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ABSTRACT:

Meta-evaluation is a process to be used for the comparison of results across Intelligent Transportation Systems (ITS). Operational tests, a component of the ITS program administered by the Federal Highway Administration (FHWA), are expected to be the richest source of information and data. Supporting information or data from other ITS initiatives may be used as well. This document describes the steps in the meta-evaluation process. Also included, as an appendix, is an extensive list of Measures of Effectiveness (MOEs) that can be used in the meta-evaluation process. The MOEs are presented in a hierarchy format to reflect the goals, objectives, and activity areas of the ITS Program.

Keywords: Intelligent Transportation Systems, ITS, Measures of Effectiveness, MOEs, meta-evaluation

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SECTION 1

INTRODUCTION

1.1 BACKGROUND

The Intelligent Transportation Systems (ITS) program administered by the Federal Highway Administration (FHWA) of the U.S. Department of Transportation (DOT) has been established to use advanced technology to improve the efficiency of the nation's surface transportation resources. Operational tests are a major element of the ITS program. An operational test integrates existing technology, research and development (R&D) products, institutional, and perhaps regulatory arrangements to test one, and usually more, new technological, institutional, or financial elements in a real world test. The tests permit an evaluation of the functionality of newly developed ITS technologies under real world operating conditions, as well as an assessment of the benefits and public support for the product or system.

Evaluations of these operational tests will produce documented evaluation results specific to the individual operational tests. The need exists to integrate these individual results into a consistent body of knowledge that can be used by decision makers in determining the course of the ITS program. The term meta-evaluation has been chosen to describe this process.

Although the operational tests are expected to be the richest source of information and data, supporting information or data may be available from other ITS initiatives. Data from all relevant sources will be used during the meta-evaluation.

1.2 PURPOSE

The purpose of this document is to define the meta-evaluation process and to present an initial list of Measures of Effectiveness (MOEs). MOEs can provide an effective link among the evaluation results from the individual operational tests. This document addresses the development of a list of MOEs as a first step in the meta-evaluation process.

1.3 SCOPE

This document is not intended to contain results from the meta-evaluation or address results from particular operational tests. Rather, it is intended to describe the process by which meta-evaluation findings can be developed.

The MOEs provide guidance to operational test evaluators; they are not a list of required MOEs that every test must use.

1.4 ORGANIZATION

This document is divided into three sections. Following this Introduction, Section 2 describes the Meta-Evaluation Methodology. The third section discusses MOEs. Appendix A contains suggested MOEs and Appendix B contains suggested Measures of Performance (MOPs).

SECTION 2

META-EVALUATION METHODOLOGY

2.1 META-EVALUATION AS AN ON-GOING PROCESS

The ITS operational test program is expected to continue for the foreseeable future. Operational tests in which FHWA participates are required to include evaluations, so evaluation results will continue to become available. A meta-evaluation is needed to compare, and possibly combine, evaluation results across operational tests. Reflecting the incremental availability of the evaluation results, the meta-evaluation will be an on-going process throughout the life of the operational test program.

2.2 META-EVALUATION CONTRASTED WITH META-ANALYSIS

One possible model for comparing evaluation results is meta-analysis. Since meta-analysis is an established process with which the reader may be familiar, its relation to the meta-evaluation process is discussed briefly below. However, meta-analysis proves to be too restrictive to be more than one component of meta-evaluation.

Meta-Analysis is "the systematic collation and analysis of a series of impact assessments of a program or related group of programs in order to provide a firm and generalizable estimate of net effects." [1]

> "For example, by the early 1980s there were several hundred studies of the effectiveness of psychotherapy in helping clients function more effectively. These studies differed widely in procedure, subject matter, and results. . . . In order to make sense out of this body of evidence, a group of researchers decided to treat each of the evaluations as a case. . . . Each of the 475 evaluation studies was coded according to a number of dimensions, including the size of sample used, the types of controls employed, the variety of psychotherapy being tested, and the duration of the treatment, and so on through a long list of ways in which studies of this sort could vary from one another, all of which were also relevant indicators of how well the evaluations in question were undertaken. Using the studies estimates of net effects as the dependent variable and the quality indicators as the independent variables, the researchers used . . . statistical models to obtain a best

1 Rossi, Peter H., and Freeman, H. E., *Evaluation, A Systematic Approach* , Sage Publication, 1989, page 226.

estimate of the ways in which the evaluations differed and of the true net effect of psychotherapy.'[2]

The need for results from a large number of tests with similar objectives limits the applicability of meta-analysis within the operational test program. Only a limited number of operational tests will be funded. The application of a me&analysis approach to the results from a limited number of studies would not yield statistically significant, interesting findings. This is especially true when the diversity of operational tests is taken into account.

2.3 CHALLENGES TO A SUCCESSFUL META-EVALUATION

The real-world setting of the operational tests poses the following challenges to a successful comparison of results:

- An evaluation sufficient for an isolated operational test may not be sufficient to allow a comparison with other operational tests. Similarly, earlier operational tests may not collect, or be capable of collecting, all the data that later tests may collect (due to enhanced capabilities of the systems involved).

- Not all aspects of each operational test will be evaluated, and among those aspects that are evaluated, differences in system design may not allow a direct statistical comparison of results. Evaluation resources are limited; their application is based on the best information available at the time, which may not predict future data needs.

- Factors beyond the control of the project may result in evaluations that contain valuable information that is not “valid” or “significant” in a statistical sense. For example, disruptions to a traffic network resulting from natural events could compromise the data collection effort.

- The delay between the time the results of an operational test evaluation become apparent to those participating in the operational test, and the time the results are documented could adversely affect the timeliness of inputs to the comparison of results.

- Project delays may limit the evaluation period.

- Significant advances in technology may (and hopefully, will) occur as a result of the operational test, making some results obsolete.

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2 Rossi, Peter H., and Freeman, H. E., *Evaluation, A Systematic Approach* , Sage Publication, 1989, page 263-264.

Including the long list of complicating factors is not intended to portray meta-evaluation as an impossible task. Quite the opposite, a well-executed meta-evaluation is the only way to produce objective findings from multiple operational tests. The reason for including the list is to show that a simple, mechanically applied process to the comparison of results across operational tests is not likely to be successful.

2.4 META-EVALUATION SHOULD USE ALL AVAILABLE SOURCES OF INFORMATION

Success in performing an ITS meta-evaluation depends on including all relevant sources of information, not just the results of the operational tests. It also depends on focusing the meta-evaluation to obtain objective answers to specific *questions* arising from, and relevant to, the ITS program. Limiting the meta-evaluation to an analysis of only published reports from operational tests unnecessarily restricts information sources. For example, the ITS Program Plan as well as the results of the Architecture Study are valuable sources of information that may support or challenge the results of the operational tests. Deployment experiences, results of research and development programs, and expert judgment are other valuable sources that should be included in the meta-evaluation process.

2.5 META-EVALUATION SHOULD BE DIRECTED TO ANSWER SPECIFIC QUESTIONS

The success of any evaluation is measured in the quality of answers to specific questions. A meta-evaluation must be similarly directed at answering specific questions. The results of individual operational test evaluations will be multiple and complex. They will not yield “yes” or “no” answers; rather, the results will indicate a range of effective performance specific to (often narrowly) bounded situations. From the accumulated results of operational test evaluations and program planning efforts, questions will become evident. Answers to these questions can best be found by reviewing evaluation documentation, augmenting that documentation with information from other sources, and applying analysis tools and techniques to resolve apparent discrepancies and, as far as possible, generalize the findings. This is the role of the meta-evaluation in the ITS program.

