
**Lean Six-sigma Application in Transportation Performance Management –
Six-step to Selecting Performance Measures**

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doi.org/10.51505/ijaemr.2025.1526

URL: <http://dx.doi.org/10.51505/ijaemr.2025.1526>

Received: Nov 17, 2025

Accepted: Nov 24, 2025

Online Published: Dec 24, 2025

Abstract

Transportation Performance Management (TPM) has emerged as a critical framework for standardized performance measurement, target setting, and reporting for transportation agencies. Despite its importance, implementing TPM faces several challenges, including a lack of coordination among business units and difficulties achieving consensus on strategic directions. This study proposes a structured six-step framework for selecting performance measures, complemented by Lean Six Sigma (LSS) methodologies. The aim of this is to promote stakeholder collaboration and participation and to align selected performance measures with agency goals and objectives. An overview case study of how the proposed approach was used by the Louisiana Department of Transportation and Development (DOTD) is presented. The DOTD case study illustrates the applicability of the methodology and serves as an applied example of how LSS strategies can enhance the performance measurement selection process. The proposed methodology presented in this paper provides a practical approach for transportation agencies seeking to improve their TPM.

Keywords: Transportation Performance Management (TPM), Lean Six Sigma (LSS), transportation system management and operations (TSMO), performance measures.

1. Introduction

1.1 Introduction of Problem

The Moving Ahead for Progress in the 21st Century Act (MAP-21), signed in 2012, established federal performance management regulations that created a new framework for nationally coordinated performance measurement, target setting, and reporting through Transportation

Performance Management (TPM). The Fixing America's Surface Transportation (FAST) Act, signed in 2015, built on the MAP-21 requirements and provided long-term funding certainty for surface transportation infrastructure planning and investment (FHWA, 2021). The Transportation System Management and Operations (TSMO) program, implemented by federal, state, and metropolitan transportation agencies, also requires incorporating performance measurements into transportation system management (Clark et al., 2017). These requirements have made performance measurement a vital part of transportation system management.

State Departments of Transportation (DOTs) and metropolitan planning organizations (MPOs) have responded to these requirements by prioritizing advancement in areas such as data collection, measurement calculation, target setting, coordination and communication, and performance-based planning. Organizations, including the Federal Highway Administration (FHWA), the American Association of Transportation Officials (AASHTO), and the Transportation Research Board (TRB), have worked extensively to assist agencies in implementation by fostering the dissemination and adoption of successful practices, promoting performance management concepts, and helping to develop improved tools and approaches. However, several challenges still need to be addressed (NCHRP, 2022).

The challenges of TPM include the lack of available, high-quality data for national performance measures; challenges with using national measures to support regional and local agency decision-making; the inability to integrate TPM with agency business processes and practices; and the need for alignment of performance reporting and management responsibilities (FHWA & AASHTO, 2021). Other challenges include a lack of widespread understanding within agencies of the importance of data and performance measures (NCHRP, 2019) and challenges in developing agreements on common goals, objectives, performance measures, and targets when different transportation agencies and stakeholders are involved (FHWA, 2017a; FHWA, 2017b; FHWA, 2018; FHWA, 2019; Zgoda et al., 2021).

To support TPM implementation efforts, this desk study develops a structured six-step performance measure selection framework, with suggested LSS concepts to address challenges in developing agreements on common goals, objectives, and performance measures. This structured framework and suggested LSS strategies can help improve communication and collaboration among stakeholders by providing a structured approach to selecting performance measures that are relevant and meaningful to all parties involved in setting the strategic direction of an agency or its programs.

2. Background

2.1 TPM Framework

The TPM framework is based on over a decade of TPM research and practice and expands upon the FHWA's performance-based planning and programming (PBPP) (USDOT, 2022). PBPP guides the integration of performance management concepts into the planning and programming

of transportation systems and focuses on applying performance management principles toward desired system performance outcomes (National Academies of Sciences, Engineering, and Medicine, 2009; Worth et al., 2010; Grant et al., 2014; NCHRP, 2015).

TPM, on the other hand, emphasizes the importance of Organization and Culture (Component A), External Collaboration and Coordination (Component B), Data Management (Component C), and Data Usability and Analysis (Component D). It also has Strategic Direction (Component 01), Target Setting (Component 02), Performance-Based Planning (Component 03), Performance-Based Programming (Component 04), Monitoring and Adjustment (Component 05), and Reporting and Communication (Component 06) as shown in Figure 1.

