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A GENERALLY APPLICABLE SUSTAINABILITY ASSESSMENT FRAMEWORK FOR TRANSPORTATION AGENCIES

By

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ABSTRACT

The application of the concept of sustainability by transportation agencies is often limited by agencies' understanding of what sustainability means and how it can be integrated into their regular functions. Varying definitions of the term "sustainability" and "sustainable development" can be found in research and literature. The authors of this paper consider "sustainable development" as a process of change toward a more desirable state of the world. This paper presents a flexible approach and framework that will equip transportation agencies with the tools required to understand what sustainability means, incorporate sustainability into their organizational culture, as well as to lay the groundwork for the use of performance measures to progress toward sustainability goals and outcomes. The framework development process was conducted as part of an ongoing research project under the National Cooperative Highway Research Program titled "Sustainability Performance Measures for State Departments of Transportation and Other Transportation Agencies." The proposed framework can be applied/adapted for use in a range of transportation agencies, including state departments of transportation and metropolitan planning organizations. A key feature of this framework is that it moves away from the traditional "sustainable transportation" perspective and instead promotes the consideration of transportation from a holistic "sustainable development" perspective. The framework defines broadly-applicable transportation goals that can be broken down into a menu of objectives and indicators to cover various transportation contexts. The framework is also designed to direct an agency's strategic planning toward the practical implementation of sustainability through performance measurement.

INTRODUCTION

This paper presents research performed under the National Cooperative Highway Research Program (NCHRP) project titled "Sustainability Performance Measures for State Departments of Transportation and Other Transportation Agencies." The goal of this project is to develop guidance for state departments of transportation (DOTs) and other agencies to understand and apply concepts of sustainability through performance measurement to enhance their decision-making, including planning and operations.

The vision for this project is to develop a framework that is flexible and applicable to a range of US transportation agencies. The proposed approach balances the need for addressing sustainability in a holistic manner (i.e., in terms of "sustainable development") with practical considerations that favor a sector-specific approach (i.e., "sustainable transportation"). The framework presents guidance on important sustainability principles, as a first step to understanding the subject. The framework also presents a set of broadly-applicable transportation sustainability goals that can be viewed in conjunction with an agency's strategic goals to enhance the strategic planning process. Another key aspect is the use of focus areas (i.e., transportation agency functions where sustainability can be applied) to further define the context. The practical application of the framework is through a menu of objectives and performance measures related to the sustainability goals as well as to the focus areas.

This research lays the foundation for using performance measures for sustainability by developing appropriate contexts for transportation agencies. There is a need to understand that while sustainability is a concept that reaches across sectors, it has to be translated into steps that can be taken within an agency. By taking into account both a top-down and bottom-up approach, this framework provides a start to tackling the issue of sustainability and making it accessible and relevant.

BACKGROUND AND LITERATURE REVIEW

There are vast amounts of literature covering the subjects of sustainability/sustainable transportation, performance measurement, and the application of sustainability for transportation agencies. Keeping in mind the scope and aim of this paper, this section aims to distill the most important concepts and assemble them in a concise form.

Topics covered include:

- Sustainability and sustainable development;
- Applying sustainability in the transportation sector; and
- Frameworks, indicators, and performance measures for sustainability in transportation.

Sustainability and Sustainable Development

In general, sustainability can be thought of as relating to the holistic consideration of environmental, economic, and social concerns, with a long-term perspective. The term "sustainable development" evolved to link two distinct, yet related concerns – sustainability (fairness with respect to future generations' needs – i.e., preserving the earth's natural life-support systems into the future) and development (more immediate concerns over progress and improvement in living conditions for the present) (*1*).

The emergence of the terms sustainability and sustainable development into common usage can be traced through various global events, conferences, legislation, and publications (*2*,*3*). To this day, however, a majority of work that discusses sustainability inevitably refers to the 1987 report for the United Nations World Commission on Environment and Development

(commonly referred to as the Brundtland Commission report) (*4*). This report is considered a turning point in recognizing that sustainability needs to be addressed comprehensively through coordination among various sectors, and not with a piecemeal approach (*5*). A reason for the popularity of the Brundtland definition of sustainability, as discussed by Jones et al. (*6*), can be attributed to the fact that it presents a broad agenda that even entities with conflicting interests or goals can agree upon. However, the Brundtland work has come in for criticism as being too anthropocentric (i.e., too focused on human development and needs). Alternative eco-centric approaches include the Natural Step Approach framework, postulated by Robèrt (*7*), and the concept of Natural Capitalism (*8*), which views the natural environment as the primary focus of sustainability.

Basic Requirements for Sustainability

Irrespective of the philosophical origins of a framework, some key concepts of sustainability emerge from the literature. How these criteria are addressed/and equated depends on whether a strong or weak approach to sustainability is adopted.

Sustainability Dimensions The dimensions of sustainability (also termed as the pillars of sustainability) are the environmental, economic, and social dimensions. These need to be taken into consideration when following what is termed as a triple bottom line approach to sustainability. Many definitions of sustainability address these three dimensions - for example, "striving for an optimal balance between economic, social, and ecological objectives (*9*)," or "[sustainability]… requirements reflect that social conditions, economic opportunity, and environmental quality are essential if we are to reconcile society's development goals with international environmental limitations (*10*)." It is important to understand that the dimensions do not represent isolated areas of human life but are more like metaphors for a comprehensive approach to judge if development is sustainable overall (*11*).

Relationship between Sustainability Dimensions – The notion of dimensions of sustainable development does not have a strict scientific basis. It is open to interpretation or argument how the dimensions are to be made operational, how their role with regard to one another is perceived, and how trade-offs are to be addressed. One way to relate the dimensions to one another is as a set of nested circles representing economic, social, and environmental spheres. Economic systems are contained within a social framework; similarly, society exists within the natural environment. There are many alternative representations to illustrate the linkages between the three sustainability dimensions, including the three dimensions as intersecting circles or as sides of a triangle (*3*).