2.4 META-EVALUATION COMPONENTS

In this section, the components of the meta-evaluation are described. First, the sources of information are listed, then the potential uses for the findings of the meta-evaluation are discussed, and finally, the analysis process used to create the findings from the information sources are discussed. Although this order of presentation is not a chronological sequence, discussing the uses of the findings prior to the analysis process will allow the reader to understand why specific tasks in the process have been included. Figure 2-1 shows the components in schematic form.

2.6.1 Meta-Evaluation Sources of Information

Sources of information, or inputs, that will be used during the meta-evaluation include:

- ITS Program Plan
- Architecture Study
- Operational test reports
- First hand experience, or expert judgment
- Research and Development (R&D) results
- Institutional Issues Studies

Each of these is discussed below.

The ITS Program Plan contains matrices mapping ITS User Services to ITS Goals and Objectives. The matrices will be used to structure a list of Measures of Effectiveness, addressed in Section 3 of this document. The Program Plan is expected to be a living document, reflecting the direction of the national ITS program. As such, it is an obvious source of direction for the meta-evaluation.

The ITS Architecture Study is an approach to employ the diverse talents and resources of the varied, vitally interested ITS constituencies in the development of an ITS architecture. Such a collaborative strategy will enhance the probability of the full consideration of the public interest and the development of a broadly based consensus. The method selected for accomplishing this task involved the selection of multiple consortia to concurrently develop competing candidate architectures that will be synthesized into a single national architecture. Prospective architectures will be subjected to continuous refinement, adjustment and redefinition to accommodate the views and concerns of varied interest groups. Developments *in* the *ITS Architecture Study* should be inputs to the meta-evaluation process in both the structuring of questions, as well as providing theoretical support (for example, cost studies) as part of the analysis to answer the questions.

The Operational Test Program includes requirements for the evaluation of each operational test and the reporting of the results of the evaluation. A significant aspect of the meta-evaluation will be to compare and contrast the reports produced by the operational tests. The focus will be the evaluation reports, but other operational test reports (for example, system descriptions and "lessons learned" documents) will also be used. As mentioned in section 2.3, comparing the results from the individual operational tests will not be simple or straightforward.

R&D *results* will provide information on specific technology components and integrated systems that provide ITS user services. The DOT is expected to devote significant resources

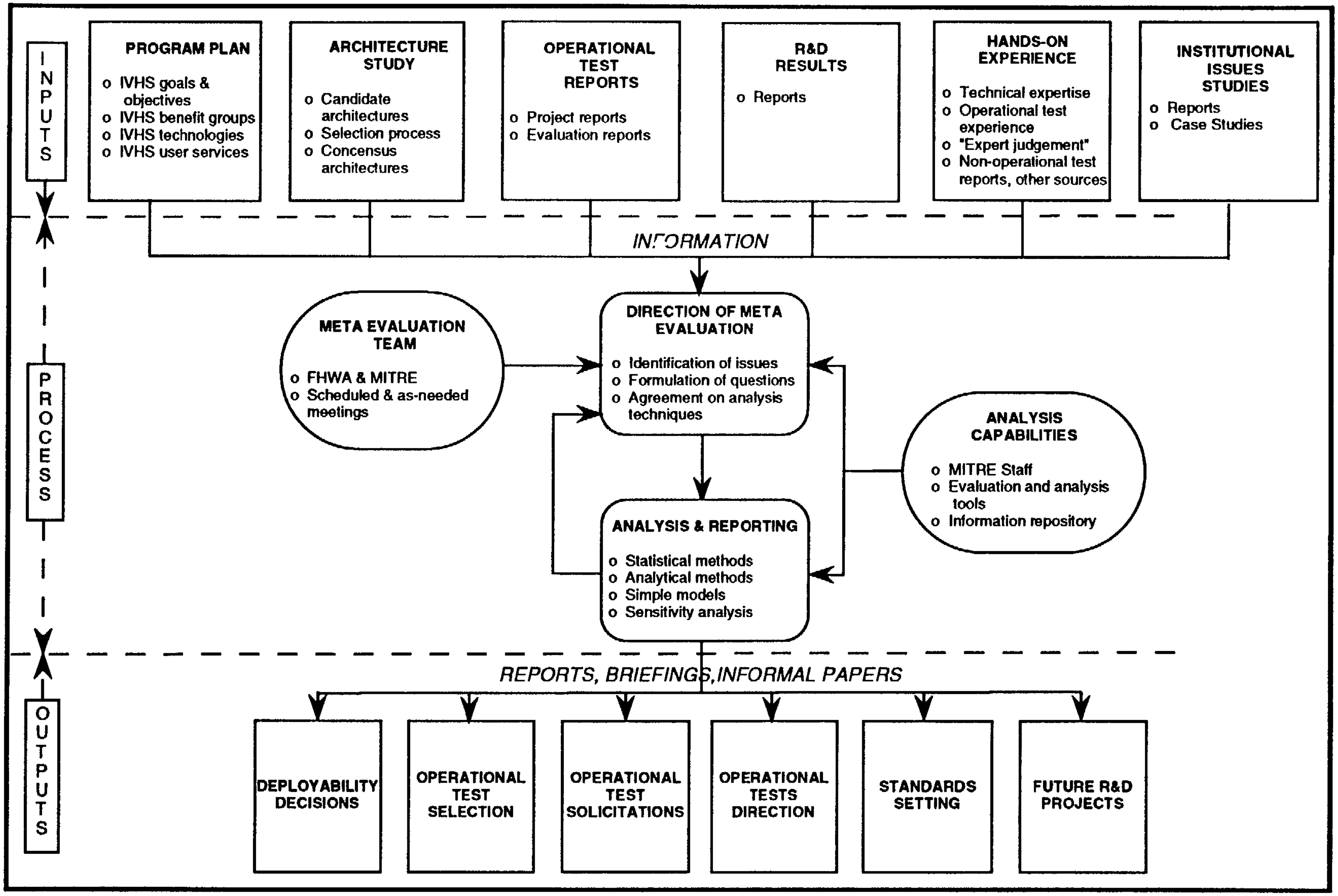

FIGURE 2-1. COMPONENTS OF THE META-EVALUATION PROCESS

to R&D activities in support of the ITS Program, to explore issues critical to ITS implementation and to provide needed insight into new technologies and applications that can be used for emerging and future ITS applications.

First-hand experience, or expert judgment is based on theoretical understanding of the specific technologies, along with practical experience and knowledge of the current state of development of ITS applications. Such expertise will rely heavily on first-hand experience within and knowledge of the operational tests. This experience is particularly important because of the delay between the performance of evaluation tests and the release of the documentation describing the results. The staff performing the meta-evaluation should have access to the day to day workings of the operational tests (but, obviously, without a vested interest in the operational tests). Understanding the context of the evaluation reports will be needed to perform an effective meta-evaluation. Such understanding can only be provided in real-time by well informed "experts" with first-hand experience.

Institutional Issues Studies represent an attempt by FHWA to provide information on a number of topics, including the definition of institutional and legal impediments, when during the life cycle the impediments occurred, how the impediments were overcome, and what were the lessons learned. This information directly impacts the technical success of operational test equipment and systems and must be considered in the comparison of results across operational tests.

