.44	10.7	48.01	14.7	27.27
2.8	59.09	6.8	57.38	10.8	47.54	14.8	26.83
2.9	59.06	6.9	57.33	10.9	47.08	14.9	26.40
3	59.02	7	57.28	11	46.62	15	25.95
3.1	58.98	7.1	57.20	11.1	46.07	15.1	25.63
3.2	58.94	7.2	57.11	11.2	45.52	15.2	25.30
3.3	58.91	7.3	57.03	11.3	44.97	15.3	24.98
3.4	58.87	7.4	56.94	11.4	44.42	15.4	24.65
3.5	58.83	7.5	56.86	11.5	43.87	15.5	24.33
3.6	58.79	7.6	56.77	11.6	43.31	15.6	24.01
3.7	58.75	7.7	56.69	11.7	42.76	15.7	23.68
3.8	58.72	7.8	56.60	11.8	42.21	15.8	23.36
3.9	58.68	7.9	56.52	11.9	41.66	15.9	23.03
4	58.64	8	56.43	12	41.11	16	22.71
4.1	58.60	8.1	56.25	12.1	40.53	17	19
4.2	58.56	8.2	56.06	12.2	39.95		
4.3	58.52	8.3	55.88	12.3	39.37		
4.4	58.48	8.4	55.69	12.4	38.79		
4.5	58.44	8.5	55.51	12.5	38.21		
4.6	58.39	8.6	55.32	12.6	37.62		
4.7	58.35	8.7	55.14	12.7	37.04		
3.8	58.31	8.8	54.95	12.8	36.46		
4.9	58.27	8.9	54.77	12.9	35.88		

Table 4.3 Speeds Associated with AWDT/C Ratios for Arterials

Source: *Estimating the Effects of Urban Transportation Alternatives* (Ref 22)

AWDT/C	Speed	AWDT/C	Speed	AWDT/C	Speed	AWDT/C	Speed
1	27.70	5	21.21	9	17.18	13	11.79
1.1	27.49	5.1	21.09	9.1	17.10	13.1	11.72
1.2	27.28	5.2	20.97	9.2	17.02	13.2	11.65
1.3	27.07	5.3	20.85	9.3	16.94	13.3	11.58
1.4	26.86	5.4	20.73	9.4	16.86	13.4	11.51
1.5	26.65	5.5	20.61	9.5	16.78	13.5	11.44
1.6	26.44	5.6	20.49	9.6	16.70	13.6	11.37
1.7	26.23	5.7	20.37	9.7	16.62	13.7	11.30
1.8	26.02	5.8	20.25	9.8	16.54	13.8	11.23
1.9	25.81	5.9	20.13	9.9	16.46	13.9	11.16
2	25.62	6	20.04	10	16.41	14	11.07
2.1	25.46	6.1	19.93	10.1	16.27	14.1	10.97
2.2	25.30	6.2	19.82	10.2	16.13	14.2	10.87
2.3	25.14	6.3	19.71	10.3	15.99	14.3	10.77
2.4	24.98	6.4	19.60	10.4	15.85	14.4	10.67
2.5	24.82	6.5	19.49	10.5	15.71	14.5	10.57
2.6	24.66	6.6	19.38	10.6	15.57	14.6	10.47
2.7	24.50	6.7	19.27	10.7	15.43	14.7	10.37
2.8	24.34	6.8	19.16	10.8	15.29	14.8	10.27
2.9	24.18	6.9	19.05	10.9	15.15	14.9	10.17
3	24.03	7	18.99	11	15.00	15	10.03
3.1	23.88	7.1	18.90	11.1	14.80	15.1	9.92
3.2	23.73	7.2	18.80	11.2	14.60	15.2	9.81
3.3	23.58	7.3	18.71	11.3	14.40	15.3	9.70
3.4	23.43	7.4	18.61	11.4	14.20	15.4	9.59
3.5	23.28	7.5	18.52	11.5	14.00	15.5	9.48
3.6	23.13	7.6	18.42	11.6	13.80	15.6	9.37
3.7	22.98	7.7	18.33	11.7	13.60	15.7	9.26
3.8	22.83	7.8	18.23	11.8	13.40	15.8	9.15
3.9	22.68	7.9	18.14	11.9	13.20	15.9	9.04
4	22.53	8	18.04	12	13.02	16	8.95
4.1	22.40	8.1	17.95	12.1	12.90		
4.2	22.27	8.2	17.86	12.2	12.78		
4.3	22.14	8.3	17.77	12.3	12.66		
4.4	22.01	8.4	17.68	12.4	12.54		
4.5	21.88	8.5	17.59	12.5	12.42		
4.6	21.75	8.6	17.50	12.6	12.30		
4.7	21.62	8.7	17.41	12.7	12.18		
4.8	21.49	8.8	17.32	12.8	12.06		
4.9	21.36	8.9	17.23	12.9	11.94		