"Strong" and "Weak" Sustainability – Also relevant in this discussion is the difference between what are termed as strong and weak approaches to sustainability (*12*). A weak approach to sustainability is one in which trade-offs among various facets of sustainable development (i.e., the dimensions) are considered to be acceptable. In other words, the weak approach views man-made capital and natural resources as interchangeable, without consideration of the finite qualities of the ecosystem. On the other hand, the strong approach views natural capital as the limiting factor. Baker's "ladder" description (*13*) provides a clear idea of the range between what can be seen as an ideal for sustainability (i.e., strong sustainability) and weaker definitions of sustainability, represented by what is termed as the "treadmill" approach. Gudmundsson also

provides a comprehensive discussion of weak and strong sustainability (*1*) stating that a more nuanced approach can be taken to the issue, for example, by identifying certain critical environmental resources that cannot be depleted, as opposed to some that may be substituted or renewed.

Applying Sustainability in the Transportation Sector

Transportation, as a major human activity, is an important consideration for sustainability. When addressing sustainability in relation to transportation, there are two divergent approaches noted among literature and practices – one that is centered on transportation and another that looks at transportation in support of a broader agenda for sustainability (*2*).

Sustainable Transportation – Holistic versus Transportation-Centered View

Using the term "sustainable transportation" can sometimes narrow the scope of the problem being addressed. To quote Greene, "Sustainability pertains to the responsibility of an entire generation of society to future generations; whether it can meaningfully be applied to a single area of human activity such as transportation has been a subject of debate. That is, sustainability must be satisfied by the integral activities of a society and so, in this sense, it is not possible to judge whether one sector of society is sustainable on its own (*14*)."

The core principles of sustainable development, i.e., meeting human needs and improving quality of life; living within the earth's ecological carrying capacity and maintaining/enhancing natural capital; and protecting future generations have been incorporated to varying degrees in several conceptualizations of sustainable transportation (*15,16,17*). In general, sustainable transportation is articulated using the sustainability dimensions (also termed as the three Es – environment, economy, and equity/society/employment) (*18,19,20,21*) and is treated as "*an expression of sustainable development in the transportation sector* (*22*)." A limitation of this conceptualization is that it has the potential to perpetuate the status quo by focusing only on change *within* the transportation sector to the exclusion of change *across* sectors. Thus, it can be argued that the sectoral focus implied by sustainable transportation may limit opportunities for radical technological and societal transformations across several systems/sectors at once (*2*). Thus, an important question is whether it is more beneficial to develop transportation policies from a *sustainable development* (i.e., holistic) rather than a *sustainable transportation* (i.e., transportation-centered) perspective.

Examples of Sustainable Transportation Definitions and Implementation into Practice

As mentioned previously, there is a significant amount of research on sustainability focused on transportation, including attempts by transportation agencies to define sustainable transportation. For example, a commonly cited definition of sustainable transportation was adopted by the European Conference of Ministers of Transport (ECMT) (*23*).The ECMT's definition is based upon an earlier definition created by The Centre for Sustainable Transport in Canada in 1997 (*24*). These definitions are in the form of principles that emphasize basic access needs, human and ecosystem health, equity, affordability, system efficiency, and limiting of emissions and waste.

Banister described a sustainable mobility paradigm involving four primary elements (technology, demand management, integrated land use and transportation planning, and public awareness and acceptance) (*25*). This concept of sustainable mobility was thought of as a broader and more encompassing concept than sustainable transportation, understood to not only

refer to physical movement (i.e., transportation) but also the spatial, economic, and social contexts (*26*).

Another definition of sustainable transportation is that it balances "the need to travel with the need to improve quality of life (*27*)." In the US context, the Committee for the Conference on Introducing Sustainability into Surface Transportation Planning (*28*) defined a sustainable transportation system as "one in which (a) current social and economic transportation needs are met in an environmentally conscious manner and (b) the ability of future generations to meet their own needs is not compromised."

Studies of transportation agencies in the US indicate that while sustainability is not explicitly mentioned in the mission and vision statements of most agencies, a majority of them touch upon sustainability concerns by addressing issues such as the environment, future needs, and social equity (*29*,*30*). In terms of goals for sustainable transportation, past research has indicated that potential objectives and goals of sustainable transportation range from maximizing accessibility, safety, and pedestrian/bike usage, to minimizing ecosystem impact and costs (*31*). More recently, the American Association of State Highway and Transportation Officials (AASHTO) listed a set of 17 goals for sustainable transportation, which include improved accessibility, mobility, and safety, reduced pollution, ecosystem impacts, etc. (*32*). AASHTO also hosted a peer exchange on sustainability, that identified a set of seven focus areas for sustainable transportation, including social well-being and responsibility, material flows and management, energy, fuel and climate, habitat, ecosystems and storm water, economic efficiency, health and safety, and land use (*33*).

A review of the literature indicates that there are certain commonalities among various sustainable transportation initiatives and definitions; these broadly include concerns about environmental impacts, emphasis on safety, affordability, and accessibility of transportation services, etc. There are many challenges involved with evaluating sustainability from a transportation perspective, depending on the scope of the analysis, the level at which it is undertaken, or the agency being considered. A proposed set of principles that capture the essence of sustainable development is provided below:

"Sustainability entails meeting human needs for the present and future, while:

- *Preserving environmental and ecological systems,*
- *Improving quality of life,*
- *Promoting economic development, and*
- *Ensuring equity between and among population groups and over generations"*

The purpose of these principles is to ensure that the transportation sector encourages, supports, and maintains progress toward sustainability. These principles are general in nature, aiming to be inclusive. The description of goals in the next section helps to clarify how the broad sustainability principles translate to transportation.

Frameworks, Indicators, and Performance Measures for Sustainability in Transportation

Organizational Considerations

The lines that delineate traditional transportation agency organizational boundaries and the siloed nature of responsibilities for managing the nation's transportation system often present challenges for practitioners seeking to implement transportation sustainability principles.