This list of sources represents the primary sources, but should not be read as restricting the sources of relevant information. The list of sources will increase over the meta-evaluation period. Further, the meta-evaluation process may promote the development of other sources of information. For example, just as evaluation has been emphasized in the funding of operational tests, contractual agreements to provide for evaluation of deployment projects could be included. As with the operational tests, the ability of FHWA to perform additional evaluations of deployment projects should be included in any contracts.

2.6.2 Uses of Meta-Evaluation Outputs and Findings

The findings of the meta-evaluation and uses of those findings are bound together; it makes no sense to produce findings that will not be used. The parameters to be characterized by the meta-evaluation will drive the choice of analysis techniques. The findings of the meta-evaluation can be used to provide:

- Guidance for the deployability decisions of ITS technologies
- Guidance for the development of future ITS operational test solicitations
- Guidance for future R&D projects
- Guidance for the operational test selection process
- The basis for direction of on-going operational tests or R&D projects
- Support for the selection of ITS standards

Outputs of the meta-evaluation will be documented at an appropriate level. Documentation of the findings of the meta-evaluation will take the form of reports, briefings, and informal papers. Timeliness of the documentation must be sensitive to the reporting process from the individual operational tests; for example, findings should not be included in public documents before the distribution of results by the operational test.

2.6.3 Meta-Evaluation Process

The meta-evaluation process comprises the steps described in the following sections.

2.6.3.1 Define MOEs

For each ITS Program Goal a set of suggested MOEs will be established. Because of the dynamic nature of the operational test program, as well as the evolutionary aspect of the technology, the set of MOEs can also be expected to evolve. Since relatively few operational tests have reached the point of reporting evaluation results, the initial list of MOEs will represent a largely theoretical list, that will he refined as additional results are obtained.

Section 3 of this document addresses the list of MOEs, and a proposed list of MOEs is included in Appendix A.

2.6.3.2 Establish a Meta-Evaluation Team

The first step is to establish a Meta-Evaluation Team (MET), composed of FHWA and MITRE staff. A core group responsible for on-going meta-evaluation tasks should be selected, with the understanding that other staff from both organizations will be expected to participate in their areas of expertise. MITRE staff would be expected to:

- Chair the MET
- Participate in selected operational tests
- Suggest areas of focus for analysis
- Perform analysis as needed
- Prepare materials for solicitation preparation and selection
- Report findings
- Brief FHWA staff on findings

FHWA staff would be expected to:

- Participate in MET meetings
- Direct and approve the focus of analysis
- Ensure timely transfer of field reports to MITRE staff
- Review, accept, and use materials created by the MET

2.6.3.3 Establish an Evaluation Information Library

MITRE will establish an information library through the collection and review of evaluation reports from the operational tests. This is an internal function needed to support meta-evaluation. (It is not duplicative and should not be confused with the ITS AMERICA information data base, or the data repository that MITRE has recommended the FHWA establish.) This information library will also contain other relevant published reports and articles, and will include informal operational test documents, as available. MITRE currently has access to most pertinent documentation, but a formal structure is needed to ensure a comprehensive collection. Procedures will be established to identify documents expected from the operational tests, provide for their transfer to MITRE, and enter them into a data base, or library. The purpose is not to limit the documentation that can be included, but to ensure that those participating in the meta-evaluation are aware of all relevant documentation available.

2.6.3.4 Participation in Operational Tests

MITRE will designate individuals to participate in key operational tests. The role will include maintaining an understanding of the progress made by the operational tests and the impact of that project on the national evaluation effort. Activities will include participation in design reviews, evaluation planning and review of intermediate results, and review of project documentation as it is developed. The purpose of this participation is to provide the meta-evaluation team with current information that may impact the meta-evaluation team's focus or findings.

2.6.3.5 Establish Evaluation and Analysis Infrastructure

Although appropriate analysis techniques and tools for any given question cannot be identified in advance, certain techniques will be applicable to a wide range of analysis. For example, the use of statistical techniques such as regression analysis, risk assessment, and modeling and simulation will be used. These tools can be thought of as an infrastructure to support the meta-evaluation. Early in the on-going process, widely applicable tools, such as desktop based spreadsheets and databases will be used. As experience is gained and certain meta-evaluation tasks are seen to be repetitive in nature, additional infrastructure in the form of specialized application software may be needed. Since the meta-evaluation will be focusing on the big-picture, integration of these tools will be critical.

MITRE has begun defining appropriate analysis techniques. MITRE is preparing a document entitled *A Data Fusion Framework for Meta-Evaluation of ITS Effectiveness.* This document deals with specific methods to merge data from different operational tests and other data sources.

2.6.3.6 Define the Meta-Evaluation Schedule

Although scheduled MET meetings are expected, much of the meta-evaluation work will be driven by the need for outputs and findings. Scheduling the timing of the outputs necessarily reflects the time they are needed. Three examples are provided below.

- Guidance for the development of future ITS solicitations.
  - Three(?) months prior to a solicitation, the MET meets.
  - The MET establishes priority areas, e.g., Travel Demand Management (TDM)
  - MET staff (MITRE) reviews existing information on TDM and suggests areas for further analysis.
  - The MET directs the MET staff (MITRE) to perform further analysis.
  - Findings are presented to the MET in time to influence the language in the solicitation.

- Guidance for use in operational test selection process.
  - During the test selection process, questions concerning the need for further test and evaluation of specific technologies arise.
  - The MET establishes priorities, and the process continues as described in the preceding bullet.

- The basis for direction of evaluations of on-going operational tests
  - During the on-going evaluation of an operational test, the results of the evaluation of other operational tests or the results of the Architecture Study become available.
  - MET staff (MITRE) reviews the available evaluation results to determine validity and generalized applicability of the results.
  - MET staff (MITRE) reviews the available results to determine correspondence between the availahle results and on-going operational test evaluation.
  - The MET meets, is briefed on the findings, and makes suggestions for additional analysis.
  - The MET directs the MET staff (MITRE) to perform further analysis
  - MET staff (MITRE) performs additional analysis outside the scope of any individual operational test (possibly statistical combinations of the data from multiple tests or additional statistical tests).
  - MET staff (MITRE) finds the results to be valid, but contradictory (or valid, but only narrowly focused; or, likely to yield additional useful information with the addition of findings in a related area, for example)

- MET staff (MITRE) reports findings to the MET.
- The MET uses the findings to influence evaluations of the on-going operational test.

2.6.3.7 Analysis Techniques

Meta-evaluation implicitly assumes that analysis of existing information and data will be used to provide additional information and insights into the ITS program. Such analysis will focus on:

- Determining the validity of results from operational tests
- Determining the general applicability of results
- Determining those areas that need more testing and those that don't
- Resolving apparent conflicting results using statistical and analytical methods
- Extending the results through the use of modeling and simulation
- Predicting synergistic effects from results of different operational tests

In response to specific meta-evaluation questions, the following actions might be taken

- Identify all relevant materials and documents, and obtain copies
- Review available information for validity
- Compare results from all sources, using statistical techniques
- If further analysis is needed
  - Identify available data
  - Collect additional data, or data from other sources
  - Combine data from multiple sources, if needed
  - Perform statistical analysis
  - Create (simple) models for sensitivity analysis
  - Document findings

Models suggested in this document should be understood in the broad sense of the word. Although models are used to support the analysis, the meta-evaluation is not a modeling task. Any models created would be simple, with a short development time.