Table 4.4 Emission Factors Associated with the Speeds

Source: *Estimating the Effects of Urban Transportation Alternatives* (Ref 22)

Speed (mph)	CO (gms/mile)	NO_x (gms/mile)	HC (gms/mile)
5	66.71	2.00	8.04
10	35.55	1.78	4.30
15	25.30	1.71	3.15
20	20.25	1.68	2.51
25	16.86	1.73	2.14
30	14.55	1.77	1.89
35	12.89	1.80	1.71
40	11.67	1.82	1.56
45	10.78	1.84	1.44
50	10.36	2.00	1.38
55	10.36	2.37	1.36
60	18.93	2.74	1.60
65	27.51	3.11	1.84

SCRITS estimates energy and environment benefits for only three ITS strategies: Closed Circuit Television (CCTV), freeway traffic detection, and information and traffic signal systems.

Closed Circuit Television (CCTV). The installation of CCTV results in the capability to visually observe the incident scene and the surrounding areas. This will enable the responsible agencies to respond rapidly and in an efficient manner. The main benefit of this is a likely reduction in incident duration. SCRITS analyzes the environmental benefits of using the following procedure:

The relevant parameters that the user is required to enter are:

1. Number of cameras installed
2. Percentage of CCTV coverage before improvement
3. Percentage of CCTV coverage after improvement
4. Estimated reduction in incident duration
5. Savings, in VMT, per weekday

Along with these parameters, the user also has to enter in the baseline worksheet the baseline VMT for freeways, recurring VHT for freeways, and weekdays per year. The user has the option of entering the ratio of nonrecurring VHT to recurring VHT. If the user fails to enter the ratio of nonrecurring CHT to recurring VHT, than SCRITS calculates from the look-up Table 4.1 based on the AWDT/C ratio.

To obtain the percentage of reduction in average incident duration, the change in the percentage coverage after improvement is multiplied by the reduction in incident duration. The incident related VHT is assumed to vary linearly with the incident duration, and so the percentage of savings in incident related VHT is presumed to be the percentage of change in incident duration. This gives the savings of incident related VHT after improvement. The freeway VMT after improvement can be calculated from the baseline VMT and the savings in freeway VMT. During the course of the analyses, the daily values are converted to yearly values.

The average weekday speeds before improvement are calculated by dividing the weekday freeway VMT by the sum of recurring and nonrecurring VHT. The average weekday speeds after improvement is calculated in a similar manner by calculating the values of the parameters after the improvement.

The emission factors for CO, NO_x, and HC in gms/mile as a function of average speed is taken from the look-up Table 4.4. The speeds in the look-up tables are in increments of 5 mph so linear interpolation may be required to get the emission factors. These emissions before and after improvement are found by multiplying these emission factors by the corresponding Vehicle Miles Traveled (VMT's), and the differences in these emissions are taken to be the benefits of Closed Circuit Television (CCTV). All the above calculations, including getting the required values from the look-up tables, are performed automatically within the SCRITS worksheets.

Freeway Traffic Detection and Information. This ITS strategy involves strategically placing detection devices such as inductive loops to detect unusual traffic flow circumstances and instances to better respond to such occurrences. The user designates the estimated reduction in average incident duration as well as the percentage of freeway being covered by the detection devices, thus resulting in a reduction in incident duration. In this respect, the analysis of the environmental benefits of this strategy is similar to those of CCTV.

Traffic Signalization Strategies. These strategies cover a broad range of improvements like using multiple time of the day timing plans and fully actuated traffic signals. In analyzing the environmental benefits of this strategy, SCRITS assumes that deploying this strategy will lead to an increase in the average system speed. The user supplies the estimate of the percentage increase in speed from which the average speed after the improvement is calculated. The emissions factors for before and after improvement are taken from the look-up tables. These emissions factors are derived by multiplying current factors by the corresponding yearly values for before and after scenarios, thus resulting in an estimate of emissions of the pollutants for before and after improvement situation. The difference in these estimates are the benefits of the ITS deployment.