Transportation sustainability concerns – such as climate change or economic growth – often extend beyond the organizational boundaries of national, state, and local transportation agencies. Likewise, within an agency, sustainability is influenced by many traditional organizational stovepipes that comprise transportation infrastructure management, which range from planning transportation investment choices to designing infrastructure, or day-to-day operation of transportation facilities. Progress on transportation sustainability depends on the ability of agencies to acknowledge the overlaps that sustainability exposes among their organizational boundaries and their willingness to collaborate across traditional organizational lines – both inside and out. An understanding of the needs of the agencies, of how agencies interact with each other and with other elements outside the transportation sphere, is therefore required.

Applying Performance Measurement for Sustainability

Performance measures (or indicators) are measurable criteria that can be used to evaluate progress toward achieving goals. The generally-applicable performance measurement process can be described as having the following steps (*34*): 1) determine objectives; 2) set targets; 3) measure performance; 4) monitor performance against targets; and 5) evaluate and review process. The outcome of this process can lead into decision-making or actions taken to improve performance.

A question that arises is how sustainability performance measures/indicators differ from other performance measures traditionally used by transportation agencies. Litman and Burwell dtinguish between what are termed as conventional transport indicators and those that can be termed as sustainability indicators (*9*)**.** For example, there is a need to shift from using automobile-centric (and operations-focused) performance measures to assessing indicators that are more holistic, even if they are more difficult to measure. Similarly, Zietsman and Rilett noted the paradigm shift required for capturing sustainability concerns – moving from measuring mobility to accessibility, and from outputs to outcomes (*22*). Thus, while the use of sustainability performance measures and indicators require the same adherence to sound performance measurement principles (i.e., use of relevant measures, based on available data, responsive to trends, etc.), they also need to take into account a broader sense of what sustainability is. This approach is typified by Marsden (*34*) who screened sustainability indicators by considering their relevance to transportation, relevance to sustainability outcomes, as well as whether the indicators were of acceptable quality in terms of desirable characteristics for a performance measure.

There exists substantial literature on sustainability indicators – both general indicator sets and those specifically geared toward the transportation sector. Hall (*2*), Litman (*35*) and Jeon and Amekudzi (*29*) are examples of resources that provide comprehensive summaries of a range of sustainability indicator sets from many US and international organizations.

Comprehensive Sustainability Evaluation through Performance Measures and Frameworks

When creating a complete methodology of sustainability performance measurement that can be utilized by a transportation agency, it is useful to study how performance indicators are combined into frameworks and applied. A framework can be viewed as a formalized system of goals, objectives, and performance measures applied for sustainability. Another aspect of implementation is the creation of methodologies for quantifying or evaluating performance measures, benchmarking the measures or setting targets.

Defining an appropriate framework can help resolve or clarify the issues related to developing an approach to comprehensively evaluating sustainability. Pei et al. (*36*) discussed the validity of various performance measurement frameworks, including those traditionally used in sustainability assessments (such as the triple bottom line) to those usually used in other fields (such as balanced scorecards, performance prism, etc.). The authors also discussed the requirements of robust sustainability frameworks from a transportation perspective, including comprehensiveness, understanding of trade-offs, maintaining linkages with agency goals and objectives, addressing needs of all stakeholders, and being flexible.

While there are many examples of sustainability indicators available in literature, as well as guidance on indicator selection and framework development, there are very few documented examples that move through all phases of the sustainability framework application process – including defining sustainability and applying performance measures. A notable resource promoting this approach is the Performance Measurement Framework for Highway Capacity Decision-Making, or the Collaborative Decision Making Framework (*37*) developed under the Strategic Highway Research Program. Though not explicitly linked to sustainability, it provides guidance to define the appropriate use and formulation of performance measures across the stages of the planning and project development process.

APPROACH TO DEVELOPING A GENERALLY-APPLICABLE SUSTAINABLITY FRAMEWORK

In addition to the literature review and study of general practice, case study interviews were conducted for selected US and international transportation agencies to identify issues, possible approaches, and best practices applicable to the development of the sustainability framework. A preliminary set of 30 case study candidate agencies were reviewed. Further in-depth case studies were conducted for 14 of these agencies, covering a cross section of state DOTs, MPOs, and other transportation agencies.

The term “framework” in this context covers not only the implementation aspects of sustainability, but broader topics as well. This includes informational modules that discuss basic concepts of sustainability and provide an understanding of how they relate to transportation. The framework also includes guidance for transportation agencies to implement performance measures for sustainability. The framework is to ultimately take the form of a guidebook for transportation practitioners. The following points encapsulate the approach to developing a generally-applicable sustainability framework for transportation agencies based on the research team’s consolidated findings and subsequent conclusions and recommendations:

- A distinction is made that sustainability denotes a state to be aspired to, even if it cannot necessarily be reached while sustainable development can be viewed as a process by which sustainability is attained. Here, the two terms are considered as interchangeable for the sake of simplicity.
- While acknowledging the alternative definitions of sustainability, as well as the possible weaknesses of the Brundtland definition, it is proposed to use the Brundtland definition as a starting point for addressing sustainability. Since the definition of sustainability/sustainable development will be contested, a preferred approach would be to note the key components of sustainability and develop objectives and strategies to operationalize them within the relevant system boundaries.

- Sustainability is typically considered to be a combination of economic, social, and environmental progress, usually termed as sustainability dimensions. The issues of future needs (i.e., intergenerational equity) and governance are also relevant.
- It is important to acknowledge the interconnection between sustainability dimensions and to respect that while gains in all areas are desirable there will be trade-offs over time in their achievement. The aim of the framework proposed here is to provide a comprehensive coverage of sustainability issues and ensure that any prioritization is conducted and explained in a transparent manner.
- Growth in well-being rather than pure economic growth is desirable, and this brings in the issue of having a strong versus weak approach to sustainability and to understand the implications of each approach.
- While a holistic approach to sustainability is essential, it does not imply that the concept of sustainable transportation is rendered meaningless. Rather, it means that sustainability in transportation (or sustainable transportation) should be addressed keeping in mind that transportation is one part of a larger system.