SECTION 3

MEASURES OF EFFECTIVENESS

3.1 NEED FOR MOES

Developing a list of MOEs is the first step in the meta-evaluation process. MOEs provide an effective link among the evaluation results from the individual operational tests. However, a review of either operational test plans or ITS related literature indicates that a wide variety of measures have been suggested as MOEs, and that an "all MOEs are created equal" perspective was a source of inconsistency across the suggestions. Some MOEs that have been suggested are not quantifiable. Some others are quantifiable in theory, but in practice the size of the test needed to produce the quantification is simply cost prohibitive. Still other MOEs are easily quantified, but do not capture all of the effect under consideration.

This document directly addresses these concerns and proposes MOEs that can be applied across operational tests.

3.2 GOALS AND OBJECTIVES IN THE ITS NATIONAL PROGRAM PLAN

A measure of effectiveness assumes the question, "Effective at doing what?" It assumes goals and objectives-a baseline-that performance can be measured against. The baseline chosen for the MOEs in this document is the mapping of user services to ITS goals and objectives found in the ITS National Program Plan.[3] The goals form the highest level of a hierarchy, with objectives under them. A third level, added under each objective, contains activity areas. These goals, objectives, and activity areas were chosen as a base line because they represent a widely disseminated and generally accepted body of information defining what is expected of the ITS program.

More detail is added with each level of the hierarchy. Activity areas add detail to the objectives just as the objectives add detail to the goals. With the added detail, each level should also lend itself to measures that are more easily quantified than the next higher level. In fact, translating high level goals into measurable specifics is often a significant task in evaluation planning.

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3 *National ITS Program Plan,* First Edition, March 1995, Appendix B.

3.3 HIERARCHY OF MOES

The list of MOEs presented in this paper is structured as a hierarchy: direct, surrogate, and associated (with a surrogate):

- Goals do not have MOEs, because goals are at a high, general level that does not lend itself to quantifiable measures.
- Objectives have direct MOEs. In some cases, these MOEs are quantifiable; but in many cases they are not. For those that are not, the greater level of detail provided by the activity area is needed.
- Activity areas have surrogate MOEs. The name for them, surrogates, was chosen to show that these are surrogates of the needed direct MOEs identified with the objectives. In a few cases, even these surrogates present significant problems to quantify (or to obtain measurement data).
- Associated MOEs form the lowest level in the hierarchy. Associated MOEs are grouped under surrogate MOEs. An associated MOE should be measurable and quantifiable.

The crux of the problem of creating a list of MOEs is the dilemma between the need for a close relationship between the MOE as a measure of accomplishment (which may not lend itself to measurement), and the need to choose an MOE that is measurable (but may not be a clear measure of accomplishment). The further down the MOE hierarchy, the less intuitive, or conversely, the more tenuous the relationship may be between the MOE and the goal and objective.

When the knowledgeable reader reviews a group of associated MOEs, and traces the hierarchy back to, say, the goal, the reader can be expected to grasp the appropriateness of the associated MOEs, but also may find possible contradictions or counterexamples in its application. This is unfortunate, but inherent because of the complexity of ITS and traffic management. For example, reducing the vehicle miles traveled on any trip can be expected to lead to a reduction in energy consumption for that trip; but if the reduction in vehicle miles traveled results in less congestion that acts to induce additional trips, then the result may be that no net reduction in energy consumption occurs.

The list of MOEs is presented in Appendix A. An MOE can appear in more than one place in the list.

Since there are multiple goals for the ITS program, the possibility exists that MOEs for different goals can be in conflict with one another. For example, routing a driver around congestion may reduce travel time, but increase the miles traveled and the emissions produced by the vehicle.

3.4 MEASURES OF PERFORMANCE

In addition to MOEs, a list of Measures of Performance (MOP) is included. While MOEs address how effectively the system achieved the project goals, MOPs measure how the system or components performed. For example, component response time, the mean time between failure, and system stability can all be important measures of an ITS system, but they are not measures of how effectively the system met its goals and objectives. The importance of MOPs is to recognize that they measure something different than MOEs do. Perhaps the simplest way to think of them is to consider the situation where one is convinced of the effectiveness of an ITS function (automated mainline clearance of trucks, for example), and the question turns to the performance characteristics of the specific system to be installed. Once the concept embodied in an ITS application has been proven effective, then performance measures become important in the selection of a specific implementation.

Applying MOPs to operational tests is not without difficulties. For example, the operational test system may be a prototype, produced on a very limited scale with performance characteristics traded for quick implementation. The sophisticated infrastructure to diagnose failure and support repairs may not be in place. Hardware and software may evolve too rapidly to allow a reasonable period of stable operation for the MOPs to be determined. For all these reasons, MOPs should be applied with care.

The list of MOPs is presented in Appendix B.

APPENDIX A: SUGGESTED MOES

1 GOAL: IMPROVE SAFETY

Safety improvements can be measured in terms of reduction in accident rates, and, given that an accident has occurred, reduction in the resulting severity.

1.1 Objective: Reduce the Frequency of Accidents

1.1.1 Direct MOE for Frequency of Accidents

The *accident rate* is the MOE; but, the relatively few accidents that occur make it difficult to determine changes without very large sample sizes. One approach to obtaining the needed data would be to collect before-after data and control-test group data (randomized pre-test post-test design).

1.1.2 Surrogate MOEs for Frequency of Accidents

IMPROVING ON-BOARD VEHICLE SYSTEM MONITORING will result in fewer accidents, if the ITS monitoring devices can identify and warn the driver of the potentially hazardous condition, and the vehicle is removed from the roadways pending appropriate corrective action. *The* MOE is *frequency of on-road componentfailure (by type).*

REDUCING THE NUMBER OF IMPAIRED DRIVERS will result in fewer accidents if the ITS monitoring devices can identify an impaired driver, and the appropriate action is taken to remove the impaired driver from the roadways. The MOE is *number of impaired drivers.*

ENHANCING DRIVER PERFORMANCE will reduce the number of accidents if ITS technology allows the driver to react more quickly or more effectively. Using *improved driver performanceas* an MOE, performance enhancements could be measured; however, correlating it to changes in accident rates may be problematic.

ENHANCING VEHICLE CONTROL CAPABILITY will reduce the number of accidents if ITS technology provides automated functionality in the vehicle that responds more quickly or more effectively than a human could or does. Using *increased control capability* as an MOE, performance enhancements could be measured; however, correlating it to changes in accident rates may be problematic.

IMPROVING TRAFFIC SAFETY LAW ENFORCEMENT will reduce accidents if illegal actions and conditions are identified and their frequency of occurrence is lowered. The MOE *frequency of illegal actions and conditions* with ITS support could be used. Correlating the frequency with changes in overall illegal driving behavior and accidents resulting from that behavior may be problematic.

SMOOTHING TRAFFIC FLOWS is widely believed to reduce the number of accidents, particularly rear end collisions. Statistics on freeways indicate the incidence of traffic accidents is associated with congestion and the presence of a primary accident. The MOE *smoothness of traffic flow* is problematic because accepted measures of "smoothness" do not exist. Associating the change with a lower frequency of accidents could be difficult because of confounding factors, such as overall congestion levels.