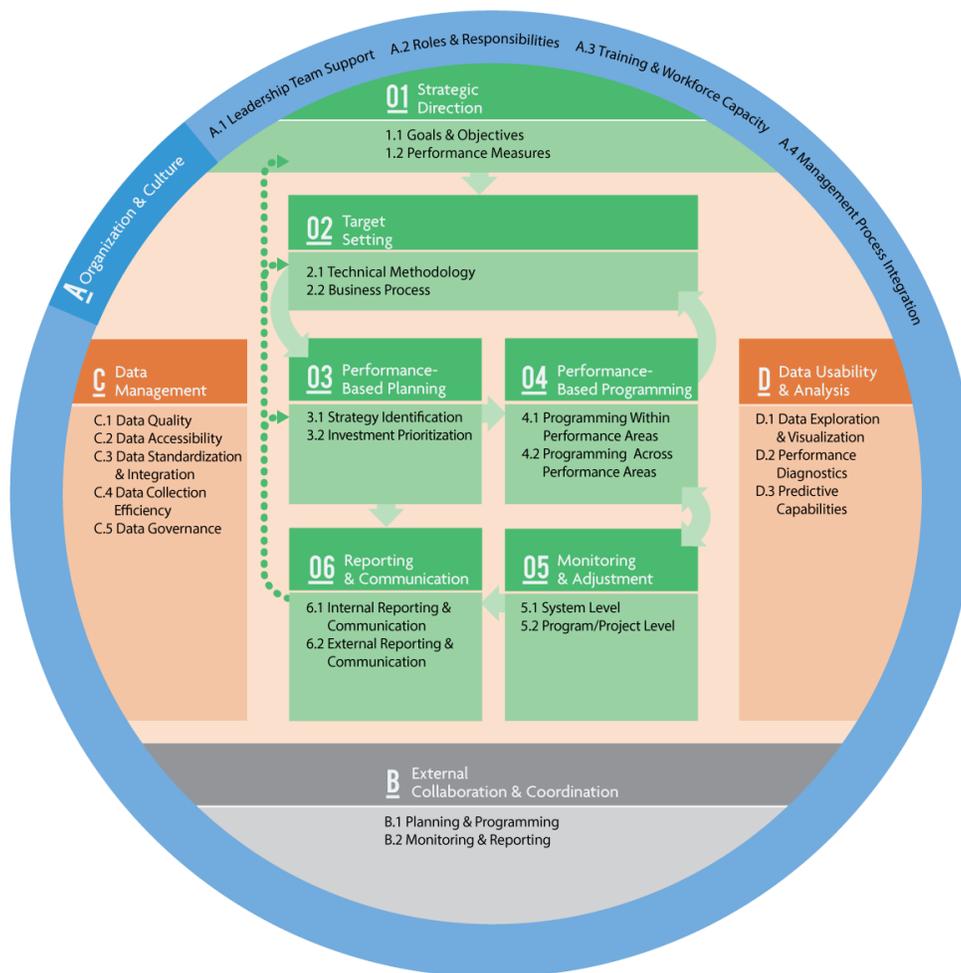


Figure 1. Transportation Performance Management Framework: FHWA TPM Guidebook (USDOT, 2022)

Component A includes building leadership support, clarifying roles and responsibilities, integrating TPM into management practices, and providing workforce training to ensure sustainable implementation. This component significantly impacts all other processes and is crucial for the successful implementation of TPM. Component B emphasizes how external partnerships and involvement are integrated throughout TPM practices, including planning, programming, monitoring, and reporting, with internal collaboration as a fundamental element across all components. Components C and D emphasize the critical role of data in transportation performance management.

Further, Component 01 focuses on establishing an agency's overarching goals, objectives, and performance measures, serving as the basis for the entire TPM framework. Component 02 ensures that performance levels are determined collaboratively, aligning investment decisions with desired outcomes based on baseline data and resource constraints. Components 03 and Component 04 focus on using agency goals to inform long-term strategies and appropriate resource allocation, ensuring that investments are directly linked to performance expectations. Component 05 allow agencies to track performance data and refine strategies, while Component 06 fosters accountability and transparency among stakeholders. Detailed definitions of each component and sub-component are in the respective chapters of the TPM Guidebook (USDOT, 2022). As in PBPP, TPM activities do not necessarily occur in order.

2.1.2 Gap to be Bridged

Though advancements have been made in implementing TPM practices, challenges and issues still hinder its practical implementation (Worth et al., 2010; USDOT, 2022; National Academies of Sciences, Engineering, and Medicine, 2022).

The challenges and issues relevant to this paper include the lack of coordination and collaboration across business units to identify common needs for transportation systems, limited understanding within agencies of the significance of performance measures, and difficulties in reaching consensus on agencies' goals and objectives. These challenges hamper the establishment of clear strategic directions for agencies and effective inter- and intra-agency coordination and collaboration, which are key elements of Component 02 and B of the TPM framework. To help address these challenges, Project 20-24(127) (NCHRP, 2022) recommends that agencies highlight and share successful examples of their collaboration and coordination efforts, along with related practical information, with other transportation agencies and partners.

2.2 Objectives of Study

In response to Project 20-24(127), this paper presents a structured six-step performance measure selection process, with suggested LSS strategies designed to facilitate collaboration and buy-in among internal and external stakeholders and to ensure alignment of performance measures with an agency's goals. This proposed approach is intended to help agencies effectively develop

metrics that enhance performance, drive continuous improvement, and improve stakeholder satisfaction—key elements of Components 02 and B of the TPM framework.

3. Methodology

A literature review was conducted to assess the current state of TPM, with a specific focus on the challenges and issues that impede its implementation. The study examined literature from sources such as the FHWA, USDOT, NCHRP, and various state DOTs over the past years. While some of the references date back more than a decade, which may indicate reliance on older sources, the cited literature remains pertinent to the arguments presented in this study and provides valuable context for current TPM discussions.

The identified TPM challenges revolved around difficulties in establishing clear strategic directions for agencies and in effective inter- and intra-agency coordination and collaboration. To address these challenges, this paper proposes integrating LSS concepts and tools into a six-step performance measurement selection process to enhance stakeholder collaboration and ensure alignment of performance measures with organizational goals.

The identification of LSS tools and concepts was based on a literature review encompassing studies across various sectors, focusing on techniques that promote stakeholder participation, collaboration, and support for continuous improvement and process traceability. A few tools and concepts were identified across various sectors, though with limited application in transportation. Following insights from the literature review, a structured six-step process was formulated to select performance measures. Each step incorporates LSS tools that facilitate stakeholder engagement, ensure transparency, and align performance measures with organizational goals and objectives. The proposed six-step performance selection framework was employed in a study to develop performance measures for DOTD's ITS program. An overview of the study's approach is presented, along with its potential benefits and limitations.

4. Discussion

4.1 Lean Six-Sigma Application in Transportation Performance Management

The potential of LSS for enhancing performance measurement in transportation has been acknowledged in studies, including TRB's second Strategic Highway Research Program Report S2-C02-RR (National Academies of Sciences, Engineering, and Medicine, 2009) and NCHRP 20-24(97) report in 2015 (NCHRP, 2015). The latter generated problem statements to understand existing practices for using LSS and other continuous improvement methodologies to bolster performance management in transportation. Despite these efforts, a review of ongoing and completed research projects under the NCHRP and allied organizations yielded no substantial results, suggesting a scarcity of information on the application of LSS initiatives and other continuous improvement methodologies in transportation system management. This scarcity underscores the need for further exploration and research to fully harness the potential of LSS and related concepts to optimize performance measurement in transportation.

A literature review, conducted primarily outside transportation, examined various LSS tools and strategies with the potential to support the setting of strategic directions and the enhancement of stakeholder collaboration and engagement in transportation. Fourteen (14) strategies were identified and briefly summarized in Table 2, offering insights into their application and relevance to TPM.