Limitations of SCRITS

SCRITS is a very useful sketch-planning tool. It is simple to use and freely available which makes it even more attractive for preliminary benefit estimation of a variety of common ITS strategies. SCRITS, however, has some limitations (Ref 20):

1. Due to the nature of the procedures used in SCRITS, the benefits estimates produced by SCRITS are approximate and do not have a high level of accuracy.
2. SCRITS calculates environmental benefits for very few ITS applications.
3. A significant amount of judgment is required on the part of the user when entering the input values. These input values can have a significant impact on the benefits estimates.
4. SCRITS does not give benefits estimates for combinations of ITS strategies. While the benefits from some ITS strategies may be mutually exclusive and can be individually calculated, in many cases the benefits overlap. SCRITS has no way of calculating these overlapping benefits, and user's judgment is required in such circumstances.

ITS Deployment Analysis Systems (IDAS)

Introduction

IDAS is another sketch planning tool that is widely used to analyze the impacts of a very broad range of ITS strategies. Though it is a sketch-planning tool, it performs more comprehensive analyses of the impacts, cost, and benefits of ITS strategies than SCRITS.

It is a tool that is based on the framework of the traditional four-step models: trip generation, trip distribution, mode choice, and traffic assignment. IDAS operates as a *post processor* to the travel demand models and incorporates the modal split and traffic assignment output associated with the traditional planning model. IDAS focuses on the effects of the ITS deployment projects (Ref 19). These include:

1. Frequency and magnitude of recurring and non recurring congestion
2. Travel time and throughput on all links and nodes in the analysis area
3. Public safety
4. Energy and environment
5. Agency efficiency and system reliability

IDAS provides users with three resources when conducting ITS analyses (Ref 23):

Default ITS Impact Settings. The default settings are based on the reviews of observed impacts that are available in the ITS library. These default settings may need to be modified to reflect the local transportation and traveler characteristics.

Equipment Database. The equipment database is a comprehensive inventory of ITS equipment and costs associated with various ITS improvements. The database can be modified depending on the situation.

ITS Library. The ITS library catalogs the documented impacts of many ITS technologies applied at different places around the world. It provides the user with information concerning the previous application of a specific ITS technology.

The Structure of IDAS.

IDAS is comprised of five modules that allow the user to perform a comprehensive analysis of the impacts of various ITS options. These five modules are described below (Refs 2, 23).

Input/Output Interface. This is the interface used by IDAS to convert the data files that are provided by the regional planning models to a format that can be used internally. The data includes the characteristics of the network in terms of the nodes, links and flows. This data establishes the baseline scenario.

Alternatives Generator. This module allows the user to code the ITS deployment options in the network using a Graphical User Interface (GUI). The 12 major components that can be coded into IDAS are:

1. Arterial traffic management systems
2. Freeway traffic management systems
3. Advance public transportation systems
4. Incident management systems
5. Electronic payment collection systems
6. Railroad grade crossings
7. Emergency management systems
8. Regional multi-modal traveler information systems
9. Commercial vehicle operations
10. Advanced vehicle control and safety systems
11. Supporting deployments
12. Generic deployments

Benefits Module. The benefits module of IDAS has four submodules: travel time/throughput, environment, safety, and travel time reliability. This module quantifies the benefits from ITS deployment. The default values are based on national averages of ITS deployments and/or research studies.

Cost Module. The cost module allows the user to define the incremental costs of the various ITS deployments being studied, including capital costs and operating and maintenance costs.

Alternatives Comparison Module. The alternatives comparison model provides the user with the costs and benefits information for different ITS deployment options.

The general structure of IDAS module is shown in Figure 4.1.