1.1.3 Associated MOEs for Frequency of Accidents

Associated MOEs for Improving On-Board Vehicle System Monitoring include:
Frequency of potentially unsafe components identified

Associated MOEs for Reducing the Number of Impaired Drivers include:
Number of impaired drivers identified

Associated MOEs for Enhancing Driver Performance include:
Frequency of abrupt maneuvers
Frequency of close calls (or near-misses)
Response time
Speed variance
Unplanned following distance incursions (frequency and duration)
Unplanned lane deviations and excursions (frequency and duration)

Associated MOEs or Enhancing Vehicle Control Capability include:
Frequency of abrupt maneuvers
Frequency of close calls (or near-misses)
Speed profiles
Unplanned following distance incursions (frequency and duration)
Unplanned lane deviations and excursions (frequency and duration)

Associated MOEs for Improving Traffic Safety Law Enforcement include:
Frequency of identification of illegal actions and conditions with ITS support
Frequency of use of enforcement supporting information
Locations of availability (mobile and fixed) of citation for safety violation data
Locations of availability (mobile and fixed) of out-of-service data
Timeliness of citation for safety violation data
Timeliness of out-of-service data

Associated MOEs for Smoothing Traffic Flows include:
Frequency of stops
Frequency of vehicles entering and exiting freeways (e.g., at weighstations)
Hours of non-recurrent congestion
Speed profiles
Speed variance
Time stopped

1.2 Objective: Reduce Severity of Accidents, Including Fatalities, Injuries, and Property Damage

1.2.1 Direct MOEs for Severity of Accidents

The *fatality rate*, the *level of property damage* and the *severity of injuries sustained* associated with traffic accidents are MOEs of the severity of accidents. The relatively few accidents that occur make it difficult to determine changes without very large sample sizes.

1.2.2 Surrogate MOEs for Severity of Accidents

ENHANCING DRIVER PERFORMANCE will reduce the severity of accidents if ITS technology allows the driver to react more quickly or more effectively. Using *improved driver performnnce* as an MOE would be straightforward, but correlating it to changes in the severity of accidents may be problematic.

ENHANCING VEHICLE CONTROL CAPABILITY will reduce the number of accidents if ITS technology provides automated functionality in the vehicle that responds more quickly or more effectively than an unaided human could or does. Using *increased control capability* as an MOE would be straightforward, but correlating it to changes in the severity of accidents may be problematic.

IMPROVING EMS/ROADWAY SERVICES RESPONSIVENESS is expected to lower the fatalities. The MOEs would be *quality of medical assistance* and *time to provide medical assistance* to accident victims.

IMPROVING PASSENGER PROTECTION (RESTRAINT) will lower fatalities and lessen injuries resulting from accidents. *Reduced severity of injury in vehicles equipped with restraints* is the MOE.

1.2.3 Associated MOEs for Severity of Accidents

Associated MOEs for Enhancing Driver Performance include:
- Frequency of close calls (or near-misses)
- Speed profiles
- Steering wheel movement
- Unplanned following distance incursions (frequency and duration)
- Unplanned lane deviations and excursions (frequency and duration)

Associated MOEs for Enhancing Vehicle Control Capability include:
- Frequency of abrupt maneuvers
- Frequency of close calls (or near-misses)
- Speed profiles
- Steering wheel movement

Unplanned following distance incursions (frequency and duration)
Unplanned lane deviations and excursions (frequency and duration)

Associated MOEs for Improving EMS/Roadway Services Responsiveness include:
Accuracy of accident identification
Accuracy of identification of needed EMS service
Accuracy of needed EMS service provided
Time for EMS service to respond
Time to identify accident
Time to identify need for EMS service
Time to identify type of EMS service needed
Time to provide needed EMS service

Associated MOEs for Improving Passenger Protection (Restraint) include:
Percentage of vehicles equipped with restraints
Restraints deployed

2 GOAL: IMPROVE SERVICE LEVEL (EFFICIENCY)

2.1 Objective: Increase Capacity of the Transportation System

There is some imprecision in speaking of increasing the capacity of the transportation system, since capacity is often applied to specific facilities comprising the transportation system. The Highway Capacity Manual describes capacity of a facility as "the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform segment of a lane or roadway during a given time period under prevailing traffic, roadway, and control conditions." ITS could alter the traffic, roadway geometry, or control conditions.

2.1.1 Direct MOE for Capacity of the Transportation System

The capacity of the *transportation system* is the MOE, but it may be difficult to quantify because of the aggregate nature of the "transportation system" and the uncontrollable factors that would affect any results based on data collected over time.

An alternative to increasing capacity is to reduce or shift demand. Such actions will not increase capacity, but will allow drivers still using the traffic network to travel as if capacity had been increased, that is, they would experience less congestion and delay.

2.1.2 Surrogate MOEs for Capacity of the Transportation System

INCREASING AVERAGE VEHICLE OCCUPANCY will increase the capacity of the transportation system, in terms of people moved. The MOE is the *average vehicle occupancy*. Usually this is thought of in terms of occupancy in private vehicles, but mass transit vehicles should also be included. Results can be obtained with before/after testing, for example. One approach to obtaining the needed data would be to collect before-after data and control-test group data (randomized pre-test post-test design).

INCREASING VEHICLE CAPACITY OF HIGHWAYS will increase the capacity of the transportation system by allowing a greater number of vehicles to use the system. Capacity standards for roadways and intersections have been developed over the years and are listed in the Highway Capacity Manual. *Capacity of a roadway or intersection* can be used as an MOE. Within the time frame of an operational test, changes in accepted values for capacity cannot be expected; but results showing increased throughput to levels above the listed capacity make a strong argument that the capacity standards should be changed.

INCREASING DRIVER NAVIGATIONAL EFFECTIVENESS will increase the capacity of the system by minimizing "wasted" miles, that is, miles that are not needed in order to achieve the goals of the trip. Increased effectiveness can result from 1) the driver making a more informed choice as a result of having better information, or 2) a computer aiding route selection. The MOE is the *effectiveness of the routes,* but effectiveness needs to be further defined. It should be noted that routes can be user optimal (best for the driver on the route) or system optimal (best for all drivers).

MATCHING DEMAND TO AVAILABLE HIGHWAY SYSTEM CAPACITY is an alternative to increasing capacity. ITS can support demand matching providing the means to implement congestion pricing policies. Measuring demard can be difficult; and demand varies with cost. The MOE of interest is the *volume to capacity profile.* It should be noted that achieving desired volume to capacity ratios will be a function of the *elasticity of demand.*

2.1.3 Associated MOEs for Capacity of the Transportation System

Associated MOEs for Increasing Average Vehicle Occupancy include:

- Car and van pool riders
- HOV counts
- Modal shift
- Modal split
- Park and ride lot usage (average space occupancy, number of cars)
- Transit riders

Associated MOEs for Increasing Vehicle Capacity Of Highways include:

- Lane geometries
- Level of service
- Queue length
- Total system delay
- Travel delay
- Safe vehicle headway
- Throughput

Associated MOEs for Increasing Driver Navigational Effectiveness include:
- Frequency of on-time arrival
- Frequency of wrong or missed turns
- Route quality (e.g., number of turns, number of stops)
- Trip distance
- Trip time

Associated MOEs for Matching Demand to Available Highway System Capacity include:
- Hours of non-recurrent congestion
- Hours of recurrent congestion
- Level of congestion
- Peak demand
- Periods of peak demand
- Route diversions
- Variability of travel time across routes
- Variability of level of service on alternate routes

2.2 Objective: Reduce Congestion Due to Incidents

Congestion from incidents can be reduced by providing timely information to drivers on congestion and alternate routes, and by reducing the duration of the incident.

2.2.1 Direct MOE for Congestion Due to Incidents

Hours of non-recurrent congestion as an MOE is difficult to quantify (although routinely estimated) because of the random nature of its occurrence and because uncontrollable factors affect any results based on data collected over time. *Percentage of miles traveled in congestion* is another appropriate MOE.

2.2.2 Surrogate MOEs for Congestion Due to Incidents

IMPROVING INCIDENT MANAGEMENT can reduce congestion due to incidents by improving performance in the identification of the incident, providing the appropriate staff and equipment at the scene, and directing the clearing of the incident. The MOE is the *quality of incident management*.

IMPROVING INCIDENT INFORMATION TO DRIVERS can reduce congestion by providing drivers real-time information to make decisions on how they can best avoid the incident, thereby reducing the resulting congestion. The MOE *quality ofincident information* can be measured subjectively using survey techniques.

IMPROVING THE ABILITY TO RESPOND TO HAZMAT INCIDENTS is **a** special subset of incident management. ITS can reduce congestion by providing cargo information needed for proper incident management. As was noted above, providing the information is only one stage in incident management. In order make use of the rapid availability of the information, a response plan with equipment and staff must be in place and available, otherwise timely, appropriate measures cannot be anticipated. *The* MOE *is quality of response to HAZMAT incident.*

2.2.3 Associated MOEs for Congestion Due to Incidents

Associated MOEs for Improving Incident Management include:
- Appropriateness of equipment at incident site
- Mean time to detect incident (false alarm rate, accuracy)
- Time for equipment to reach incident site
- Time for staff to reach incident site
- Time to clear incident
- Total system delay

Associated MOEs for Improving Incident Information To Drivers include:
- Number of drivers notified
- Quality of information
- Timeliness of information
- Total system delay
- Travel delay

Associated MOEs for Improving Ability To Respond To HAZMAT Incidents include:
- Quality of information
- Time to clear incident
- Time to determine HAZMAT materials involved in incident
- Time to implement appropriate measures
- Time to notify appropriate staff of materials

2.3 Objective: Improve Transportation Customer Service

Improving transportation customer service should increase the number of riders, resulting in fewer private vehicles on the roadways and higher occupancy rates on public transportation vehicles. Improving customer service includes those actions which make use of the transportation system or private vehicles more convenient, enjoyable, or attractive.

2.3.1 Direct MOE for Customer Service

Transportation Customer Service includes a number of characteristics of the transportation system. Subjective measures of *quality of customer service* could be used as an MOE. The perception of quality of service, along with the actual quality of service, is important in stimulating mode shift.

2.3.2 Surrogate MOEs for Customer Service

IMPROVING QUALITY OF TRANSIT INFORMATION will improve customer service, for example, by providing potential riders with information on alternatives. The MOE *quality of transit information* can be measured subjectively using survey techniques.

IMPROVING TRANSIT SCHEDULE ADHERENCE will improve customer service, for example, by allowing riders to adhere to their schedules. The MOE *schedule adherence* can be measured subjectively using survey techniques or quantified in terms of deviations from schedule.

IMPROVING TRANSIT RESPONSIVENESS will improve customer service, for example, by providing public transport where and when needed. The MOE *quality of transit responsiveness* can be measured subjectively using survey techniques.

IMPROVING SERVICE REQUEST RESPONSIVENESS will improve customer service, for example, by supporting on-time delivery or providing public transport where and when needed. The MOE *quality of service request responsiveness* can be measured subjectively using survey techniques or quantified in terms of response time.

IMPROVING CONVENIENCE OF TRANSPORTATION PAYMENT will improve customer service, for example, by making public transportation more attractive. *Convenience of payment* can be measured subjectively using survey techniques.

2.3.3 Associated MOEs for Customer Service

Associated MOEs for Improving Quality of Transit Information include:
- Accesses to on-line data bases
- Accuracy of transit information
- Completeness of transit information
- Frequency and type of inquires
- Frequency of information use to assist mode change
- Frequency of kiosk use, by location
- Frequency of suggestions and complaints

Associated MOEs for Improving Transit Schedule Adherence include:
- Schedule deviation statistics (mean time, mode, variance, etc.)
- Frequency of deviations from schedule
- Frequency of on-time arrivals
- Frequency of on-time departures

Associated MOEs for Improving Transit Responsiveness include:
- Access time
- Accuracy of planned service time
- Frequency of off-route pick-ups

Frequency of reservation requests accommodated
Frequency of reservation requests denied
Response time

Associated MOEs for Improving Service Request Responsiveness include:
Frequency of on-time delivery
Frequency of service requests accommodated
Frequency of service requests denied
Order delivery cycle time
Order delivery error rate
Time from request to service

Associated MOEs for Improving Convenience Of Transportation Payment include:
Frequency of use
Percentage of users choosing new payment option
Transaction time

3 GOAL: REDUCED ENERGY AND ENVIRONMENTAL IMPACT

3.1 Objective: Reduce Harmful Emissions Per Unit of Travel

Environmental impact can be reduced by reducing harmful emissions. ITS can help by reducing harmful emissions per unit of travel. The unit of travel could be a trip, for example.

3.1.1 Direct MOE for Harmful Emissions Per Unit of Travel

The MOEs are (NOx) *emissions per trip, (HC) emissions per trip,* and (CO) *emissions per trip.* One approach to obtaining the needed data would be to collect before-after data and control-test group data (randomized pre-test post-test design).

3.1.2 Surrogate MOEs for Harmful Emissions Per Unit of Travel

REDUCING VEHICLE MILES TRAVELED will reduce harmful emissions, since emissions are produced during each mile traveled. *Vehicle miles traveled* is a quantifiable MOE.

REDUCING EMISSIONS DUE TO CONGESTION can be accomplished by reducing congestion or having vehicles take alternate routes to avoid the congestion. Measuring the "emissions due to congestion" would be difficult; it could be estimated on the basis of a reduction in the time spent in congestion.

IMPROVING POLLUTION SOURCE IDENTIFICATION can reduce harmful emissions by identifying vehicles with higher than acceptable pollution rates, if the identified vehicles are brought into compliance or removed from the road. The MOE would *befrequency of pollution sources identified.*

SMOOTHING TRAFFIC FLOWS will reduce harmful emissions, because emissions increase with variation in speed. The MOE *smoothness of traffic flow is problematic* because accepted measures of "smoothness" do not exist. Associating the change with reduced emissions could be done if speed profiles are included.

3.1.3 Associated MOEs for Harmful Emissions Per Unit of Travel

Associated MOEs for Reducing Vehicle Miles Traveled include:

- Navigational efficiency
- Wasted mileage

Associated MOEs for Reducing Emissions Due To Congestion include:

- Emissions per vehicle mile
- Emissions per vehicle passing through intersection
- Hours of congestion

Associated MOEs for Improve Pollution Source Identification include:

- Frequency of out of compliance vehicles identified
- Frequency of repeat offenders

Associated MOEs for Smoothing Traffic Flows include:

- Frequency of stops
- Frequency of vehicles entering and exiting freeways (e.g., at weighstations)
- Hours of non-recurrent congestion
- Speed profiles
- Time stopped

3.2 Objective: Reduce Energy Consumption Per Unit of Travel

Energy consumption can be reduced by reducing harmful emissions. ITS does not apply to engine characteristics, but ITS can help by reducing energy consumption per unit of travel. The unit of travel could be a trip, for example.

3.2.1 Direct MOE for Energy Consumption Per Unit of Travel

Energy consumption per trip is an aggregate term determined by summing energy consumption from all vehicles in all conditions. Sampling could be used to determine the impact of ITS. Given the relatively limited scope of most operational tests, changes in the aggregate may be too small to measure.

3.2.2 Surrogate MOEs for Energy Consumption Per Unit of Travel

REDUCING VEHICLE MILES TRAVELED will reduce energy consumption, since energy is consumed during each mile traveled. *Vehicle miles traveled* is a quantifiable MOE.

SMOOTHING TRAFFIC FLOWS will reduce energy consumption per unit travel because energy consumption increases with speed variation. *The* MOE *smoothness of traffic flow is* problematic because accepted measures of "smoothness" do not exist. Associating the change with a reduced energy consumption could be done if speed profiles are included.

REDUCING FUEL WASTED IN CONGESTION can be accomplished by reducing congestion or having vehicles take alternate routes to avoid the congestion. Measuring the "consumption due to congestion" would be difficult, but could be estimated on the basis of time spent in congestion.

3.2.3 Associated MOEs for Energy Consumption Per Unit of Travel

Associated MOEs for Reducing Vehicle Miles Traveled include:
- Navigational efficiency
- Wasted mileage

Associated MOEs for Smoothing Traffic Flows include:
- Frequency of stops
- Frequency of vehicles entering and exiting freeways (e.g., at weighstations)
- Hours of non-recurrent congestion
- Speed profiles
- Time stopped

Associated MOEs for Reducing Fuel Wasted In Congestion include:
- Hours of congestion

3.3 Objective: Reduce New Right of Way Requirements

Reducing new right of way requirements would reduce the environmental impact of the transportation system by alleviating the need for more highways.

3.3.1 Direct MOE for Reduced Right of Way Requirements

"Right of Way Requirements" would be the direct MOE. The right of way added is measurable; however, measuring a reduction in requirements would be quite difficult.

3.3.2 Surrogate MOEs for Reduced Right of Way Requirements

REDUCING VEHICLE MILES TRAVELED will reduce the right of way requirements, because there will be less demand on the transportation system.

3.3.3 Associated MOEs for Reduced Right of Way Requirements

Associated MOEs for Reducing Vehicle Miles Traveled include:

- Lane-width reduction
- Navigational efficiency
- Wasted mileage

4 GOAL: ENHANCE PRODUCTIVITY

4.1. Objective: Reduce Costs Incurred by Fleet Operators, Operating Agencies, and Individuals

4.1.1 Direct MOE for Reducing Costs Incurred by Fleet Operators, Operating Agencies, and Individuals

Cost is the straightforward MOE for reducing costs. The difficulty with using an overall cost is that it does not lend itself to isolating the effect of ITS, and comparisons would depend on the accounting system in use.

4.1.2 Surrogate MOEs for Reducing Costs Incurred by Fleet Operators, Operating Agencies, and Individuals

REDUCING THE COST OF REGULATING VEHICLES and REDUCING THE COST OF FEE COLLECTION focus on two areas that could be automated. *Cost of regulating vehicles* (both for the private carrier and the regulating agency) and *cost of fee collection* are straight forward MOEs. Isolating the ITS effects and the differences in accounting systems pose difficulties.

IMPROVING THE EQUITY OF FEE COLLECTION could be accomplished by ensuring, through automated means, that fees are paid by all who should. The MOE for equity would be a measure of *unpaid fees,* as well as the *unpaid fees distribution among users.*

IMPROVING VEHICLE AND STAFF UTILIZATION would increase efficiency, providing more service without increasing vehicles or staff. This represents a cost reduction. *Utilization rates* would be the MOE, but comparisons would require standard definitions that may not exist.

4.1.3 Associated MOEs for Reducing Costs Incurred by Fleet Operators, Operating Agencies, and Individuals

Associated MOEs for Reducing Cost Of Regulating Vehicles include:
- Time to process credentials, permits, wavers, etc.
- Vehicles inspected, credentials checked, etc., per staff

Associated MOEs for Reducing Cost of Fee Collection include:
- Fees collected per staff
- Time to collect fees

Associated MOEs for Improving Equity of Fee Collection
- None identified

Associated MOEs for Increasing Vehicle and Staff Utilization include:
- Staff needed
- Worker productivity measures
- Worker stress

4.2 OBJECTIVE: REDUCE TRAVEL TIME

Reducing travel time should result in higher productivity because a trip would require less (time) resources. An additional benefit will be more predictable scheduling, particularly arrival times.

4.2.1 Direct MOE for Reducing Travel Time

Travel time is the MOE, and can be measured in controlled experiments or collected for a sample of users of the transportation system. Results can also be obtained from models.

4.2.2 Surrogate MOEs for Reducing Travel Time

REDUCING TIME LOST IN INTERMODAL INTERCHANGE will reduce travel time. *The* MOE is *time spent in intermodul interchange.*

REDUCING DELAYS OF REGULATING VEHICLES will reduce travel time. The MOE is *time to regulate vehicles.*

REDUCING DELAY ASSOCIATED WITH CONGESTION will reduce travel time. The MOE is *time spent in congestion.*

REDUCING TIME WASTED DUE TO NAVIGATIONAL INEFFICIENCY will reduce travel time. The MOE is *time wasted per trip.* Another MOE is the *effectiveness of the routes,* but effectiveness needs to be further defined. It should be noted that routes can be user optimal (best for the driver on the route) or system optimal (best for all drivers).

4.2.3 Associated MOEs for Reducing Travel Time

Associated MOEs for Reducing Time Lost In Intermodal Interchange include:
- Frequency of on-time arrivals
- Frequency of on-time departures
- Schedule delay

Associated MOEs for Reducing Delays Of Regulating Vehicles include:
- Time (and staff time) needed to obtain permits
- Time saved by bypassing weigh stations

Associated MOEs for Reducing Delay Associated With Congestion include:
- Average speed
- Delay at intersections
- Hours of non-recurrent congestion
- Hours of recurrent congestion
- Queue lengths
- Time below free flow speed

Associated MOEs for Reducing Time Wasted Due To Navigational Inefficiency include:
- Frequency of lost driver conditions
- Frequency of on-time arrivals
- Frequency of wrong or missed turns
- Route quality

4.3 Objective: Improve Transportation System Management and Planning

4.3.1 Direct MOE for Improving Transportation System Management and Planning

Quantitative measurement of the improvement is difficult. The MOE *improvement in transportation system management and planning* can be measured subjectively using survey techniques.

4.3.2 Surrogate MOEs for Improving Transportation System Management and Planning

REDUCING THE COST OF DATA COLLECTION can improve transportation system management and planning. The MOE would be the *cost of data collection*.

IMPROVING THE QUALITY OF DATA COLLECTED can improve transportation system management and planning. The MOE would be *quality of data collected* which can be measured subjectively using survey techniques.