Table 1. Potential LSS Tools in TPM Implementation

LSS Tools	Overview
Define, Measure, Analyze, Improve, and Control (DMAIC) (Mandal, 2012, pp. 231-250)	A systematic process improvement methodology that helps organizations identify issues, make data-driven decisions, implement effective solutions, and maintain improved processes.
Process Mapping (Kumar et al., 2021, pp. 1964-1991)	A visual representation of a sequence of process activities that provides understanding of steps, decisions, inputs, outputs, and interactions. Enhances efficiency, reduces errors, and achieves better outcomes for organizations.
Responsible, Accountable, Consulted, and Informed (RACI) matrix (Jackson, 2020)	A tool that outlines roles and responsibilities within a team or across stakeholders. Define who is responsible, who is accountable, and who needs to be consulted or informed about a task, decision, or activity. Establishes clarity and accountability and facilitates collaboration, efficient task execution, and successful process outcomes.
Voice of the Customer (VOC) (Aggarwal, 2021, pp. 65-90)	A method of understanding customer preferences, needs, and feedback to improve product and service quality. Techniques include surveys, interviews, focus groups, social media monitoring, customer feedback forms, and direct customer interactions.
Kano Analysis (Min et al., 2018)	A method used in product development and customer satisfaction research to prioritize features based on customer preferences and satisfaction levels. Helps to prioritize resources, improve one-dimensional qualities, and consider attractive qualities to prevent dissatisfaction.
Suppliers, Inputs, Process, Outputs, and Customer (SIPOC) diagram (George et al., 2005)	A visual tool that provides a high-level view of process elements, focusing on interactions between suppliers, inputs, the process, outputs, and customers. Helps understand scope of process, identify key stakeholders, and facilitate communication among teams and stakeholders.
Critical-to-quality (CTQ) requirements (He et al., 2009)	Specific, measurable characteristics of a product or service that fulfil customer expectations and satisfaction. They are identified through surveys, focus groups, market research, and direct

	interactions.
Brainstorming (Paulus & Nijstad, 2019)	A collaborative method that generates numerous ideas within a group, helping with problem-solving, innovation, and decision-making.
Affinity Diagram (Widjaja & Takahashi, 2016)	A visual tool that organizes ideas into themes during brainstorming and project planning, helping teams understand complex information, identify patterns, and gain insights.
Fishbone Diagram (Ilie & Ciocoiu, 2010, pp 120)	A visual tool that helps identify and organize potential causes of a problem, facilitating comprehensive analysis and collaborative problem-solving through a structured approach.
Measurement Selection Matrix (Systems2win, 2021a)	A structured tool for evaluating and selecting metrics aligned with project goals, ensuring feasibility and value for decision-making.
Data Collection Planning (George et al., 2005)	A structured approach to designing and organizing methods for collecting data for projects or analyses, focusing on the data types, collection methods, and suitable tools and techniques.
Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis (Hessing, 2021)	A strategic planning tool used to assess internal and external factors impacting an organization, facilitating informed decision-making and resource allocation.
Multi-voting (He et al., 2009)	A decision-making technique that helps to prioritize options in group discussions by enabling participants to express their preferences through voting.

The structured six-step performance measure selection process and the suggested application of LSS methodologies within it are briefly discussed below.

4.2 Six-Step Systematic Approach to Selecting Performance Measures

The precursor to the logical steps of the structured six-step framework shown in Figure 2 is the identification of all relevant stakeholders, including government agencies, local municipalities, transportation planners, and community representatives. This ensures that the perspectives and needs of all stakeholders are considered throughout the process.

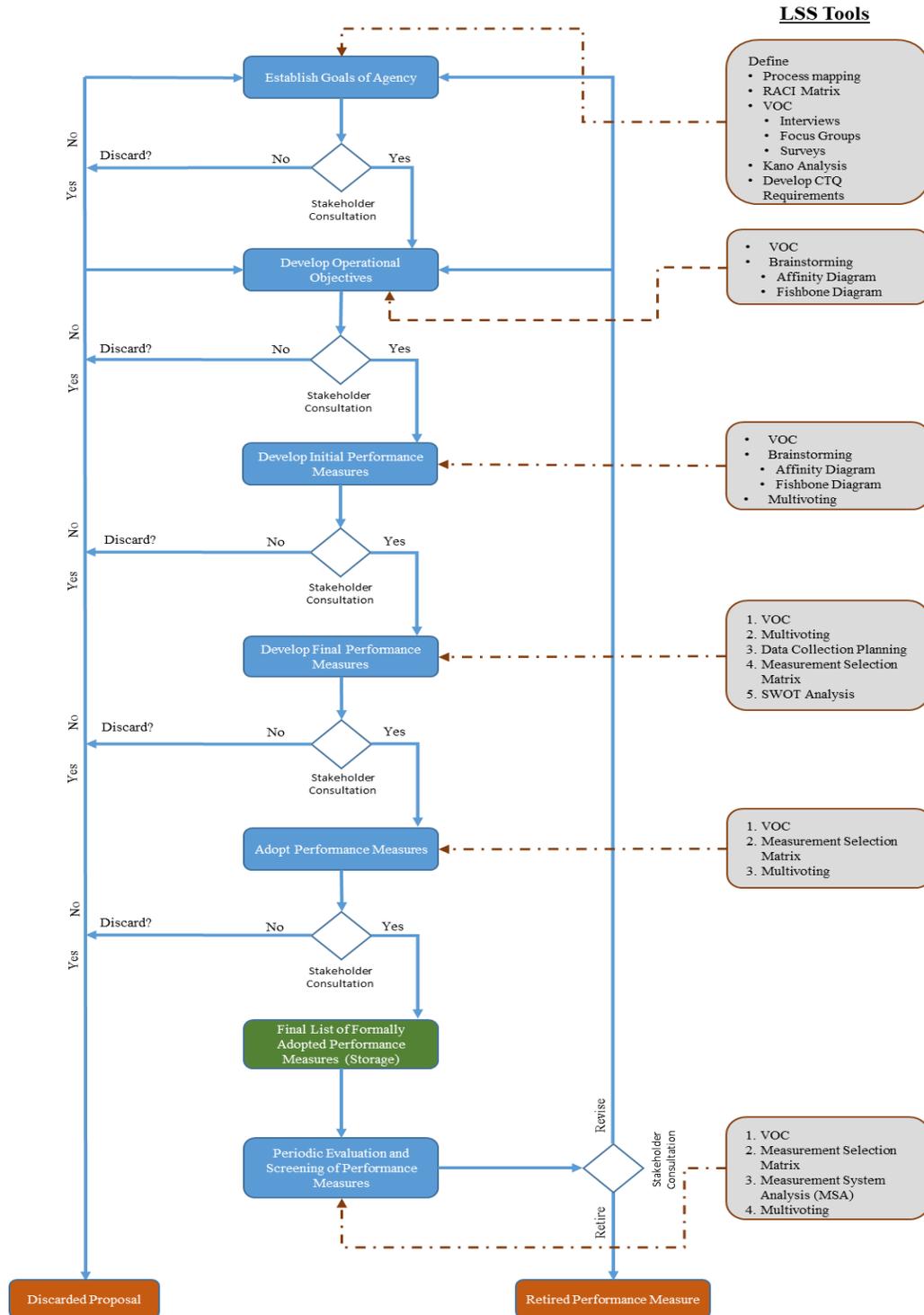


Figure 2. Six-step process for selecting performance measures

The logical steps of the structured six-step framework are establishing organizational goals; developing objectives; developing an initial list of performance measures; developing a final list of performance measures; adopting the final list of performance measures; and periodic evaluation and screening of performance measures, as shown in Figure 2. The proposed structure ensures that each step builds on the previous one, enabling a logical progression that aligns with agencies' goals and facilitating a comprehensive approach.