The authors believe specific emphasis should be given to the design of *integrated* and *coherent* policies and programs that seek to improve the social, environmental, and economic performance of the transportation sector without negatively affecting the performance of other sectors.

IDENTIFYING COMPONENTS FOR A GENERALLY-APPLICABLE SUSTAINABILITY FRAMEWORK

A key consideration was to have the framework remain comprehensive without introducing cumbersome levels of detail. In identifying components to be included in the sustainability framework, the question to be answered is "*what does a transportation agency need to be equipped with in order to successfully address sustainability issues through performance measurement?"* Keeping this in mind, the basic steps by which a transportation agency can implement sustainability concerns/goals include:

- Understanding the universal principles/concepts of sustainability and using these to lead into a general definition of sustainability;
- Tailoring this general definition to fit the context in which performance measures are to be used; and
- Defining appropriate sustainability goals and objectives, linking performance measures to these goals, and then applying performance measurement.

Four major components were identified as part of the framework: 1) general sustainability principles; 2) goals for sustainability in the transportation sector; 3) framework application guidance; and 4) sustainability objectives and performance measures. The four major components of the framework are described in the following sections of the paper.

GOALS FOR SUSTAINABILITY IN THE TRANSPORTATION SECTOR

The framework presented in this research proposes a set of goals to provide guidance on how to operationalize the general sustainability principles within the transportation sector. Goal-setting is a crucial part of the process, as it allows transportation agencies to deliberate how goals of the organization relate to sustainability. Depending on the transportation agency and its function, the

particular goals prescribed in the framework may or may not be explicitly used as a part of the sustainability performance measurement in their entirety.

"Provide and Protect" Approach to Sustainability Implementation

The approach to implementing sustainability in terms of goals for the transportation sector can be characterized as to "*provide and protect*." This phrase encapsulates what we look for in sustainability – meeting human needs (i.e., *provide*) and ensuring that the environment is adequately safeguarded, and that the interests of vulnerable populations are promoted (i.e., *protect*). This approach is similar to how sustainability is often characterized and enacted across various nations, states, and agencies. For example, the government of Sweden organized its transportation policy in two categories – termed as functional and impact objectives (*38*). As indicated by the name, the functional objectives deal with how the transportation system serves its main functions, while the impact objectives consider broader impacts of the system on the natural and human environment. This characterization (which mirrors the "provide and protect" terminology) helps us understand how sustainability can be addressed by transportation agencies or in the transportation sector – firstly, in how agencies provide transportation facilities and services, and secondly, in how they impact broader issues.

Developing a Recommended Set of Goals

The development of a set of goals is an important part of the process of thinking through what the sustainability principles mean for the transportation sector and for transportation agencies. A set of 11 goals (shown in Table 1) were identified as key goals for transportation agencies to promote sustainability in their activities. The goals were developed based on a review of critical sustainability and transportation issues identified from literature review findings and issues raised by practitioners and researchers during case studies conducted as part of the research project. The development of these goals also took into account how sustainability needs to be addressed both in terms of system function and system impacts. While these goals are broadly relevant to transportation agencies and their functions, it is acknowledged that transportation agencies would wish to review these goals in relation to their own strategic goals and concerns. The goals can be incorporated in a selective manner while applying the framework, as discussed in the description of the goal review process in the next section.

Classification as Functional and Impact Goals

In the approach to characterizing sustainability for transportation agencies, the recommended goals are broadly classified as: 1) functional goals (relating to sustainability in how the transportation system functions – i.e., goals that "provide" and 'ensure") and 2) impact goals (relating to how sustainability is to be considered in terms of the transportation system's broader impacts – i.e., goals that "protect" and "reduce"). This is also shown in Table 1. This approach is also helpful in the goal review process, in which agencies modifying/incorporating goals selectively can use the impact/functional classification of goals to ensure development of a comprehensive goal set for their particular context.

TABLE 1 Listing of Prescribed Goals and Their Classification as Functional/Impact Goals

Functional Goal	Impact Goal
Provide ... *1. a safe transportation system for users and the general public.* *2. a transportation system that offers accessibility that allows people to fulfill at least their basic needs.* *3. options that allow affordable and equitable transportation opportunities for all sections of society.* **Ensure ...** *4. the transportation system's functionality and efficiency is maintained and enhanced.* *5. the transportation system is secure from, ready for, and resilient to threats from all hazards.* *6. the transportation system's development and operation support economic development and prosperity.* *7. the economic feasibility of transportation investments over time.*	**Protect and Enhance ...** *8. environmental and ecological systems while developing and operating transportation systems.* **Reduce ...** *9. waste generated by transportation-related activities.* *10. the use of non-renewable resources and promote the use of renewable replacements.* *11. transportation-related emissions of air pollutants and greenhouse gases.*

These goals also provide transportation agencies with the means to work with other agencies and organizations that have a shared intention or mission with regards to sustainability and transportation. Such organizations can leverage each other's work when it comes to these goals, through cost savings obtained by matching funds, or by working together to reduce the costs relating to public engagement and process costs.

Mapping Goals to Sustainability Principles

As mentioned previously, the above 11 goals were developed based on findings from literature review and case studies. When further broken down into objectives and performance measures, the applicability is retained even for agencies that review and modify the goals as a part of the framework application process.

The criterion for a goal to be included in the proposed set is that it should have a clear relation to at least one principle of sustainability, but it could also reflect more than one principle. The four components of the principles from the previous section can be summarized as:

- Preserving environmental and ecological systems,
- Improving quality of life,
- Promoting economic development, and
- Ensuring equity.

The above four components were used to map the sustainability goals to the principles, as shown in Figure 1 for one example goal. For the first three components, the applicability of the goal to the principles was in the form of a yes/no binary (indicated by a check mark in the figure). Overall, a mapping of the entire goal set to these components indicated a comprehensive coverage of all principles by the goals.

The final component (equity) is seen as a special principle that needs to be an integrated part of the framework. There can, for example, be concerns relating to how the economic and environmental benefits of new transportation initiatives are distributed. However, these equity impacts are often neglected or "traded-off" for economic and environmental gain, even in the traditional triple-bottom line approach to sustainability. Rather than assess applicability as a "yes" or "no" in this case, it was felt that a discussion of each goal with respect to equity is of more value to practitioners. Thus, the last principle is included as "equity and distributional impacts" – in the form of an assessment of the equity or distributional impacts that may be considered important for each goal, both in an intra-generational (i.e., present-day) and inter-generational (i.e., future) context.

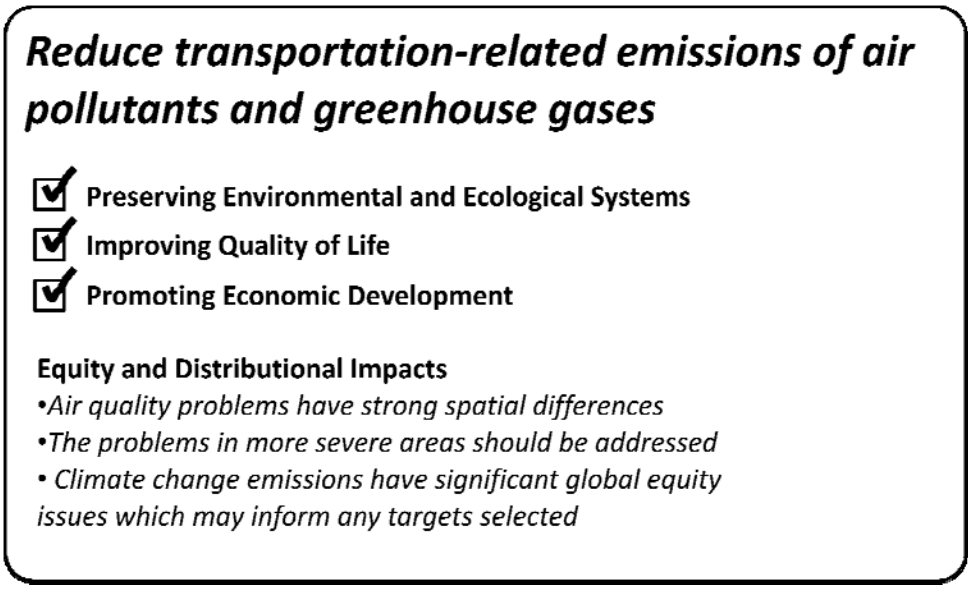

FIGURE 1 Example of mapping of goals to principles.

In applying this framework it is important to accept that some goals may not apply to some agencies or may have radically different importance within different local contexts. Specific local goals may need to be added, while others in the proposed goal set may not be included. It is anticipated that the goal review process would help agencies justify their selected goals, and explain clearly the rationale for and connection to the principles of any new or additional goals. This is explained in detail when discussing the application of the framework.

APPLICATION OF THE FRAMEWORK – TURNING PRINCIPLES AND GOALS INTO PERFORMANCE MEASURES

A step-wise process is anticipated to interpret the sustainability principles and goals into performance measures which work in different application areas within an agency. The main steps in the process of framework application are as follows:

1. Develop an Understanding of Sustainability
2. Goal Review
3. Framework Application – Focus Areas and Business Units
4. Framework Application – Whole Agency

These steps are not completely sequential, in that many involve feedback loops and cross-checking between steps for proper implementation of the framework. These are shown in the proposed framework layout shown in Figure 2 below. Each of the steps is then described in further detail.

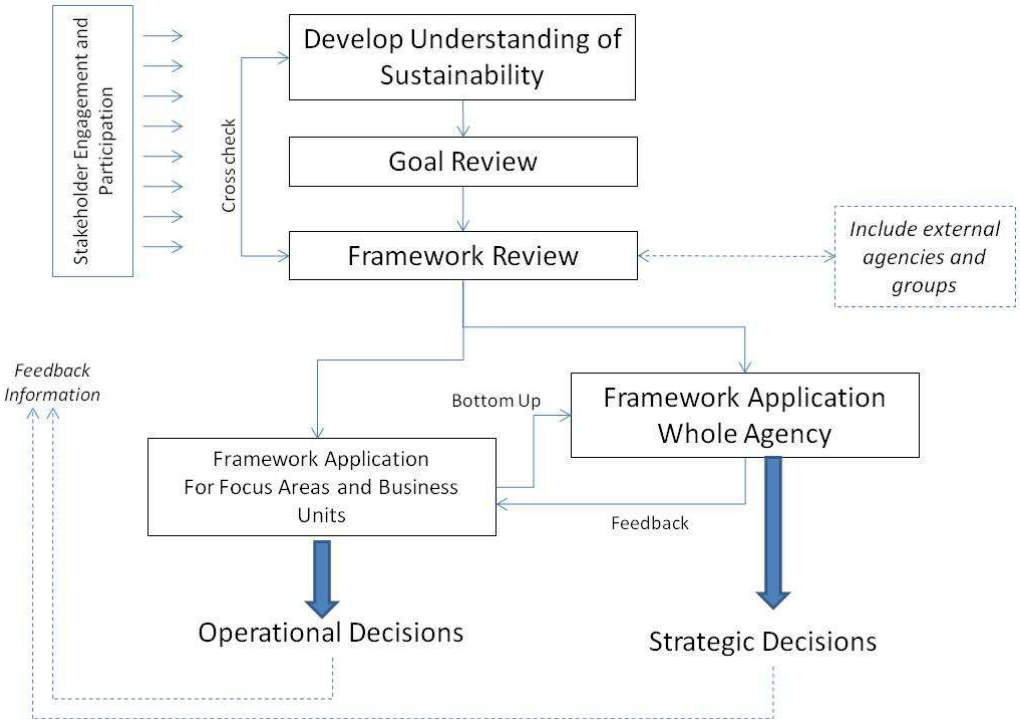

FIGURE 2 Proposed framework layout.

1. Develop an Understanding of Sustainability – The organization should understand the principles and debate how they relate to their context and their specific organization.

2. Goal Review – The set of 11 goals described in the previous section may not be applicable in their entirety to a particular agency. Agencies should review the goals against their own remits and the strategic goals which they are being asked to support and deliver. Goals can be added and their linkages to the principles given due consideration, especially of the extent to which equity issues are important. Agencies should also ensure that both functional and impact goals are a part of the final goal set.

Since the final set of goals developed will be transportation-focused, it is important that agencies still keep in mind the holistic nature of sustainability issues. For example, if agencies find they are restricted from addressing important aspects of sustainability, this highlights the need for inter-agency cooperation to ensure that the goal is being adequately covered and monitored elsewhere. While this is not an issue that can directly be addressed within the framework, it is still necessary for agencies to understand the bigger picture issues, and to think and work in a holistic manner.

A few additional comments on the goal review process are provided below:

- When goals are omitted or realigned, the agency should attempt to maintain a goal set that is representative of all aspects of the sustainability principles, and provide explicit reasoning and justification for over-representation or the lack of representation of certain principles in the set of goals.
- As part of the goal review process, organizations should develop clear directions of change for their goals and include a transparent statement about how the equity impacts of their policies are being considered.
- It is recommended that the goal review process be given adequate consideration in the application of the framework, as the goals are considered to be critical in developing agency-level directions for sustainability. These goals can then be applied in the framework for specific areas within the agency, or for the agency as a whole.
- It is possible to apply the framework while bypassing the development of goals by directly linking performance measures to sustainability principles. It can be argued, however, that the development of goals is still implicit to this process. Therefore, the use of the following hierarchy: sustainability principle -> sustainability goal -> sustainability objective/performance measure is preferred. In this hierarchy, the goals relate to the entire agency, while objectives and performance measures may be specific to only particular aspects of an agency's functioning.

3. Framework Application – Focus Areas and Business Units – The application of the framework within the various operational arms of the agency will vary quite significantly. The proposed framework considers this in terms of two elements – termed as focus areas and business units. The focus areas are broadly defined generic categories applicable to transportation agencies (for example, operations or planning). Business units refer to specific divisions or sections in an agency that might be tasked with implementing performance measurement for sustainability in their particular area. The boundaries of a particular business unit may or may not coincide with the focus areas prescribed in the framework. The application of the framework and selection of performance measures need to take both these elements into account.

Specific business units should identify which of the goals they contribute to. This performs two roles. First, the whole agency sustainability manager can understand which business activities impact which goals. If no activities impact on a specific goal then it may be that core business activities are not being interpreted broadly enough or that the goal may have little organizational relevance and might be removed. So, for example, the street lighting section may have strong connection only to goals related to non-renewable energy and safety. Construction activities may focus on waste generation, emissions, and environmental protection. The goals will be subject to performance indicators which are specific to that business unit. There will therefore be multiple performance indicators across the organization that are contributing toward the achievement of the goals. Some standardization will be necessary and desirable (for example in carbon footprint calculation) and must be addressed as relevant.

4. Framework Application – Whole Agency – The application of the framework for a whole agency can include top-down applications that look at the various focus areas or business units,

as well as the development of strategic direction on sustainability for the agency as a whole, as described below:

- Performance measurement and reporting across focus areas and agency divisions can also help identify areas for improvement. The agency's approach and understanding of the implementation of sustainability is developed and improved (by iteration) through interaction with the business units, for which a clear reporting framework needs to be established.

- It is also important for the framework to influence important strategic decisions rather than just the detailed implementation practices at the business unit level. This can be done for example, through the development and application of sustainability reporting scorecards which are supplied and discussed as part of all major board level decisions. This approach is used in the UK Highways Agency.

Figure 2 also includes a "framework review" step, between the goal review and framework application sections. As mentioned in the previous section on the development of sustainability goals, the framework review provides the opportunity to include external agencies and groups in the review process. These entities can help the agency search for potential avenues for collaboration that can save costs, pool resources, and share expertise/knowledge in the case of multiple agencies working toward common sustainability goals. As shown in Figure 2, stakeholder participation is necessary in understanding sustainability, developing the goals, and reviewing the framework.

The framework application, resulting in operational and strategic decisions does not represent the termination of the sustainability assessment and performance measurement process. Feedback information on whether the decisions are leading to the desired/intended outcomes is an essential part of the process, and must lead to refinements being made to the framework application to ensure continual improvement. Another aspect of the framework targeted at the strategic level could be the decision to develop an agency-wide definition or statement on sustainability. It is proposed to include guidance on this topic in the form of additional material in the finalized framework.

SUSTAINABILITY OBJECTIVES AND PERFORMANCE MEASURES

The aim of this section is to provide a menu from which performance measures can be selected for use in the framework application process. This takes the form of a matrix of objectives and indicators covering the 11 goals. The role of the objectives is to further define how goals can be linked to targets and outcomes in specific focus areas, with appropriate indicators and performance measures linked to each objective.

The matrix of objectives and performance measures are organized to cover five focus areas:

- Planning
- Programming and Project Development
- Construction and Maintenance
- System Operations
- Organization and Administration

The contents of this matrix will help with the selection of performance measures, as well as in the development of new performance measures when necessary. The main concept here is that a transportation-sector sustainability goal can translate into different objectives and measures according to the focus area under consideration. An example is provided in Table 2, again for the goal relating to air pollutants and greenhouse gases. The example lists one potential objective and related indicators per focus area, and is meant to illustrate how objectives and indicators targeting the same goal may differ in terms of scope and coverage. Only the first four focus areas are covered in this manner - the final focus area (organization and administration) is considered to be an overarching category for which objectives and indicators will not necessarily be goal-specific.

TABLE 2 Potential Objectives and Indicators (by Focus Area) for an Example Goal

GOAL - REDUCE TRANSPORTATION-RELATED EMISSIONS OF AIR POLLUTANTS AND GREENHOUSE GASES		
FOCUS AREA	***EXAMPLE OBJECTIVE***	***POTENTIAL INDICATORS***
Planning	**Promote land use compactness, density, and balance of interacting uses**	• travel distances between interacting land uses • floor area ratio • population per square mile • jobs per square mile • labor force/jobs balance
Programming and Project Development	**Promote use of non-motorized modes**	• Planned route or service miles of: transit routes, pedestrian facilities, designated bike facilities, • population within one mile of transit, • person-miles walk distance to transit stops • person-miles distance from building entrances to public pedestrian facilities (sidewalks, pedestrianways), • connectivity index: (pedestrian facilities, bike facilities, transit)
Construction and Maintenance	**Reduce adverse impact on traffic operations (lane reductions, traffic interruptions, detours, night operations)**	• reduction in peak hour/period capacity • vehicle or person hours of delay, • extra VMT generated, • percent of passing VMT affected by construction/ maintenance operations
System Operations	**Reduce congestion-related emissions**	• percent of VMT at low emission speed ranges, • total vehicle delay, • percent of approaching traffic that is stopped • multimodal level of service (by mode)

The completed matrix will contain multiple example objectives and indicators presented in a similar manner to Table 2, covering all goals and focus areas. Further information, including translation of indicators to specific performance measures, units of measure, computation methods, and data will also be included. In addition to the focus areas, further context will be established in the objectives and performance measures by addressing issues such as area type,

environment (natural and built), and users. It should be noted that some objectives and indicators may overlap between focus areas, and there is the possibility of having indicators and performance measures that may be used in a cross-cutting manner or for multiple purposes.

On completion of the goal and framework review steps in the framework application, the contents of this matrix can guide in the selection of appropriate performance measures, as well as in the development of new objectives and measures if necessary for goals that are not covered in the set of 11 proposed goals. It is to be noted that certain business units in an agency might find the above focus areas not completely aligned with their structure – but due to the differences among the structure of DOTs and other agencies, this is not addressed in the organization of the matrix. It is recommended that agencies address these overlaps by selecting objectives and performance measures from multiple focus areas as necessary.

FRAMEWORK IMPLEMENTATION

The previous sections outline the approach a transportation agency could use to apply the framework in practice. This includes developing an understanding of sustainability, identifying appropriate sustainability goals that are also relevant from a sustainability perspective, and identifying suitable objectives and performance indicators or measures to operationalize the process for selected focus areas and business units. Additionally, the application of the framework for the agency as a whole can also aid in aligning an agency's strategic planning and direction to be in line with sustainability considerations.

Prior to implementing the framework, a thorough review of the framework is desirable to ensure a comprehensive and robust approach to sustainability. The framework review process should examine the goals, along with selected objectives and performance measures to determine if satisfactory coverage of the principles is achieved. Agencies must use the opportunity to collaborate with external agencies in a synergistic manner. Stakeholder input is also a vital part of the framework development process. The overall shape of the framework should be studied to ensure that each of the principles is covered and that the coverage is not disproportionately weighted to one principle. It should be reflected and explained explicitly if there is a purposeful emphasis/de-emphasis on some principles. The whole agency sustainability strategy should be described and developed around this set of top level principles and goals. Upon implementation of the framework, feedback based on the outcome and effectiveness of resulting decisions should drive further refinements to the framework.

CONCLUDING REMARKS

This paper outlines the foundation for a framework that will enable transportation agencies to integrate the notion of sustainability into their decision-making. The authors believe specific emphasis should be given to the design of integrated and coherent policies and programs that seek to improve the social, environmental, and economic performance of the transportation sector without negatively affecting the performance of other sectors.

The approach and framework presented here addresses the critical bridge between the seemingly abstract concept of sustainability to the everyday practice of transportation planning and system management. Through a clear step-by-step framework, transportation agencies and practitioners can understand sustainability, develop context-appropriate goals and objectives, and apply performance measures to incorporate sustainability considerations into their activities.

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REFERENCES

1. Gudmundsson, H. *Sustainable Mobility and Incremental Change – Some Building Blocks for IMPACT*. WP2 IMPACT, TransportMistra, Sweden, 2007.

2. Hall, R. P. Understanding and Applying the Concept of Sustainable Development to Transportation Planning and Decision-Making in the U.S." Ph.D. Dissertation, MIT, 2006.

3. Kelly, C. *Origins of Sustainability*. Report for Task 1.1, Appraisal of Sustainability Project Report, Institute for Transport Studies, University of Leeds, Leeds, UK. Working Paper. http://www.its.leeds.ac.uk/projects/sustainability/project_outputs.htm

4. U.N. World Commission on Environment and Development. *Our Common Future: Report of the World Commission on Environment and Development* (A/42/427). 4 August 1987.

5. Clayton, A., and N. Radcliffe. *Sustainability: A Systems Approach*, Westview Press, Boulder, Colorado, 1996.

6. Jones, C., M. Baker, J. Carter, S. Jay, M. Short, and C. Wood. *Strategic Environmental Assessment and Land Use Planning: An International Evaluation*, Sterling, VA: Earthscan, London, 2005.

7. The Natural Step. http://www.naturalstep.org/the-system-conditions. Accessed November 25, 2009.

8. Hawken, P, A. Lovins, and L. H. Lovins. *Natural Capitalism: Creating the Next Industrial Revolution, 1st Edition*. Little, Brown, and Co., Boston, 1999.

9. Litman, T., and D. Burwell. Issues In Sustainable Transportation. *Int. J. Global Environmental Issues*, Vol. 6, No. 4, 2006, pp. 331-347.

10. Mihelcic, J. R., J. C. Crittenden, M. J. Small, D. R. Shonnard, D. R. Hokanson, Q. Zhang, H.Chen, S. A. Sorby, V. U. James, J. W. Sutherland, and J. L. Schnoor. Sustainability Science and Engineering: The Emergence of a New Meta-Discipline. *Environmental Science and Technology*, Vol. 37, No. 23, 2003, pp. 5314-5324.

11. For a more detailed discussion of these dimensions of sustainable development, see Gudmundsson, H.. *Sustainable Mobility and Incremental Change – Some Building Blocks for IMPACT*. WP2 IMPACT, TransportMistra, Sweden, 2007.

12. Turner, R. K. *Sustainable Environmental Economics and Management: Principles and Practice*. Bellhaven, London, 1993.

13. Jones, C., M. Baker, J. Carter, S. Jay, M. Short, and C. Wood. *Strategic Environmental Assessment and Land Use Planning: An International Evaluation*, Sterling VA: Earthscan, London, 2005.

14. Greene, D. L. Sustainable Transportation. pp. 15335-39 In Baltes, Paul B. and Smelser, N. J. (eds.). *The International Encyclopaedia of the Social & Behavioural Sciences*. Elsevier Science Ltd., Oxford, 2001.

15. Holdren, J. P., C. Daily, and P. R. Ehrlich. The Meaning of Sustainability: Biogeophysical Aspects. *Defining and Measuring Sustainability: The Biogeophyiscal Foundations*, M. a. S. Munasinghe, W. (ed.), World Bank, distributed for the United Nations University, Washington, D.C., 1995.

16. Rees, W. E. Achieving Sustainability: Reform or Transformation? *Journal of Planning Literature*, Vol. 9, No. 4, 1995, pp. 343-361.

17. U.N. World Commission on Environment and Development. *Our Common Future: Report of the World Commission on Environment and Development* (A/42/427). 4 August 1987.

18 . Button, K. *Transport, the Environment and Economic Policy*. Edward Elgar, Aldershot, 1993.

19. The Centre for Sustainable Transportation (CST). *Definition and Vision of Sustainable Transport.* CST, Ontario, October 2002.

20. *Organisation* for Economic Co-operation and Development (OECD). *Environmentally Sustainable Transport: Futures, Strategies and Best Practice.* Synthesis Report of the OECD project on Environmentally Sustainable Transport EST. Organisation for Economic Co-operation and Development (OECD), Paris, 2000.

21. Transportation Research Board (TRB). *Toward A Sustainable Future: Addressing the Long-Term Effects of Motor Vehicle Transportation on Climate and Ecology*, National Academy Press, Washington, D.C., 1997.

22. Zietsman, J., and L. R. Rilett. *Sustainable Transportation: Conceptualization and Performance Measures*. In Report SWUTC/02/167403-1, Southwest Region University Transportation Center, Texas A&M University, College Station, March 2002.

23. European Conference of Ministers of Transport (ECMT). Assessment and Decision Making for Sustainable Transport. Organization of Economic Coordination and Development, 2004.

24. The Centre for Sustainable Transportation (CST). *Definition and Vision of Sustainable Transport.* CST, Ontario, October 2002.

25. Banister, D. The Sustainable Mobility Paradigm. *Transport Policy*, Vol. 15, No. 2, 2008, pp. 73-80.

26. Gudmundsson, H. Making Concepts Matter: Sustainable Mobility and Indicator Systems in Transport Policy. *International Social Sciences Journal*, Vol. 176, 2003, pp. 199-217.

27. Ferrary, C. and H. Crowther How Realistic Are Sustainability Appraisals? A Review of Research on the Transport Implications of Regional Policies for Yorkshire and Humber. *3rd Transport Practitioners Annual Meeting*, Aston University, 6th July 2005.

28. Black, W. R. Sustainable Transport: Definitions and Responses. *Integrating Sustainability into the Transportation Planning Process*, Conference Proceedings 37, Committee for the Conference on Introducing Sustainability into Surface Transportation Planning, July 11-13, 2004, Baltimore. Transportation Research Board, Washington, D.C., 2005, pp. 35-43.

29. Jeon, C. and A. Amekudzi. Addressing Sustainability in Transportation Systems: Definitions, Indicators, and Metrics. *Journal of Infrastructure Systems*, ASCE, March 2005. pp. 31-50.

30. University of Washington: State DOT Mission Statements http://pavementinteractive.org/index.php?title=UW:State_DOT_Mission_Statements. Accessed February 2010.

31. Zietsman, J. *Incorporating Sustainability Performance Measures into the Transportation Planning Process*. Ph.D. Dissertation, Texas A&M University, December 2000.

32. AASHTO Center for Environmental Excellence. American Association of State Highway and Transportation Officials. http://environment.transportation.org/environmental_issues/sustainability/#bookmarksubGoalsforTransportation. Accessed February 2010.

33. CH2M Hill and Good Company. *Sustainability Peer Exchange: Transportation in Service of a Sustainable Society.* Summary Report, June 29, 2009. Prepared for the Center for Environmental Excellence, American Association of State Highway and Transportation Officials. From the Sustainability Peer Exchange, Gallaudet University Kellogg Conference Center, Washington, D.C., May 27-29, 2009.

34. Marsden, G. Monitoring Across Sectors and Spatial Levels for Sustainable Transport: A Good Practice Guide. Available at www.distillate.ac.uk Accessed July 2010.

35. Litman, T. *Well-Measured – Developing Indicators for Comprehensive and Sustainable Transport Planning*. Victoria Transport Policy Institute, Victoria, British Columbia, Canada, 2009.

36. Pei, Y. L., A. A. Amekudzi, M. D. Meyer, E. M. Barrella, and C. L. Ross . *Performance Measurement Frameworks and the Development of Effective Sustainable Transport Strategies and Indicators*. Georgia Tech University. Presented at the 89th Annual Meeting of the Transportation Research Board, 2010.

37. SHRP 2 Performance Measurement Framework for Highway Capacity Decision Making http://shrp2webtool.camsys.com/ Accessed July 2010.

38. *Overall Objective of the Swedish Transport Policy*. Ministry of Enterprise, Energy and Communications, Stockholm, May 14, 2009.