4.3.3 Associated MOEs for Improving Transportation System Management and Planning

Associated MOEs for Reducing Cost of Data Collection include:
Cost of data management system
Staff hours dedicated to data collection

Associated MOEs for Improving Quality of Data Collection include:
Accuracy of data
Coverage of data collection area
Timeliness of data

5 GOAL: IMPROVE MOBILITY

5.1 OBJECTIVE: ENHANCE TRAVELER SECURITY

Transportation related crime is a subset of the larger problem of violence and destruction of property. Fear for personal safety, or the removal of that fear, are reflected in travel choices. Crime can be reduced through deterrence, thwarting, or apprehension.

51.1 Direct MOEs for Traveler Security

The *crime rate associated with travel* would be a direct measure of effectiveness and could be applied area wide or to a specific facility, such as transit station or rest stop. The difficulty in determining changes in these rates is the relative infrequency of crimes and the lack of control over potentially confounding variables.

5.1.2 Surrogate MOEs for Traveler Security

INCREASING THE AVAILABILITY OF COMMUNICATIONS DEVICES can increase traveler security if the presence of the devices acts as a deterrent to crime or if the use of the devices results in the a rapid response in an emergency situation. Number *of communication devices* is the MOE.

REDUCING VEHICLE THEFT RATE is a subset of reducing the crime rate. ITS vehicle location devices, for example, can provide a way of locating a stolen vehicle. Comparing the *vehicle theft rate* of cars equipped with automated location (anti-theft) devices with those cars that are not equipped would provide the measure.

INCREASE MONITORING OF TRANSPORTATION FACILITIES can increase traveler security making travelers or passengers visible to transit personnel, the police, or other enforcement officials, reducing criminal acts or summoning help quickly. A quantitative MOE for monitoring is problematic. The MOE is *area of surveillance.*

5.1.3 Associated MOEs for Traveler Security

Associated MOEs for Increasing the Availability Of Communications Devices include:
- Accuracy of location
- Area of coverage
- Emergency response time
- Frequency of use of emergency communication devices
- Roadside emergency response time

Associated MOEs for Reducing Vehicle Theft Rate include:
- Frequency of recovered stolen vehicle
- Frequency of use of automated anti-theft devices

Associated MOEs for Increasing Monitoring Of Transportation Facilities include:
- Frequency of monitored criminal activity
- Hours of surveillance per day per facility
- Time to respond to monitored criminal activity

5.2 Objective: Reduce Travel Stress

5.2.1 Direct MOEs for Traveler Stress

Stress is difficult to quantify. Traveler stress could be measured by monitoring bodily changes, but only in highly controlled environments. *Traveler stress* can be measured subjectively using survey techniques. Stress could be measured in terms of, for example, anxiety, frustration, or anger.

5.2.2 Surrogate MOES for Traveler Stress

IMPROVING THE QUALITY OF TRAFFIC INFORMATION would allow travelers to plan their travel more effectively, and provide them with the real time information needed to alter travel plans during the trip. It would reduce the stress that accompanies the lack of knowledge of conditions on alternate routes, allowing informed decisions to be made. The MOE *quality of traffic information* can be measured subjectively using survey techniques.

SMOOTHING TRAFFIC FLOWS will lower stress. The MOE *smoothness of traffic flow* is problematic because accepted measures of “smoothness” do not exist.

IMPROVING TRAVEL TIME PREDICTABILITY would allow travelers to plan their travel more effectively, resulting in less need to alter travel plans during the trip and less need to adjust to consequences of late arrivals. *Travel time predictability* as an MOE is problematic.

5.2.3 Associated MOEs for Traveler Stress

Associated MOEs for Improving Quality of Traffic Information include:

Accuracy of traffic information
Frequency of use of traffic information
Timeliness of traffic information

Associated MOEs for Smoothing Traffic Flow Rate include:

Frequency of stops
Frequency of vehicles entering and exiting freeways (e.g., at weighstations)
Hours of non-recurrent congestion
Speed profiles
Time stopped

Associated MOEs for Improving Travel Time Predictability include:

Frequency of stops
Hours of non-recurrent congestion
On-time performance
Trip time compared to expected or scheduled

5.3 OBJECTIVE: IMPROVE ACCESSIBILITY TO TRANSPORTATION

5.3.1 Direct MOEs for Accessibility to Transportation

A measure of effectiveness for accessibility to the transportation system is the change in the number of *trips taken*, with the assumption that more accessibility results in more trips. This approach, however, should account for any general change in demand for transportation or in the transportation infrastructure. *Accessibility to transportation* can be measured subjectively using survey techniques.

5.3.2 Surrogate MOEs for Accessibility to Transportation

IMPROVING TRANSPORTATION AFFORDABILITY will increase the accessibility if the demand for transportation is "elastic", that is, there is greater demand for transportation if the price goes down. This is the typical situation with goods and services and can be expected to apply to transportation. The MOE would be the affordability, or *cost of transportation relative to the cost of other goods and services.* The cost for different modes of transportation could also be compared.

IMPROVING QUALITY OF TRAVEL OPTIONS INFORMATION will increase the accessibility to transportation if travelers currently have insufficient information concerning travel options. The MOE is *quality of travel option information* and can be measured subjectively using survey techniques

IMPROVING AVAILABILITY OF ALTERNATE MODES will increase the accessibility if the alternate modes fill a shortfall in the mix of modes available to the traveler. The MOE is *availability of alternate modes* which can be measured subjectively using survey techniques.

IMPROVING DRIVER PERFORMANCE for people with driving impairments will allow them to make more use of the transportation system. Similarly, improving driver performance will allow all drivers to access the transportation system in adverse conditions, such as fog. Measuring *increased performance of impaired drivers* appears possible, but correlating the change in performance to increased use by impaired drivers may be problematic, except, possibly through survey techniques.

5.3.3 Associated MOEs for Accessibility to Transportation

Associated MOEs for Improving Transportation Affordability include:
- Convenience of payment method
- Cost of providing service
- Fares charged

Associated MOEs for Improving Quality of Travel Options Information include:
- Accuracy of travel options information
- Frequency of scheduled service
- Frequency of use of travel options information
- Timeliness of travel options information

Associated MOEs for Improving Availability of Alternate Modes include:
- Frequency of scheduled service
- Late reservations requests accommodated
- Scheduled trips
- Frequency of use by mobility impaired

Associated MOEs for Improving Driver Performance include:
- Frequency of abrupt maneuvers
- Frequency of close calls (or near-misses)
- Frequency of trips under "adverse conditions"
- Response time for vehicle control related actions
- Speed variance
- Steering wheel variance
- Unplanned following distance incursions (frequency and duration)
- Unplanned lane deviations and excursions (frequency and duration)

APPENDIX B: SUGGESTED MOPS

MOP Categories and Sample MOPs Applicable to Most Systems:

Reliability
- Availability
- Failure rate
- Mean time between failure
- Mean time to repair
- Mean time to restore service
- For software: failures (departure from program operation); faults (s/w defect that causes failure); errors (human action during design)

Human Factors
- Deviations from ergonomic designs
- Distractions from primary task
- Ease of use
- Illumination levels

User acceptance
- Perception of worth
- Perception of value
- Perception of effectiveness
- Units sold or installed

Cost
- Cost per unit
- Cost per passenger mile

Capacity
- Maximum number of users supported
- Response time

MOP Categories and Sample MOPs Applicable to Information Systems

Data Collection
- Accuracy
- Time to collect

Data Communication
- Speed/Capacity
- Accuracy
- Coverage

Data Processing
- Accuracy
- Speed/Capacity

Data Presentation

Accuracy

Timeliness of information

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