The proposed structure also includes a few suggested LSS tools and methodologies to support the selection of performance measures. These suggested tools and methodologies are aimed at maintaining a structured selection approach that emphasizes stakeholder engagement, data-driven decision-making, consensus-building, and alignment. Additionally, to facilitate stakeholder involvement and secure common agreement and buy-in for proposals stemming from each step, a stakeholder consultation decision gate is proposed after each step.

Employing LSS tools and methodologies to facilitate decision-making, stakeholders must decide at each decision gate, for instance, (Yes/No) if a proposal is to progress to the next step or an unsupported proposal (No) is outrightly discarded or recycled to step 1 or step 2 for re-evaluation, as shown in Figure 2. The stakeholder consultations at the decision gates ensure that each proposal aligns with organizational goals and objectives.

By following this logical six-step framework, transportation agencies can effectively select, adopt, and manage performance measures that align with their organizational goals and objectives. The following sections discuss each proposed step in detail, along with the LSS concepts that could be applied at each level.

4.2.1 Establishment of Goals.

The first step in the six-step selection process is establishing agency goals, which are usually derived from the strategic vision. Here, thoughts about using established goals are made, recognizing links between transportation and other societal goals (USDOT, 2022; Worth et al., 2010). It is therefore important to involve all stakeholders at all levels, both internal and external. The Define phase of DMAIC is proposed as an LSS strategy.

At the Define phase, a team is tasked with identifying an agency's stakeholders, defining what constitutes value to them, and establishing the key processes that deliver that value (Mandal, 2012, pp. 231-250; Năstase et al., 2024). Primarily, here, a team must establish agency or system goals, prioritize areas for improvement, and assign responsibility to appropriate departments. Proposed LSS tools used in the Define phase to establish the agency goals are listed in Figure 2 and include Process Mapping, RACI Matrix, and VOC. Some of these tools and concepts are briefly discussed in this step, while others are covered in subsequent steps.

Process mapping (flowcharts) can be used to clearly show how various stakeholders contribute to achieving the goals and to provide a basis for evaluating how effectively they contribute to the

goals (Kumar et al., 2021, pp. 1964-1991). The primary benefit of this high-level visual aid at this stage is that it clarifies processes, aligns stakeholders, and helps identify areas for improvement (Akamavi, 2005, pp. 28-53). It can also help identify bottlenecks, streamline processes, and ensure compliance with requirements (Fülscher & Powell, 1999, pp. 208-238; Barbrow & Hartline, 2015, pp. 34-47; White, 2021, pp. 55-67). The SIPOC diagram is an example of a process flowchart that can be used (Murad et al., 2018, pp. 102-107; Kumar et al., 2021, pp. 1964-1991; Hamta et al., 2023).

The RACI matrix can be used to detail the roles and responsibilities of stakeholders associated with activities, describing how each stakeholder contributes to completing tasks, deliverables, or processes (Jackson, 2020). The RACI matrix can help effectively clarify roles and responsibilities throughout the performance management process, reducing confusion and ensuring that all stakeholders know their responsibilities.

The VOC can be used to ascertain what matters to the stakeholders, establish priorities and goals consistent with stakeholder needs, and determine which stakeholder needs can be profitably met. This enables the identification of sublevels of stakeholders with distinct needs or requirements, which is useful when dealing with a moderate-to-large stakeholder base (Aggarwal, 2021, pp. 65-90; Jach et al., 2022, pp. 448-475).

Interviews, focus groups, and surveys can be used to collect VOC. By collecting and analyzing stakeholder feedback, a team can identify areas for improvement, prioritize and enhance services, and gain a competitive edge. Additionally, VOC can help an agency build stronger relationships with its stakeholders during the performance measurement process by demonstrating that their inputs are valued and that the agency is committed to meeting their needs.

Further, CTQ requirements can be developed to define key measurable characteristics of processes or services that are critical to meeting agencies' needs and goals (He et al., 2009; Logan et al., 2019; Mcilroy, 2019, pp. 139-149). By developing the CTQ requirements, a team can transition from vague statements about goals and other information about an agency's performance measurement process to precise functional or service requirements that are most important to stakeholders. Kano analysis can then be used to determine the value or priority to be assigned to each of these requirements (Min et al., 2018).

4.2.2 Developing Operations Objectives.

Unlike goals, objectives are precise and tangible and often expressed in specific metrics or key performance indicators that can be tracked and evaluated over time (Market Business News, 2023; Coleman, 2021). Overall, developing objectives would provide clear direction and focus for activities, establish priorities, and ensure that an agency's performance can be effectively monitored and evaluated. The target here is to develop measurable objectives aligned with the goals from Step 1.

In addition to the VOC suggested in Step 1, brainstorming can be used at this step to resolve specific problems, to analyze data, stimulate creative thinking, and to develop new ideas through unrestricted, spontaneous discussion (Paulus & Nijstad, 2019; Systems2Win, 2021b). Using the brainstorming approach, a wide range of possible objectives for each goal can be developed, evaluated, and refined to determine the best course of action.

The Affinity Diagram can facilitate communication and collaboration among stakeholders in defining the agency's objectives during brainstorming (Widjaja & Takahashi, 2016), while the Fishbone Diagram can help uncover potential root causes, provide a structure for cause identification, and ensure balanced lists of ideas are generated (George et al., 2005; Ilie & Ciocoiu, 2010, pp. 120).

4.2.3 Developing Initial Performance Measures.

Following the establishment of goals and operational objectives, the next step is to develop the initial performance measures based on the agency's requirements. It is not necessary to specify the minimum or maximum number of performance measures to be developed at this step; however, at least one performance measure should be established for each objective. These may be derived from literature reviews or directly from other agencies measuring similar goals.

Besides VOC and brainstorming, multi-voting can be used to narrow the long list of initial performance measures (Hessing, 2023). The narrowing criteria may include how well an initial performance measure aligns with an agency's goals and objectives, whether the initial performance measure is understandable and straightforward, the availability of accurate and reliable data, or how the initial performance measures meet agency reporting responsibilities.