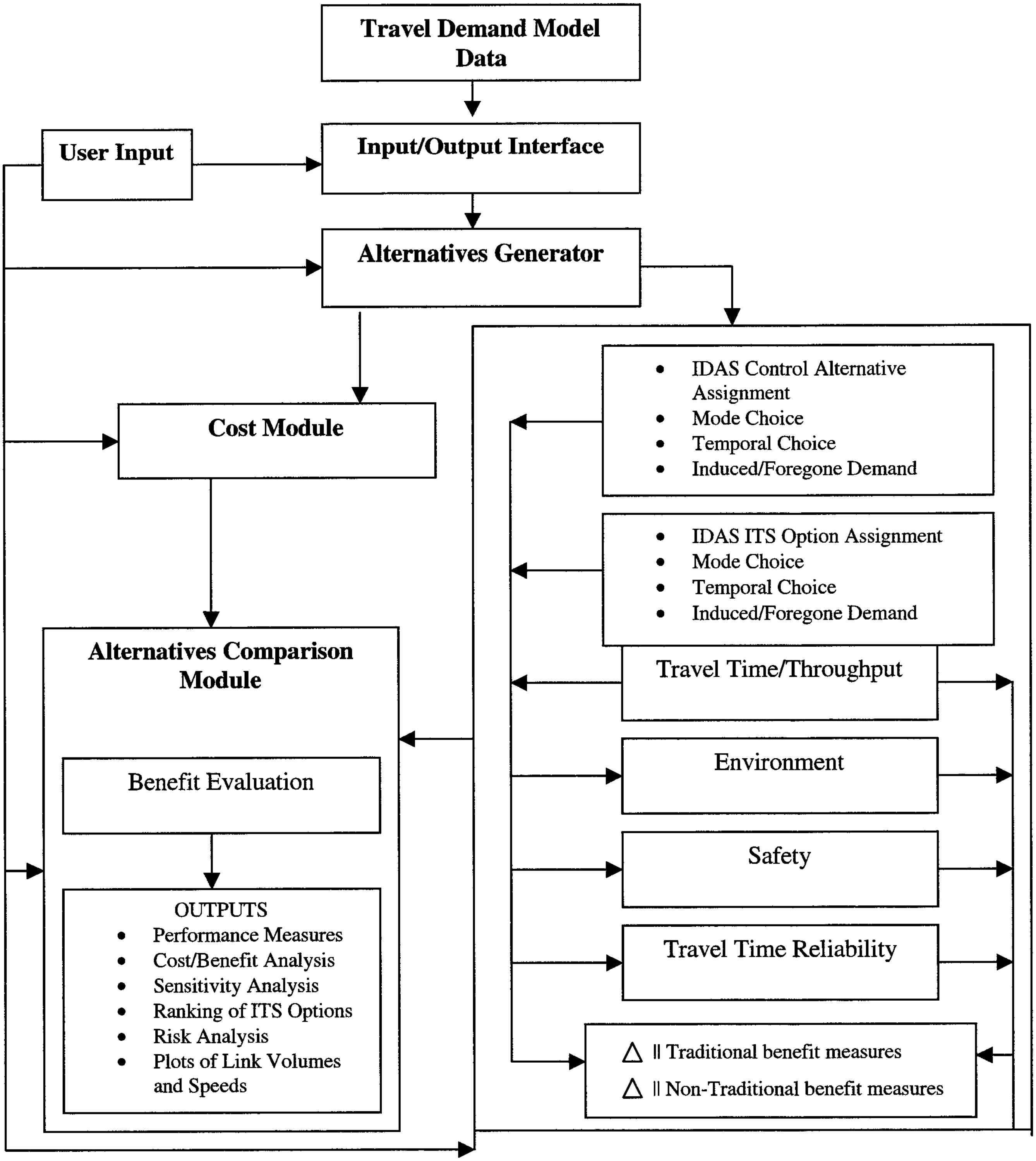

Figure 4.1 IDAS Model Structure

Source: *Estimating Potential ITS benefits and Costs Using IDAS* (Ref 23)

IDAS Environment Submodule

The environment submodule estimates the environmental performance measures by using a series of detailed look-up tables that consider emissions rates by specific network volume and traffic operating characteristics (Ref 24). The values in the look-up tables are incorporated from sources such as Mobile 5 and California Air Resources Board's EMFAC (EMission FACtor). The IDAS graphical user interface (GUI) permits the user to update the emission rates in these look-up tables.

IDAS default Mobile 5a rates are based on the Chicago region rates (CATS) and are formatted by speed range, pollutant type, and eight vehicle type categories. For metropolitan areas in California, EMFAC-based emission rates look-up tables by pollutant type, vehicle type, speed range, and temperature range by year are used (Ref 24).

The vehicle activity parameters, like Vehicle Miles Traveled (VMT), that are required by the environment submodule come from the travel time/throughput submodule. The environment submodule also uses outputs from the final trip assignment and the benefits module to reference the look-up tables and to produce emissions estimated for each link. The link emissions estimates are then aggregated to get the total emissions.

The environment submodule uses the output from the final assignment and the benefits module for both the control alternative as well as the ITS option. The environmental impacts of both scenarios are than estimated by the environment submodule. The values for the control alternative are subtracted from the ITS option to determine the direction and magnitude of the environmental impacts of the ITS improvements (Ref 24).

The inputs (both user inputs as well as those from other IDAS modules) and the outputs are summarized below (Ref 24).

Table 4.5 IDAS Environment Submodule Inputs and Outputs

Source: *IDAS-User's Manual* (Ref 24)

User Inputs of Defaults

Mobile 5a emission rates by:

- Pollutant type
- Speed range
- Vehicle type distribution

California EMFAC emissions rate by:

- Pollutant type
- Speed range
- Analysis year
- Vehicle type distribution
- Temperature range

Fuel consumption rates by:

- Facility type
- Speed range
- Vehicle type
- Gas/diesel

Other:

- Emission cost ($) by pollutant
- Energy cost ($) by fuel type
- Fuel type (%) by market sector

Inputs from Travel Time/Throughput Module

Trips/VMT by:

- Facility type /link
- Vehicle type/mode
- Speed range
- Time of day

Outputs to Alternative Comparison Module and Cost Module

Emissions (kg) by:

- Pollutant type
- Vehicle type/mode
- Facility type/link

Emission costs ($) by:

- Pollutant type
- Vehicle type/mode
- Facility type/link

Energy consumption (gallons/liters) by:	*Energy costs ($) by:*
• Fuel type • Vehicle type/mode • Facility type/link	• Fuel type • Vehicle type/mode • Facility type/link

Limitations of IDAS

IDAS is a fairly comprehensive sketch-planning tool. It also performs modal split and traffic assignment, which may prove to be more accurate than SCRITS. However IDAS suffers a number of limitations (Ref 25):

1. Considerable time and resource investment is required to learn and master the skills needed to use IDAS effectively.
2. Familiarity with travel demand modeling is helpful in setting up the model.
3. The run time for IDAS can range from a few minutes to a few hours, depending on the network characteristics and other factors.

CHAPTER 5. CONCLUSIONS

This report provides an overview of the various evaluation frameworks and methodologies that have been used to assess the environmental impacts of Intelligent Transportation Systems (ITS). The report has a particular focus on two of the most widely used sketch planning or immediately applicable methods. The report discusses in detail the structure of these methods as well the methodologies employed by these methods for analyzing environmental impacts of ITS. The following observations can be made about the state of these methodologies:

1. Most methodologies for assessing environmental impacts of ITS involve two major steps: estimating the emissions producing activity and translating these activities into emissions.
2. Many approaches with varying degrees of complexity and sophistication have been used to perform each of these steps based on the purpose of evaluation.
3. The most widely used assessment methodology is a combination of travel demand models or micro simulation models with emission factor models such as the MOBILE series and EMFAC.
4. These models can however be applied at varying levels of spatial and temporal aggregation to achieve a desired representation of various transportation improvement strategies. These levels range from using a static assignment model combined with the emission factor model to using a dynamic assignment model with a modal emissions model.
5. The operational and information-oriented nature of ITS technologies makes it very difficult to develop Immediately Applicable (IA) methods that would be based on average values for various performance measures.
6. Very little work has been done in developing IA methods. Most current work is either based on the database of reported benefits of ITS deployment or on look-up tables developed using various simulation tools.
7. The IA methods, though useful for obtaining an early indication of the magnitude and ITS benefits and for comparative analysis of different ITS options, are not very

suitable as a detailed and comprehensive analysis, because of the assumptions and the uncertainties relating to the exact impact of many ITS strategies.

8. A considerable amount of judgment is required on the part of the analyst when preparing the inputs for these IA methods. The inputs should reasonably capture the ITS improvements that are being analyzed.
9. Sensitivity analysis with regard to the input parameters is recommended when using IA methods to test the assumptions made in the analysis.
10. Induced demand is an important consideration when evaluating long-term impacts of ITS technologies and should be incorporated into the evaluation framework.

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