4.2.4 Developing Final Performance Measures.

It is important to limit the number of performance measures that make the final cut at the start of the performance management program, as too many for a given goal area may create conflicts, confusion, and unnecessary work, and may result in measures not being used for decision-making (Oregon Department of Transportation, 2022). Here, the final performance measures can be shortlisted from the initial list based on agreed criteria. The shortlisting criteria that could be applied include ease and cost of data collection and reporting, time frame, sensitivity, and geographic location (Neudorff et al., 2003).

A team may need to determine whether the time frame covered by a performance measure is sufficient to monitor policy plans effectively, provide consistent guidance on needed improvements, and determine whether objectives are being met or whether data can be compared over time. For sensitivity, the team may need to determine whether the measured change in magnitude corresponds to the expected magnitude of the implemented actions. The geographic appropriateness of the performance measure must also be determined for a proposed location or area (Neudorff et al., 2003). Measurement Selection Matrix, SWOT analysis, and Data

Collection Planning can be used, in addition to VOC and multi-voting, as LSS tools at this step to shortlist final performance measures from the previously developed initial list.

The Measurement Selection Matrix can be used to validate and select key measures by assessing which measures are most closely linked to an agency's requirements (Systems2win, 2021a). The critical requirements identified in the previous steps should be prioritized, and an initial list of performance measures should be developed to build the matrix. A team can work through this matrix and discuss whether a strong, moderate, weak, or no relationship exists between a particular measure and a corresponding requirement (goal and objectives). Here, a team can record the consensus reached using numbers or symbols.

The SWOT analysis can help a team evaluate each performance measure based on its strengths, weaknesses, opportunities, and threats, providing a high-level view (Hessing, 2021). It can also be used to evaluate the internal and external factors that affect each performance measure, as well as its current and future potential.

A Data Collection Plan can then be developed to detail the exact steps and sequence to be followed in gathering data for performance management. The purpose of this plan is to ensure that the collected data are meaningful and valid, and that all relevant data are collected concurrently. It also ensures that stakeholders are on the same page regarding data requirements (George et al., 2005; Master of Project Academy, 2021). The output of the data collection planning may, at a minimum, include the measurement selection matrix, stratifications, operational definitions, and SWOT for each performance measure.

4.2.5 Adopting Performance Measures.

Adoption of performance measures may take different procedures; however, this paper recommends formal adoption through a public planning process or by designated management groups. The Minnesota Department of Transportation uses these approaches (MnDOT, 2021). A Measurement Selection Matrix, Brainstorming, Multi-voting, or any other method can be used depending on a team's needs.

4.2.6 Maintenance of a List of Adopted Performance Measures and Periodic Evaluation and Screening.

It is suggested that an agency maintain a formally adopted performance measures list, which must include, at a minimum, the name of the adopted performance measure, a description of the metric, the objective for the performance measure, the methodology for evaluating results; and a description of how and when the measure was adopted, last amended, and, if applicable, retired (MnDOT, 2021). Further, adopted performance measures must be evaluated and screened periodically to assess their relevance and ensure the accuracy of goal, objective, commitment, and priority assessments. It also indicates when to retire a performance measure or reevaluate it.

The evaluation could be annual, but a different duration may be chosen to suit an agency's schedule and needs.

4.3 Case Study: Selection of Performance Measures for the DOTD ITS Program

4.3.1 Background

DOTD Intelligent Transportation Systems (ITS) programs, as of 2020, had no structured performance measurement approach to assess the benefits of implemented strategies. A research project commenced in the third quarter of 2020 by the Louisiana Transportation Research Center (LTRC) aimed at developing performance measures to assess the performance and benefits of these programs (LTRC, 2020).

To facilitate the selection of appropriate performance measures and address related challenges that hamper the setting of clear strategic directions for agencies and effective coordination and collaboration, this project developed and employed the structured six-step performance measurement selection process. Due to COVID-19 and the need to maintain social distancing during the research project phase (August 2020 – July 2022), team meetings and stakeholder consultations were held remotely via email and online meetings.

The following sections summarize a case study of how the structured six-step process was used to develop performance measures, with a focus on the adoption of the final list of performance measures for the ITS program areas. This summarized case study provides an introduction to the structured six-step process and describes how LSS concepts were applied.

4.3.2 Identifying Stakeholders and Establishing Goals of Louisiana DOTD

An eight-member project review committee (PRC) was appointed as a focus group to work with one principal investigator and two project research collaborators. The PRC was composed of DOTD ITS managers, transportation engineers, and representatives from DOTD, FHWA, Freight, and Transit organizations, hereinafter referred to as the project team. Their diverse backgrounds and expertise allowed for a comprehensive review of the ITS improvement initiatives and the identification of potential synergies. A detailed list of roles and responsibilities, describing each stakeholder's contribution, was created using the RACI matrix. This helped define and clarify stakeholders' roles and responsibilities and established vital processes under each stakeholder's control.

Twenty-four (24) goals were identified for Louisiana's ITS program areas from various documents, including the latest versions of Louisiana ITS Strategic Plan (DOTD, 2018), the Louisiana Statewide ITS Architecture (DOTD, 2016), and the National ITS Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) (USDOT, 2020). These goals were assigned to appropriate departments and prioritized in accordance with the strategic vision of the implemented DOTD ITS programs.

A stakeholder consultation was used to discuss all 24 goals identified and to determine whether each goal met the DOTD's vision (Yes/No) or if it needed revision or had to be discarded. Three goals were discarded during the stakeholder consultation due to a lack of feasibility and alignment with the DOTD's strategic vision. The remaining goals were revised and refined to ensure they were realistic, achievable, and in line with the desired outcomes of the DOTD ITS programs.

The process flow for establishing the goals is summarized in Figure 3.

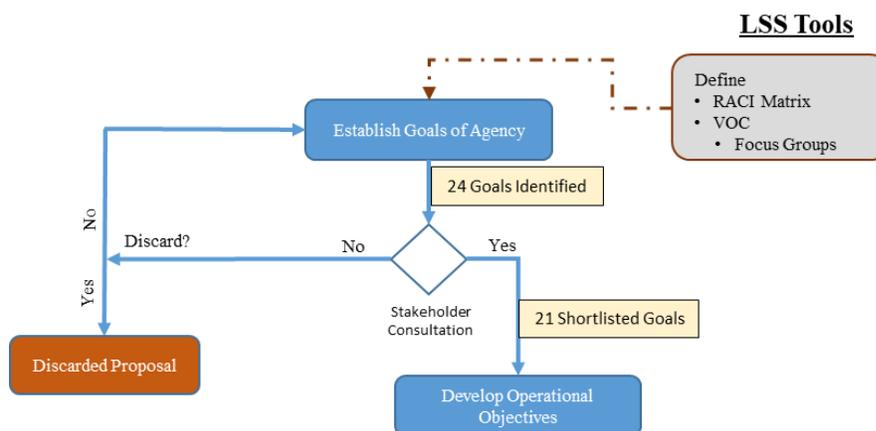


Figure 3. Establishing goals for agency

4.3.3 Developing Operations Objectives

One hundred eighty-eight (188) potential operational objectives that connected to each goal were gathered from the Louisiana ITS Strategic Business Plan, the Statewide ITS Architecture, ARC-IT, and documents from other states' transportation agencies. Using the Affinity Diagram to organize opinions and issues, the brainstorming technique was used to map each goal to one or more operational objectives, ensuring balanced lists of ideas are generated, and major causes are not overlooked.

Again, a stakeholder consultation was used to determine (Yes/No) whether each operation objective was adequately connected to a goal, and whether a particular operational objective needed to be revised or discarded. One hundred twenty (120) of the potential operations' objectives were discarded for reasons including insufficient support for goal assessment.

The process flow of developing the operational objectives is summarized in Figure 4.

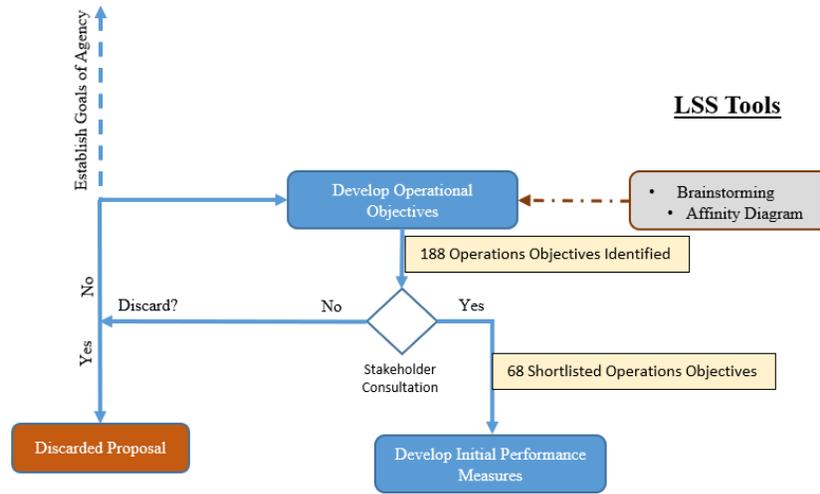


Figure 4. Establishing operational objectives

4.3.4 Developing Initial Performance Measures

Based on the understanding of the goals and objectives of the ITS program areas, at least one outcome performance measure was established and mapped to assess each operational objective using affinity diagrams. Two hundred eighteen (218) initial performance measures were gathered from ARC-IT, literature reviews, a nationwide qualitative survey (Abedi et al., 2023), and other agencies that measure similar organizational goals.

Multi-voting was used to condense and prioritize the large number of initial performance measures into high, medium, and low priorities for each ITS program area, and to decide (Yes/No) which performance measure made it to the final selection and which (No) needed to be discarded or revised further. The criteria employed were based on how a performance measure aligned with the goals and objectives, its understandability and straightforwardness, the availability of accurate and reliable data, and its compliance with the reporting responsibilities for each program area.

One hundred and forty-three (143) of the initial performance measures were discarded. A sample initial performance measure proposal sheet is attached in Appendix A, as Table A. The process flow of developing the initial performance measures is summarized in Figure 5.

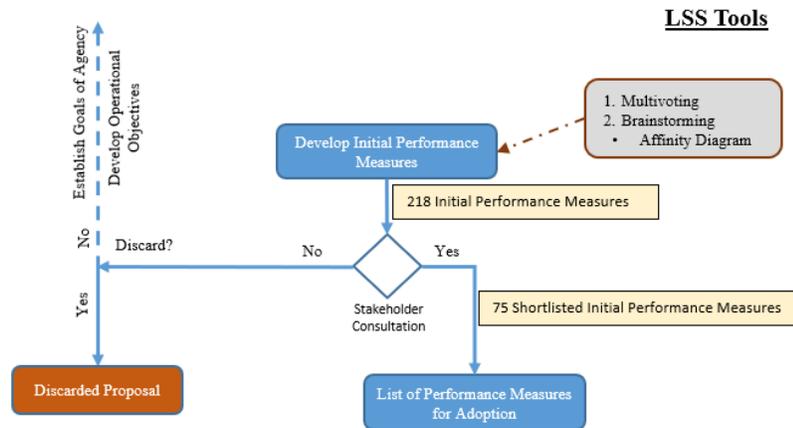


Figure 5. Establishing initial performance measures

4.3.5 Developing Final Performance Measures

Data Collection Planning was used to detail the steps and sequence for gathering data for the 75 shortlisted performance measures. The plan included operational definitions, a list of available data, the required data volume, the geographic location for data collection, and the responsible data collection agency. Using a stakeholder consultation, the measurement selection matrix was employed to shortlist the initial list (Yes/No) by assessing how each performance measure aligned with the agency's overall vision and goals. Fifty-two (52) of the initial performance measures were discarded during the stakeholder consultation for reasons including data unavailability, acquisition costs, and the effort required to process the data.

The process flow of developing the final performance measures is summarized in Figure 6.

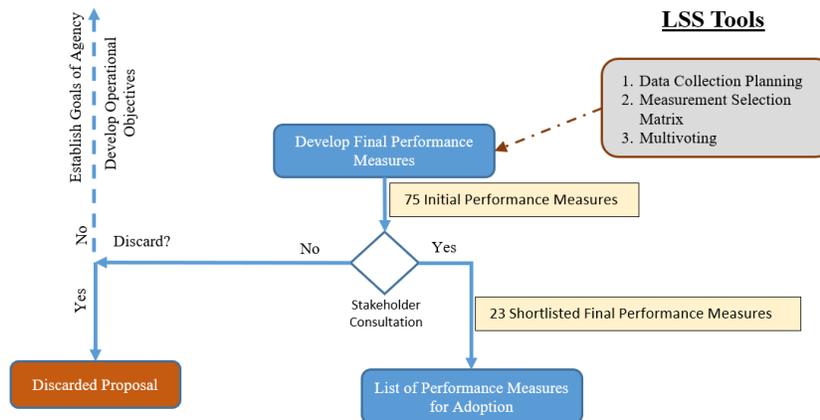


Figure 6. Establishing final performance measures

4.3.6 Adoption of Performance Measures

The final performance measures were adopted through an internal review by the PRC. In its review, the management group critically evaluated the alignment of proposed performance measures with the DOTD ITS program's strategic vision, Louisiana state and federal requirements, ITS department priorities, and public expectations. The group also considered data management requirements and the implications of each proposed performance measure and target for existing DOTD commitments. A data collection matrix, a measurement selection matrix, and brainstorming were employed as LSS strategies to facilitate the process.

Twenty-one (21) performance measures were adopted, which corresponded to 20 specific goals and 16 operational objectives. The final selected performance measures were pilot-tested to evaluate the performance of DOTD's ITS program areas, along with a reporting framework that detailed how data would be collected, reported, and evaluated over time (Thapa et al., 2022).

A copy of the performance measure screening and adoption form is attached in Appendix B, along with other associated forms. The process flow for adopting the final performance measures is summarized in Figure 7.

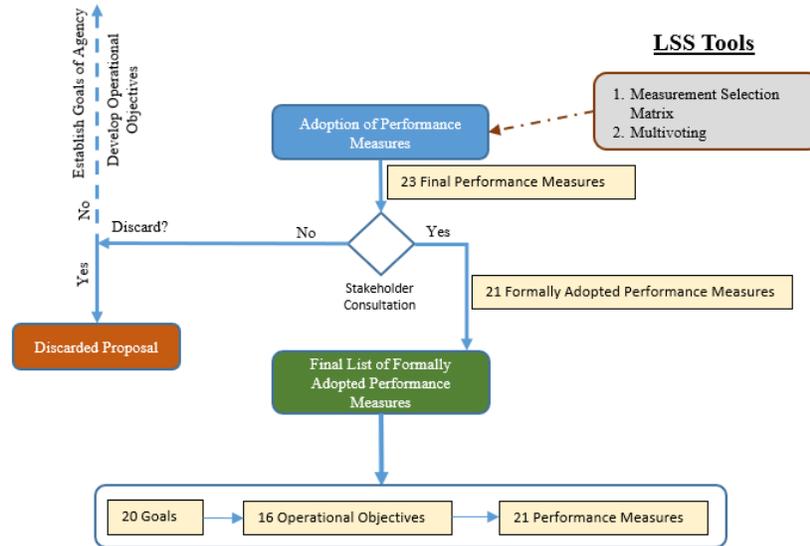


Figure 7. Adopting final performance measures

4.3.7 Lessons Learned from Case Study

Key lessons from the case study included the following:

- Importance of Stakeholder Engagement: Engaging stakeholders throughout the process is critical to ensuring performance measures are relevant to all stakeholders and that there is buy-in at all levels. Early involvement of all relevant stakeholders promotes commitment and

supports data sharing.

- **Flexibility and Adaptability:** The framework needs to be adaptable to a transportation agency's specific context. For instance, the case study highlights the need to be flexible in revising measures as new data and stakeholder feedback become available.
- **Data Quality:** The challenges faced in procuring high-quality data emphasized the need for agencies to invest in data management systems and capabilities. Reliable data is fundamental to effective performance monitoring and decision-making.
- **Continuous Improvement:** The application of LSS principles reinforced the value of a continuous improvement mindset. Regularly revisiting performance measures and making necessary adjustments helps to ensure their ongoing relevance and effectiveness.

By documenting these methodologies and outcomes, the Louisiana DOTD case study serves as a practical example of how a structured approach, combined with LSS principles, can enhance TPM.

4.4 Practical Implications for Other Transportation Agencies

The structured six-step framework for selecting performance measures offers the following significant practical implications for transportation agencies seeking to enhance their TPM efforts.

- **Improved Collaboration and Consensus Building:** The structured framework emphasizes collaboration and communication, engaging stakeholders from the outset. By actively involving diverse groups—such as state DOTs, MPOs, and local agencies—transportation agencies can foster collective ownership of the performance measures. This collaboration helps develop measures that are relevant across different contexts, increases buy-in, and facilitates smoother implementation and adherence to performance management principles.
- **Culture of Continuous Improvement:** Transportation agencies can utilize the iterative cycles characteristic of LSS methodologies to regularly review and refine their performance measures based on evolving data and feedback. Such ongoing assessments ensure that measures remain relevant and practical in driving continuous performance and improvement.

These insights highlight the relevance and usefulness of the proposed methodology in addressing the ongoing challenges faced by transportation agencies.

4.5 Expected Benefits of the Study

The expected benefit of this paper is to provide a structured, six-step performance-measure selection framework, with suggested LSS concepts, to aid TPM implementation efforts. The framework and suggested LSS tools can help improve communication and collaboration among stakeholders by providing a structured approach to selecting performance measures that are relevant and meaningful to setting the strategic direction of an agency or its programs. The case study presented in the paper demonstrates that the proposed methodology can be successfully applied in practice, providing a valuable example for other transportation agencies seeking to improve their performance management efforts.

4.6 Limitations and Directions for Future Studies

The study's execution during the COVID-19 lockdown led to remote stakeholder engagement, limiting the implementation of certain LSS tools and extending the case study timeline. This posed challenges, including diminished team engagement. It also prevented detailed, step-by-step documentation of applying the LSS tools and the quantitative validation of the proposed methodology during the case study.

These limitations, coupled with limited depth in exploring LSS methodologies, may result in varying effectiveness of the proposed framework across contexts. Given these limitations, additional case studies are therefore suggested to unearth and document the benefits of the proposed framework and to identify potential modifications.

4.6.1 Boundaries of Applicability

The findings and recommendations presented in this desk study are primarily applicable to state DOTs and MPOs engaged in TPM. While the proposed methodology demonstrates practical application in the context of the DOTD's ITS program, it does not account for unique regional challenges, regulatory environments, or institutional practices that vary across different states or municipalities. Transportation agencies should therefore consider adapting the framework to their specific contexts, resources, and stakeholder dynamics.

Further, this study's reliance on desk research implies that its findings are heavily reliant on the analysis of existing literature and case studies rather than on empirical data collection. Agencies seeking to implement this framework should also conduct their investigations and stakeholder assessments to confirm the relevance and applicability of the recommended practices to their specific needs.

5. Conclusion

The successful implementation of TPM is essential for enhancing the effectiveness and accountability of transportation systems. This framework not only facilitates standardized performance measurement but also fosters a culture of data-driven decision-making among transportation agencies. Challenges in TPM often stem from a lack of coordination, poor data quality, and varying understandings of performance metrics among stakeholders.

To address these issues, the proposed six-step framework for selecting performance measures, combined with Lean Six Sigma methodologies, serves as a strategic approach to promoting stakeholder engagement and aligning objectives across transportation agencies. The DOTD case study demonstrates the ability of this structured methodology, showing tangible improvements in collaboration and stakeholder buy-in.

By focusing on clear communication and consensus-building around performance measures, this approach enhances managerial insights and ensures that selected metrics are meaningful and

relevant to an agency's goals. Ultimately, this strengthens the overall effectiveness of transportation performance management, paving the way for improved planning, operations, and service delivery within the transportation sector.

This paper highlights a practical approach to overcoming TPM challenges and provides an example for other transportation agencies seeking to improve their TPM efforts. Future research should focus on additional case studies to validate the framework and refine its implementation strategies.

Acknowledgments

The funding support of the Louisiana Department of Transportation and Development (DOTD) is duly acknowledged.

Author Contributions

The authors confirm the paper's contribution: paper conception and design: K. Abedi, J. Lee, data collection: K. Abedi, J. Codjoe, analysis and interpretation of results: K. Abedi, J. Lee, J. Codjoe & V.J. Gopu; draft manuscript preparation: K. Abedi. All authors reviewed the results and approved the final version of the manuscript.

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APPENDIX A

Table A. Initial Performance Measure Proposal Sheet

ITS CATEGORY	Arterial Management
ITS Subcategory	Reliability
General Description	The aim is to reduce travel time variability on arterials, so users experience consistent and predictable trip time.
Performance Measurement (PM) Category	Operations
PM Subcategory	Benefit PM
Reference Number	1.1.1.1
Objectives	Reduce buffer index on arterials during peak and off-peak periods by X percent in Y years
Performance Measure	Buffer index or buffer time
Presentation	Percentage change before and after to be presented. Time-series data to be presented as a line graph
Anticipated Data Need	Travel time
Data Resources and Source	Providers of travel data on freeways, including State DOTs or transportation management centers.
Frequency	Monthly, quarterly, annually, or as preferred
References	MnDOT, ARC-119, Desk Reference [9]
Stakeholder Evaluation Factors	
PM Usage (Select)	local (L), regional (R), state (S), and/or other (O)
Ease of Data Collection (Select)	Low / Medium / High
Cost (Select)	Relative cost of acquiring and analyzing data (Low / Medium / High)
SWOT ANALYSIS	
Strengths	
Weaknesses	
Opportunities	
Treats	
Stakeholder Vote (Select)	YES / NO

APPENDIX B

1. Performance Measure and Target Proposal Evaluation Matrix

For use by management groups reviewing a performance measure or target proposals

Criteria	Evaluation Scale	Notes
Significant to DOTD managers & stakeholders Does the measure or target track something LADOTD and stakeholders consider and understand?	1 2 3 4 5 Low High	
DOTD ability to impact performance Is this a performance measure of something that DOTD can influence over a period?	1 2 3 4 5 Low High	
Alignment with DOTD vision and plans Will progress on this performance measure or target contribute significantly to the achievement of DOTD goals and objectives?	1 2 3 4 5 Low High	
Alignment with existing commitments Do investments required to influence this performance measure align with Louisiana state or federal requirements, existing agency commitments, objectives, priorities, and public expectations?	1 2 3 4 5 Low High	
Data collection and management costs Have the costs to develop, maintain, and report the data for this measure been estimated?	1 2 3 4 5 Low High	
Reporting level and frequency Has the appropriate reporting level and frequency been determined based on who will be in a position to act on a measure and how often they need updated results to make decisions?	1 2 3 4 5 Low High	
Impact on LADOTD communications Has the impact on DOTD communications been considered?	1 2 3 4 5 Low High	
Additional Notes:		

2. DOTD Performance Measure & Target Screening Form

Contact DOTD ITS program office if assistance is required in completing this form.

Submitter Contact Information

Name: Click or tap here to enter text. Date: Click or tap here to enter text.
Division/Office: Click or tap here to enter text. Unit: Click or tap here to enter text.
Phone: Click or tap here to enter text. E-mail: Click or tap here to enter text.

Basic Information about Performance Measure or Target Proposal

1. Is this a proposal to create, amend or retire a measure or target? Check all that apply.

Create New Amend Existing Retire Existing
Measure Measure Measure
Target Target Target

[Empty text box for notes]

2. Performance measure or target name: Click or tap here to enter text.

3. Is the performance measure or target included in or significantly like one contained in the List of Formally Adopted Measures & Targets? Yes No Unsure.

If "like" an existing measure or target, which one? Click or tap here to enter text.

4. Briefly describe the measure/target, the reason for it, and the manner in which it will be used.

[Empty text box for description]

5. Does the performance measure or target directly measure progress toward goals or objectives identified by DOTD ITS Strategic Plan or any other statewide transportation plan? Yes No Unsure.

If yes, which goal, principal, or objective? Click or tap here to enter text.
In what planning document can it be found? Click or tap here to enter text.

6. Does the performance measure or target impact DOTD investment in ITS or the development and improvement of transportation systems? Yes No Unsure.

If yes, please describe the implications. Click or tap here to enter text.

7. Does the measure or target assess the effectiveness or efficiency of DOTD products or services delivered directly to the public? Yes No Unsure.

If yes, which one? Click or tap here to enter text.

3. DOTD Performance Measure & Target Adoption Form

Contact DOTD ITS program office if assistance is required in completing this form.

Contact Information

1. Performance measure owner (unit, office, or division):
Contact name: E-mail:

2. Data owner (unit, division, or office):
Contact name: E-mail:

Measure Description

3. Performance measure:
4. Definition of performance measure:

5. Basic metrics:

6. Measurement methodology:

7. Frequency of reporting and approach:

8. The rationale for selecting performance measure:

Target Description

9. Performance target:
10. Minimum performance threshold level:
11. The rationale for performance target and minimum performance threshold level:

Draft Form

DOTD ITS Performance Measurement Program

Connection to DOTD Decision-Making

12. Do performance measures guide state highway system investments or modal system improvements?

Yes No

If yes, please explain:

13. Is performance measure towards the objective of DOTD ITS strategic plan? Yes No

If yes, please explain:

4. DOTD Performance Measure & Target Revision Form

Contact DOTD ITS program office if assistance is required in completing this form.

Revision Description

1. Performance measure: [Click or tap here to enter text.](#)
2. The proposed revision to performance measures or targets:

3. Reason for proposed change:

4. Describe anticipated costs or impacts associated with proposed revision: