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Public Health Assessment for Transportation Projects

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16. Abstract

Transportation projects can affect health through multiple pathways, e.g., by degrading air quality or encouraging active transportation. There is a need to incorporate health considerations in transportation decision making to achieve health-related community goals. The objectives of this research project were to assess the state-of-the-practice on incorporating health in transportation decision making, primarily through project prioritization processes, and to propose health-related criteria that can be included in the Massachusetts Department of Transportation's highway project prioritization scoresheet. Information was obtained through an extensive review of publications and interviews with state departments of transportation, state departments of public health, and metropolitan planning organizations. General health assessment methods and tools used in practice, as well as prioritization processes, performance measures, models, and datasets utilized to assess health-related criteria, were investigated. This information guided the development of eight new criteria related to air quality, accessibility, equity, physical activity, and safety that are recommended for incorporation in the Massachusetts Department of Transportation highway project scoring process. The research also identified existing collaborations between departments of transportation and public health, as well as research needs and challenges related to incorporating health in transportation decision making.

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Public Health Assessment for Transportation Projects

Final Report

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Executive Summary

Transportation affects health through various pathways, including air quality, accessibility, equity, physical activity, and safety. The Massachusetts Department of Transportation (MassDOT) has been a pioneer in recognizing the connection between transportation and health since its onset in 2009. The department's efforts have materialized through the introduction of the Healthy Transportation Compact in 2009 and the Healthy Transportation Policy Directive in 2013, which have established health-related design guidelines that must be adhered to more broadly. In addition, federal requirements such as the Moving Ahead for Progress in the 21st Century Act and the Fixing America's Surface Transportation Act require that plans be performance based, utilizing performance measures data for several categories including operations, safety, and air quality.

The importance of incorporating health in transportation planning and decision-making has also become apparent through recent federally supported efforts to identify research gaps associated with health-related performance measures and other challenges at the intersection of transportation and health, as well as to develop a research roadmap for transportation and health. As a result, it is evident that there is a need to account for health outcomes in transportation decision making and performance evaluation.

The objectives of this project are to:

1. Identify health assessment methods and decision-making processes used for transportation projects, with an emphasis on project scoring criteria, performance measures, data, and models that can be used by MassDOT to assess the impact of transportation projects on health outcomes.
2. Develop project scoring criteria that can be readily incorporated into MassDOT's Highway Division project prioritization process. This includes definition of performance measures, criteria standards, and data needs.
3. Recommend specific topics and relationships that should be further investigated.

Methodology

The project performed both a comprehensive review of published literature and interviews with 14 agency representatives from state departments of transportation (DOTs), departments of health (DPHs), and metropolitan planning organizations (MPOs) to understand existing practices for including health in transportation decision making. The information that was gathered was critical for identifying important health outcomes that were not considered in the current version of the MassDOT Highway Division project scoring process and proposing and updating criteria that could capture some of these pathways connecting transportation and health.

Health Impact Modeling Tools

In recognition of the need to relate changes of the built environment and transportation system operations to health outcomes, several health impact modeling tools have been developed. These tools report outcomes in health impact metrics such as mortality, morbidity, and disability-adjusted life years and, in some cases, also include economic metrics such as willingness to pay and monetary cost of health outcomes (e.g., reductions in mortality). A review of these models has revealed that they rarely account for accessibility and never for equity. Many of them just focus on assessing impacts for one of these factors or are capable of only assessing changes related to limited modes, e.g., walking and biking projects. In addition, extensive calibration efforts required as well as restrictions in area resolution that they are applicable for (some are applicable at the Census Tract level and some at the regional level) limit their feasibility in assisting with decision making and project scoring.

Health Impact Assessment

Health Impact Assessment (HIA) studies utilize multiple models, tools, and other qualitative and quantitative techniques to study the health impacts of projects, plans, and policies in an effort to understand health implications, engage the affected populations, and guide decision making toward health-improving policies, plans, and projects. HIAs have been successful in connecting transportation and health professionals and improving awareness of health issues, but their actual impact on transportation decision making remains limited to a few cases. Their success in influencing decisions is highly dependent on the involvement of interested stakeholders, the proper timing and alignment with preset goals, as well as the availability of resources. Consistency in HIA methodology and documentation of outcomes have also been listed as ways to improve success rates for HIAs. Overall, while being comprehensive in that they capture multiple pathways through which transportation affects health, HIAs have several limitations. They are resource-intensive and expensive and are, therefore, most frequently implemented for single projects when evaluation of alternatives is of interest. As a result, HIAs are not appropriate for scoring multiple projects to assist with budget allocation decisions. Reliance of HIAs on single grants deters continuous tracking of impacts, while lack of institutionalization restricts their widespread implementation.

Project Scoring and Prioritization

An alternative way to incorporate health in transportation decision making is through project scoring and prioritization processes. Such processes have been developed by many state and regional agencies in an effort to ensure transparency in decision making and to satisfy federal requirements for performance-based transportation planning. Recent efforts have directly considered the impacts of transportation and health and have incorporated relevant criteria. Overall, the review of eight project scoring and prioritization frameworks revealed that:

- Project scoring and prioritization frameworks consist of various categories of scoring criteria, e.g., mobility, safety, economic impact, etc., each of which is weighted by a certain value.
- The magnitude of the measure and weighting factors used significantly affects the final scoring outcome and types of projects that tend to be funded.
- Normalization is a common way to addresses differences in measure magnitudes when absolute values are utilized. Monetization of benefits that accounts for project size can also be considered to ensure fair comparisons among projects.
- Accessibility is the second most common health-related factor, after safety, that is included in project scoring and prioritization frameworks.
- Air quality criteria also exist in most of the reviewed project scoring frameworks but, in their majority, focus on climate change through GHG emission-related measures.
- Equity is addressed through criteria developed to assess whether improvements in transportation will benefit disadvantaged populations.
- Physical activity is not commonly assessed in a direct way; rather, it is assessed indirectly based on the existence of active transportation or complete street elements.
- Safety is always captured and assessed based on quantitative criteria (e.g., crashes, crash rates); however, the impact of proposed improvements is often hard to capture.
- It is common for agencies developing these frameworks to have a workgroup that provides recommendation on the scoring process and reviews scoring of project.
- While the rankings produced by these project scoring frameworks are the basis for funding decisions, they are not binding in any of the reviewed cases.
- Documented outcomes are encouraging in that adjustments made to scoring criteria in an effort to improve health do translate into higher numbers of low-cost projects focused on improving active transportation and, therefore, health.
- Overall, changing project scoring criteria is seen as a very cost-effective way of incorporating health in project prioritization and decision making.

Recommendations for developing or updating a project prioritization framework include the following:

- Project scoring processes should be developed for transparency and, therefore, be easy to understand.
- First, issues that are of most importance to a state or region should be identified, and scoring criteria should be adjusted to reflect those priorities. This could result in higher public acceptance.
- Project scoring should be applicable to all types of modes.
- Caution is recommended when assigning weights to different criteria or factors to avoid disproportional impacts of criteria weights on the total score. Different weighting factors should be considered for different areas and districts, potentially areas with different socioeconomic characteristics or needs.

Caution is also needed when assigning ranges of values and determining the lowest and highest values that can potentially be assigned to a criterion, as well as when normalizing such values to ensure fair comparisons.

- The overlap of measures or criteria should be minimized.

- Risk management, life-cycle cost analysis, and performance management should be considered in project prioritization.
- Categorical variables should be avoided.
- Benefits should be monetized.

Some funding should be allocated to increase awareness of the importance of active transportation projects.

Collaborations and Research Needs

The interviews performed with state and regional agency stakeholders and the comprehensive review of publications revealed that there are several challenges and research needs related to transportation and health, including the following:

- Need for accurate and representative data.
- Improvements in model accuracy and assumptions (through measurement and surveillance) to better represent reality and explicitly link infrastructure to behavior-health outcomes.
- Addressing the mismatch between the resolution of transportation and health data.
- Attribution of health impacts to transportation vs. other factors and industries (e.g., factories in an area).
- Complexities of different regions and development of objective measures to be used for comparison and resource allocation.
- Scalability of tools for statewide purposes to different area sizes.
- Impact of technology (e.g., connected and automated vehicles) on health.
- Resources: Staff availability with expertise in epidemiology has been mentioned as a primary obstacle in moving toward a more direct assessment of transportation impacts on health.
- Complexity of transportation-health relationships, especially in how transportation facilities are used by different populations.
- Balancing perspectives of different agencies.
- Time frame of health benefits will only become evident after many years.
- Definition of indicators, as some are still too broad for use in scoring individual projects.
- Integration of community feedback in project scoring.
- Attention to unintended consequences.

Collaborations Between DOTs and DPHs

Interviews with relevant stakeholders revealed that there is an increasing trend in the interactions and collaborations of state DPHs with state DOTs. The form of these collaborations varies widely, but has so far not included any direct involvement of a DPH in any DOT project scoring framework development. Notably, the team’s research revealed that there is a high interest by DOTs, most importantly at the higher level of administration, to increase collaborations with DPHs in the near future.

MassDOT Highway Division Project Scoring Process and Proposed Criteria

The MassDOT Highway Division's project scoring process includes eight criteria categories, referred to as sections in this report: (1) System Preservation, (2) Mobility, (3) Safety, (4) Economic Impact, (5) Social Equity and Health Effects, (6) Environmental, (7) Policy Support and Project Risk, and (8) Cost Effectiveness. Each of these criteria contains multiple factors that are scored with values from a range of -1 to 3. Some of these criteria are data-driven and others are qualitative. The eight categories included in the process are weighed differently, with Mobility (20%), System Preservation (15%), and Safety (15%) receiving the highest weights. All other categories receive weights of 10%. The highest overall score can be 100 points.

An advantage of this framework is the wide scope of factors that it considers, capturing aspects of all five health-related factors. The framework's simplicity and limited redundancy are additional advantages. However, limitations exist in directly incorporating health outcomes. Air quality is only assessed via reduction to GHG emissions, which is a criterion best suited for assessing climate change rather than health outcomes due to air pollution. In addition, crash rates or numbers of crashes are not assessed separately for bicyclists and pedestrians, and the severity of crashes is not captured. Physical activity is not explicitly addressed. Many of the criteria are scored based on whether an improvement is substantial or not introducing subjectivity in the scoring process. Finally, Mobility, Safety, and System Preservation receive the highest weighting factors. This could have implications on the types of projects being prioritized.

The proposed criteria of this study have focused on five factors for health assessment, in particular: (1) air quality, (2) accessibility, (3) equity, (4) physical activity, and (5) safety. These factors are highly correlated with health outcomes. Eight project scoring criteria have been developed and proposed as shown in the table that follows. These include two criteria for accessibility (plus a third one that covers both accessibility and equity), equity, safety, and one for each of the air quality and physical activity factors. Notably, the air quality criterion is taking into consideration two important air pollutants. Two of these criteria, namely the $PM_{2.5}$ mass and NO_2 concentration, as well as some aspects of the proposed job accessibility factor, have been included in the latest version (version 4.0) of the MassDOT Highway Division project scoring criteria. A community engagement criterion is present in the last few versions of the scoresheet, assigning points based on whether a public outreach meeting has been performed. However, the proposed criterion expands on it to capture the level of community engagement when assigning scores, e.g., Inform, Consult, Involve, or Collaborate.

In addition to the proposed criteria mentioned, the research team recommends the following:

- Adjust criteria weights to more explicitly account for exposures affecting health and to emphasize nonmotorized transportation projects.
- Seamlessly incorporate project scoring with geoDOT (i.e., MassDOT's GIS platform for transportation data).
- Conduct a travel survey in collaboration with MDPH to incorporate questions related to active mode trips and behavior.
- Pursue bicycle and pedestrian data collection studies to obtain necessary data related to demand safety (e.g., crashes and near-misses).
- Pursue research efforts to develop lists summarizing types of projects that have been found to significantly affect (positively or negatively) the criteria of interest (e.g., accessibility, air quality, safety, etc.).

Proposed criteria for the MassDOT Highway Division project scoring framework

Factor	New Criteria
Air Quality	• **$PM_{2.5}$ mass concentration and NO_2 concentration**
Accessibility	• **Job accessibility** • Accessibility by walk/bike to other points of interest • Transportation disadvantage access (composite indicator)
Equity	• Transportation disadvantage access (composite indicator) • Community engagement
Physical Activity	• Physical activity-related chronic disease
Safety	• Bicycle/Pedestrian crash rate • Annual number of fatal and severe injury crashes

Note: Criteria in bold indicate the criteria that have already been included in the latest version (version 4.0) of the MassDOT Highway Division project scoring framework.

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List of Acronyms

Acronym	Expansion
ALS	Advanced Life Support
BEQI	Bicycle Environmental Quality Index
BLS	Basic Life Support
BenMAP-CE	Benefits analysis and Mapping Program-Community Edition
BRFSS	Behavioral Risk Factor Surveillance Survey
Caltrans	California Department of Transportation
CEDAR	Cambridge University's Centre for Diet and Activity
CDPH	California Department of Public Health
CHD	Coronary Heart Disease
CMAQ	Congestion Mitigation and Air Quality
CREAL	Centre for Research in Environmental Epidemiology
CTPS	Central Transportation Planning Staff
DALY	Disability-adjusted life year
DPH	Department of Public Health
DOT	Department of Transportation
EJ	Environmental Justice
EPA	Environmental Protection Agency
EPHT	Environmental Public Health Tracking
FAST-Act	Fixing America’s Surface Transportation Act
FHWA	Federal Highway Administration
GBD	Global Burden of Disease
GHG	GreenHouse Gases
GIS	Geographic Information System
HEAT	Health Economic Assessment Tool
HIA	Health Impact Assessment
HIAP	Health in All Polices
HPI	Healthy Places Index
HSIP	Highway Safety Improvement Program
HTC	Healthy Transportation Compact
ITHIM	Integrated Transport and Health Impact Modelling Tool
MAP-21	Moving Ahead for Progress in the 21^{st} Century
MBTA	Massachusetts Bay Transportation Authority
MassDOT	Massachusetts Department of Transportation
MDH	Minnesota Department of Health
MDPH	Massachusetts Department of Public Health
MPHA	Massachusetts Public Health Association
MPO	Metropolitan Planning Organization
MnDOT	Minnesota Department of Transportation
MOVES	Motor Vehicle Emissions Simulator
NCHRP	National Highway Cooperative Research Program
NHTSA	National Highway Traffic Safety Administration
N-PHAM	National Public Health Assessment Model

Acronym	Expansion
PEQI	Pedestrian Environmental Quality Index
$PM_{2.5}$	Particulate $Matter_{2.5}$
RLAJ	Relative Loss in Access to Jobs
RSA	Road Safety Audit
PSAC	Project Selection Advisory Council
SPF	Safety Performance Function
SPR	State Planning and Research
SWAMP	Sammamish-Washington Analysis and Modeling Program
TNM	Traffic Noise Model
T4MA	Transportation for Massachusetts
U.S.	United States
USD	United States Dollar
UTOPHIA	Urban and TranspOrt Planning Health Impact Assessment
VMT	Vehicle Miles Traveled
WASIST	Washington State Intersection Screening Tool
WSDOH	Washington State Department of Health
WSDOT	Washington Department of Transportation

1.0 Introduction

The Massachusetts Department of Transportation (MassDOT) has been prioritizing health by incorporating it in its goals and processes since the establishment of its new structure in 2009. One of the first attempts to ensure this health focus is the introduction of the Healthy Transportation Compact (HTC), an interagency agreement between MassDOT and the Massachusetts Department of Public Health (MDPH), as well as the Executive Offices of Health and Human Services and Energy and Environmental Affairs. Among other initiatives, this compact includes the incorporation of health impacts on planning decisions and mandates the development of methods to assess transportation health impacts on health with the use of Health Impact Assessments (HIA) to assess the impact of transportation projects on health (*1*). The more recent Healthy Transportation Policy Directive in 2013 has further contributed to this goal, by requiring consideration of bicycle and pedestrian facilities in all transportation projects while considering health aspects of the communities these projects served, including Environmental Justice (EJ) and air quality (*2*).

At the federal level, planning requirements dictate that state departments of transportation (DOTs) prepare 20-year statewide long-range transportation plans. In addition, the two most recent transportation bills, the Moving Ahead for Progress in the 21st Century Act (MAP-21) and the Fixing America's Surface Transportation Act (FAST-Act) require that plans be performance based, utilizing performance measures data for several categories including operations, safety, and air quality (*3*,*4*).

While several states have developed score-based processes for project scoring and prioritization to assist with funding allocation, a comprehensive performance-based assessment of transportation projects that accounts for the various pathways that transportation affects health is lacking. At the same time, HIAs tend to be more comprehensive in capturing the multiple pathways to health outcomes but are extensive efforts requiring additional resources that are not always available.

There is a need to identify performance measures and project scoring criteria that can be readily and effectively used to assess the health impact for transportation projects/initiatives. This way project scoring frameworks can be updated to allow for incorporation of health outcomes in transportation project decision making in accordance with the Healthy Transportation Policy Directive. The objectives of this research project are threefold:

1. Identify health assessment methods and decision-making processes used for transportation projects with an emphasis on project scoring criteria, performance measures, data, and models that can be used by MassDOT to assess the impact of transportation projects on health outcomes.
2. Develop project scoring criteria that can be readily incorporated in the MassDOT highway project prioritization process. This includes definition of performance measures, criteria standards, and data needs.
3. Recommend specific topics and relationships that should be further investigated.

This research project has focused on the assessment of health through five types of exposures (i.e., factors), in particular: (1) air quality, (2) accessibility, (3) equity, (4) physical activity, and (5) safety. These exposures are highly correlated with transportation project characteristics (e.g., design elements, construction methods, etc.), but also the socioeconomic characteristics of the area. Furthermore, evidence exists that these are major pathways connecting transportation to health outcomes.

In addition to affecting climate change and the environment, *air quality* is directly related to health impacts through degraded local air quality and health disparities due to the inequitable distribution of pollution to areas where generally disadvantaged populations reside. The World Health Organization (WHO) cites exposure to air pollution as a primary cause of 4.2 million premature deaths annually across the world (*5*). Impaired air quality is known to contribute to disability and death from ischemic heart disease, stroke, chronic obstructive pulmonary disease, lung cancer, and acute respiratory illness.

Accessibility is defined as the ease of reaching opportunities (i.e., facilities and activities). Geurs and Ritsema van Eck define accessibility as “a person’s ability to reach necessary or desired activities using the available transportation modes in an urban area” (*6*). As a result, the level of accessibility significantly affects many aspects of human life, including job and education access, and therefore, income, access to health care services, food, and recreational activities, all of which are directly affecting health outcomes.

Wide health disparities exist between segments of the U.S. population (*7*). Transportation affects health inequitably among population groups through direct impacts on physical and mental health from differential safety, air quality, and noise exposure and physical activity opportunity; access to transportation options for employment opportunity and destinations of value such as medical services, retail centers, education, and social services; and housing costs (*8,9,10*). Advocates for transportation *equity* recommend prioritizing transportation investments that improve access to housing, jobs, and basic services, as well as prioritizing investments in pedestrian and bicycle infrastructure to increase safety and convenience, among other measures (*11*).

Fewer than one in five adults in the United States gets the recommended amount of daily physical activity (*12*). Low physical activity level is associated with significant chronic disease burden. Obesity, selected cancers, heart disease, stroke, diabetes and depression are among the conditions with the strongest risks from inadequate physical activity (*13*). Physical inactivity is also associated with substantial financial costs in the U.S. (*14*). Active transportation can contribute significantly to total physical activity (*15*), and current U.S. national health goals for physical activity include increasing trips made by walking and biking and built environment policies that enhance access to and availability of physical activity opportunities, including community-scale, street-scale, and transportation and travel policies (*16*).

Safety is the most direct and easily captured pathway to health outcomes. In 2018, 36,560 humans lost their lives in traffic crashes and another 1.8 million were injured (*17,18*). Safety affects disproportionately nonmotorized users who are less protected. While overall traffic-related fatalities decreased by 2.4% from 2017 to 2018, pedestrian and bicyclist fatalities increased by 3.4% and 6.3% respectively (*17*). Ethnic and racial minority groups, as well as low income populations and the elderly, are also disadvantaged when it comes to traffic injuries and fatalities. Pedestrian fatality rates are higher for Hispanic, African American, and Native Americans compared to Asian and White populations in the United States (*19*). Despite the fact that safety has traditionally been a priority along with mobility when it comes to transportation projects, there are still safety inequities that need to be addressed in transportation decision-making contexts.

1.1 Report Structure

The rest of the report is organized as follows. First, the methodology and sources of information used to assess existing project scoring frameworks and criteria used in transportation decision making are assessed. Next, tools and methods are presented that have been developed to directly assess health impacts of transportation projects, including Health Impact Modeling Tools and Health Impact Assessment studies. The next section describes DOT and MPO project scoring frameworks and discusses criteria specific to health that are included in those frameworks. The following two sections focus on summarizing collaborations between DOTs and DPHs and recommendations for future research. Next is a summary of scoring criteria, grouped into five categories: (1) safety, (2) equity, (3) accessibility, (4) air quality, and (5) physical activity. The proposed scoring criteria, factors, and datasets are presented that have been identified to assess those factors. Finally, the report concludes with some general observations and suggestions on effective ways to incorporate health into transportation decision making.

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2.0 Research Methodology

The research methodology consists of three components. The first was a comprehensive review of published literature and public agency documentation on HIAs and health impact modeling tools for transportation projects; project prioritization and scoring processes; and performance measures that have been used to assess health. As explained earlier, the focus was on five categories of scoring criteria and performance measures, namely: (1) accessibility, (2) air quality, (3) equity, (4) physical activity, and (5) safety, as these were believed to be directly and indirectly related to a variety of health outcomes.

The second component of this methodology was phone interviews with representatives of state departments of transportation (DOTs), departments of health (DPHs), and metropolitan planning organization (MPOs) to discuss how they have incorporated health in their transportation decision making and the level of collaboration between transportation and health agencies in their states.

Finally, once all the information from the literature and the interviews was obtained and summarized, project scoring criteria addressing each of the five categories mentioned above were proposed.

2.1 Literature Review

The review of the literature focused mainly on DOT- and MPO-published documentation related to their project scoring frameworks and project scoring and prioritization worksheets that were available, including the MassDOT Highway Division project scoresheet (*20*), among others. In addition, documentation on health impact modeling tools for transportation was reviewed and the advantages and disadvantages of the tools were summarized. Transportation HIAs across the country were also investigated, and their impacts on decision making were summarized. Refereed journal publications were also reviewed to obtain a comprehensive list of performance measures and their advantages and disadvantages, as well as data needed to obtain such performance measures.

2.2 Phone Interviews

To complement information provided by existing documentation and obtain information on existing efforts to incorporate health outcomes in their decision making processes, the team also performed interviews with representatives from state DOTs, DPHs, and MPOs. In consultation with the Massachusetts DPH and MassDOT personnel, the team developed a target list of states and MPOs likely to be innovators in health and transportation, based on recent activity in those areas.

In particular, the team interviewed representatives from MassDOT as well as from DOTs in the states of Washington, California, Oregon, Virginia, Tennessee, and Minnesota and from the Sacramento Area Council of Governments (i.e., Sacramento area MPO) (see Figure 1). The questions that were asked focused on understanding their transportation project decision-making processes, development of project scoring criteria, implementation of HIAs, level of collaboration between DPHs and themselves, and research needs to be addressed in order to achieve accounting for health outcomes in their decision-making processes. The specific questions that were asked can be found in Appendix A.

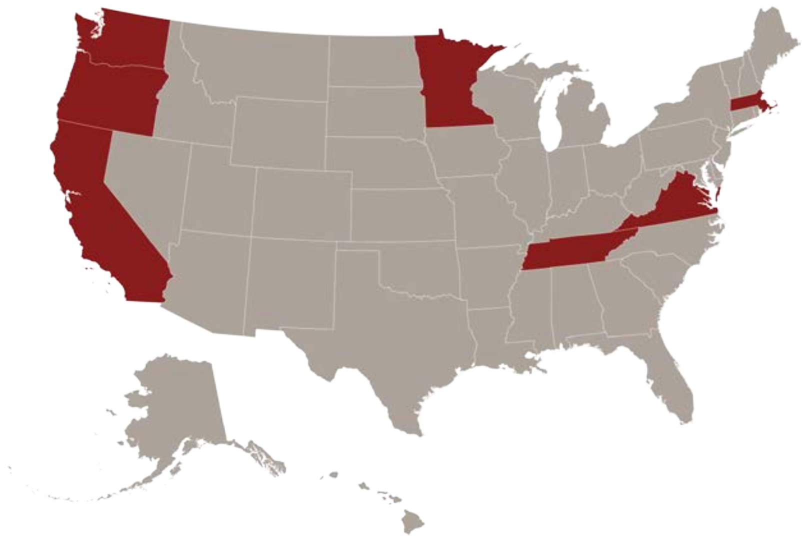

Figure 1. Map of interviewed state and regional agencies

In addition, the team interviewed representatives of the Massachusetts DPH as well as the state departments of health in California, Minnesota, Oregon, Tennessee, and Washington. Interviewees were identified as knowledgeable about their department's interactions with the respective state DOT. The team also spoke with one individual from the Massachusetts Public Health Association (MPHA) and the former policy director of Transportation for Massachusetts (T4MA) regarding their joint efforts to strengthen health and equity criteria in the 2015 project scoring update. Questions focused on understanding their experience working with their state transportation department; the frameworks, models, or tools for incorporating health into decision making they would like to see implemented in their state; public health or equity performance measures or project scoring criteria relevant to transportation that their department is interested in; and examples they are aware of from other states of incorporating health into transportation decision making.

While the geographic distribution of the interviewed agencies was not accounted for in the selection of agencies to interview, the team's research still achieved some representation from the East and West coasts, as well as the Midwest and the South, all from agencies that have been making efforts to incorporate health in their decision making.

2.3 Proposed Project Scoring Criteria

Information from the literature review and the interview components of the study was synthesized to reveal trends in how project scoring and prioritization methods are developed. An emphasis was placed on understanding and summarizing the criteria and performance measures used to assess health of transportation projects related to air quality, accessibility, equity, physical activity, and safety. This allowed the team to obtain evidence on the types of criteria that can most accurately capture transportation impacts on health, as well as advantages and challenges associated with different types of criteria, performance measures, and data to assess such criteria.

The team proposed eight different criteria, two per category mentioned previously, with the exception of air quality (which combined two air-quality performance measures) and physical activity, for which the team developed one criterion. Before any criteria were proposed, the MassDOT project scoring process and criteria were carefully reviewed to ensure minimal overlap and to make decisions on which scoring criteria should be supplemented versus replaced by the proposed criteria. For each of the proposed criteria, the team presents the evidence base justifying its connection to health and provides step-by-step methodology and standards that can be used to assess such criteria. Data requirements and availability for Massachusetts, as well as limitations, are also identified and documented.

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3.0 State-of-Practice

3.1 Health Impact Assessments

Health Impact Assessment (HIA) studies utilize multiple models, tools, and other qualitative and quantitative techniques to study the health impacts of projects, plans, and policies from various sectors of the economy such as housing, transportation, and energy (*21*,*22*). These studies are performed in an effort to understand health implications, engage the affected populations, and guide decision making toward the inclusion of health considerations as a means of improving policies, plans, and projects.

HIAs are comprehensive assessments capable of considering a greater and more flexible variety of exposure pathways and parameters than modeling tools, which generally have limited preset output possibilities (*23*). In addition, they are able to capture overlapping and indirect mechanisms of project impacts on health often utilizing health impact models and other modeling approaches related to traffic performance, accessibility, and emissions and noise estimation, while also engaging with the public and utilizing qualitative ways to assess local concerns (e.g., noise, green space accessibility, public safety, and social connectivity) (*23*).

In the United States, transportation HIAs have been mainly volunteering efforts often supported by public health agencies and, in some cases, foundations or federal grants (e.g., Center for Disease Control, Robert Wood Johnson Foundation, and Pew Charitable Trusts) (*24*,*25*). HIAs have been institutionalized in rare cases. Massachusetts has been the only state to institutionalize HIAs for transportation decision making through the Healthy Transportation Compact in 2013 (*1*), which led to the Grounding McGrath Highway HIA (*26*). Another law-mandated HIA was the one performed for the Seattle SR-520 Bridge Replacement project (*25*). Both of these are described in the next two subsections, along with the outputs and models used to assess chosen exposures of interest.

However, the success of transportation HIAs in influencing decision making remains limited (*22*). The majority of these efforts have primarily resulted in a greater understanding of the importance of health, initiated conversations between transportation and public health agencies, and facilitated community engagement (*22*, *25*). The only documented transportation HIAs that practically influenced decisions were the Atlanta Beltway and Clark County Bicycle and Pedestrian Master Plan HIAs. In the case of the Atlanta Beltway, which was a multibillion-dollar project on redevelopment and improvements along a 22-mile railway (*27*), many of the recommendations produced by the HIA were adopted (e.g., addition of accessibility criteria in the environmental impact studies and development of a housing policy), and a health professional was added to the project's advisory committee. The impacts of the HIA performed for the Clark County Bicycle and Pedestrian Master Plan (*28*) were similar in that they included the adoption of health- and equity-related project scoring criteria. This HIA also led to the development of policies to improve nonmotorized mode accessibility and general prioritization of projects that improve bicycling and walkability.

Despite the great potential HIAs have in bringing the transportation and health communities together and influencing decision making, HIAs have several limitations. Most HIAs are time- and resource-intensive processes (*27*). The examples described in Sections 3.1.1 and 3.1.2 illustrate the significant effort required for the implementation of HIAs by showing the extent of modeling effort that is required. HIAs often take many years to complete and are fairly expensive. Costs can range from $100,000 to $200,000 (*29*). As a result, HIAs are not appropriate for scoring multiple projects to assist with budget allocation; rather, they are most beneficial for assessing alternatives of a single large-scale project. Therefore, they tend to be reserved for projects with large budgets that will likely result in widespread or substantial health impacts because of the expense and effort they require. In addition, HIAs often depend on single grants that limit resource availability during a certain time period of the project, which obstructs continuous monitoring of health impacts. Lack of appropriate data or at the appropriate resolution, as well as lack of consistency and overall institutionalization of HIAs, have also been listed as deterrents to their widespread implementation (*22*,*30*). On the other hand, HIAs that have been successful in affecting decision making have been associated with engaged stakeholders (e.g., transportation and political staff), alignment of goals with political agendas, and appropriate timing (i.e., before decisions are made) (*25*,*30*).

3.1.1 McGrath HIA

The Grounding McGrath Study (*26*), completed in 2013, was conducted by MassDOT and MDPH as the pilot HIA of the Healthy Transportation Compact (HTC) component of the 2009 Massachusetts state transportation reform law. Health outcomes of alternative futures (Boulevard; Access Road; Hybrid U-Turn/Rotary; Boulevard with Inner Belt Connection; and 2035 No-Build) for the deteriorating and structurally deficient one-mile McGrath Highway section of the Route 28 corridor in Somerville and Cambridge were assessed. The focus was on the impact of those alternatives on air quality, noise, mobility and connectivity, public safety, and land use/economic development. As this project was located in a densely populated, designated EJ community, the socioeconomic context and impacts of the project, including income, housing availability and costs, and access to goods and services, on the neighborhood of interest were considered. Table 1 summarizes the health-related factors included in the McGrath HIA, as well as the outputs used to assess those factors and the models used to obtain output estimates.

3.1.2 Washington SR-520 HIA

The Puget Sound Clean Air Agency and Public Health—Seattle & King County completed the State Route (SR) 520 Bridge Replacement and High Occupancy Vehicle Project HIA in September 2008 (*31*). The assessment was mandated by the Washington State governor and legislature in the SR 520 interchange design and plan bill. The goal of this HIA was to inform the Washington State Department of Transportation decision makers on the health impacts of the SR 520 Bridge design and reconstruction of the SR 520 Bridge on local communities. Three bridge replacement alternatives were assessed cohesively on nine health-related factors: air quality, water quality, green space, physical activity, noise, mental well-being, safety, social connections, and emergency medical services. Noise, mental well-being, and emergency medical services were assessed largely through literature review and qualitative discussion of predicted impacts; social connectivity was evaluated through neighborhood connectivity and literature evidence relating daily commuting time with community involvement and social interaction. Table 2 summarizes the specific outputs and models used for each of these factors.

Table 1. McGrath HIA summary

Factors	Output	Method/Model
Air Quality	Traffic Density (surrogate) Air pollution concentration	Central Transportation Planning Staff (CTPS) Travel Demand Model CALINE-3 in CAL3QHC (air dispersion modeling)
Noise	Maximum noise levels	Federal Highway Administration (FHWA) Traffic Noise Model (TNM) Version 2.5
Mobility	Pedestrian Environmental Quality Index (PEQI) and Bicycle Environmental Quality Index (BEQI) scores	PEQI and BEQI surveys (San Francisco Department of Public Health)
Connectivity	Mode share Number of vehicles diverted to other neighborhoods	CTPS Travel Demand Model
Public Safety	Vehicle Miles Traveled (surrogate), Travel Time (public safety vehicles) Injuries and fatalities	CTPS Travel Demand Model
Land Use and Development	Households within one-half mile or walking distance to six areas with multiple goods	City maps of existing goods and services

Table 2. Washington SR-520 HIA summary

Factors	Output	Method/Model
Air Quality	Air pollution concentration Childhood asthma hospitalizations	MOBILE6 model Washington State Intersection Screening Tool (WASIST)
Water Quality	Stormwater discharge and contaminants	Sammamish-Washington Analysis and Modeling Program (SWAMP)
Noise	Maximum noise levels	Federal Highway Administration (FHWA) Traffic Noise Model (TNM) Version 2.5
Physical Activity	Walkability and bikeability	Increased bicycle/pedestrian paths and connections
Safety	Pedestrian and biker accidents	Crime Prevention through Environmental Design methods
Social Connections	Neighborhood connectedness access to destinations Availability of public spaces	Communities Count Social and Health Indicators Across King County
Mental Well-being	Depressive symptoms, physical activity, interconnectedness	Increased green space and trail connections
Green Space	Proximity to nature, nonmotorized transportation, air pollution	MOBILE6 model Washington State Intersection Screening Tool (WASIST)
Emergency Medical Services	Response time, outcome of Basic Life Support (BLS) and Advanced Life Support (ALS) responses	Medic One/Emergency Medical Services (EMS) System
Greenhouse Gas Emissions	CO_2, N_2O, CH_4 emissions Estimated energy use	Adapted Caltrans GHG estimation methodology 2004 Demo version of EPA's Motor Vehicle Emissions Simulator (MOVES)

3.2 Health Impact Modeling Tools

Various health impact assessment tools have been developed by different agencies or research groups to estimate health impacts resulting from changes in physical activity, air quality, safety, and accessibility (*32,33*). The tools have been utilized by both public health and transportation stakeholders. Most of them require the input of a baseline scenario (i.e., existing conditions) and calculate changes in health outcomes relative to this standard. Outcomes are often given in either the realm of health metrics (e.g., mortality, morbidity, disability-adjusted life year (DALY)) or economic impact metrics (e.g., cost of illness, willingness to pay). Table 3 presents a summary of these tools, focusing on their strengths and weaknesses as well as exposures and outputs involved in each one of those. Note that none of them have accounted for equity, and, therefore, this factor has been eliminated from the table. In addition, many of them just focus on assessing impacts for one of these factors or are capable of only assessing changes related to limited modes, e.g., walking and biking. Finally, extensive calibration efforts required, as well as restrictions in area resolution that they are applicable to (some are applicable at the Census Tract level and some at the regional level), limit their feasibility in assisting with decision making and project scoring. The following subsections present the methodological approach of each of the tools summarized in Table 3 in more detail, presenting factors that are considered, inputs, outputs, and real-world applications of these modeling tools.

Table 3. Health Impact Modeling Tool summary

Assessment Tool	Physical Activity	Air Quality	Safety	Accessibility	Mortality	Morbidity	DALYs	Economic Impact	Type of Model	Strengths	Weaknesses	Agency and Application	Inputs	Outputs	Output Units
HEAT Health Economic Assessment Tool	●	●	●		●			●	Comparative Risk Assessment	Combined effect of physical activity and air pollution; Minimal input data required	<20 years old are not considered; Safety not considered; Impact of air pollution only on pedestrians and cyclists	Metropolitan Area Planning Council evaluated impact of proposed public transportation fare increases and service cuts in Boston, MA	Volumes of travel (duration, distance, trips, frequency, mode), population size	Physical activity, air pollution risk, crash risk, carbon reduction	U.S. Dollars
UTO-PHIA Urban and TranspOrt Planning Health Impact Assessment	●	●		●	●			●	Comparative Risk Assessment	Considers health impacts of noise and heat exposure; Health impact calibration specific to urban areas	<20 years old are not considered; Safety not considered; Only $PM_{2.5}$ (not NO_2, other traffic-related air pollutants) considered	Centre for Research in Environmental Epidemiology (CREAL) estimated the health impacts of implementing international exposure recommendations in Barcelona, Spain	Recommended and current exposures to physical activity, air pollution, heat, noise, and access to green space; mortality rates	Decrease in annual deaths, increase in life expectancy, and economic savings of adherence to recommendations	Annual deaths, change in days of life expectancy, billions of Euros

Assessment Tool	Physical Activity	Air Quality	Safety	Accessibility	Mortality	Morbidity	DALYs	Economic Impact	Type of Model	Strengths	Weaknesses	Agency and Application	Inputs	Outputs	Output Units
Ben MAP-CE Environmental Benefits Mapping and Analysis – Community Edition		●			●			●	Comparative Risk Assessment	Pre-loaded datasets for US counties	Cannot directly model the impact of traffic pattern changes on health, only changes in air quality	University of Madison – Wisconsin assessed health benefits of decreased short-distance car trips in the Midwestern US	Pollutants, monitor datasets, incidents	Air pollution reduction policies evaluated by changes in Cost of Illness (medical and lost work expense to individuals from air pollution-related conditions) and Willingness to Pay (direct Cost of Illness expense and value of suffering, lost satisfaction, and lost time)	ug/m3 (mass PM2.5, U.S. Dollars
ITHIM Integrated Transport and Health Impact Modeling Tool	●	●	●		●	●	●		Comparative Risk Assessment	Results stratified by age and gender; Safety data stratified by modes and facility type	Appropriate only for regional analysis	California DPH evaluated health impacts of increased active transportation in the San Francisco Bay Area	Age structure, Population, GBD, Percent male and female by age group, mean travel times by age and gender, Cycling and walking MET values	Physical activity, road traffic injury risk, PM2.5 exposure	DALYs, number of attributable deaths

Assessment Tool	Physical Activity	Air Quality	Safety	Accessibility	Mortality	Morbidity	DALYs	Economic Impact	Type of Model	Strengths	Weaknesses	Agency and Application	Inputs	Outputs	Output Units
N-PHAM National Public Health Assessment Model	●		●		*Outputs dependent on paired plug-in*				Direct Estimation	Results stratified by age and income; Connects to existing scenario planning platforms	Dependent on plug-ins that interface with scenario planning tools to produce output	Air Alliance Houston assessed health impacts of a 25 mile highway expansion in downtown Houston	*Inputs and performance metrics vary with the paired scenario planning platform*		

3.2.1 Health Economic Assessment Tool

The Health Economic Assessment Tool (HEAT) (version 4.2) (*34*) estimates the monetary value of decreased mortality achieved by increases in walking and cycling associated with a project (*32*). It considers physical activity, air quality, and safety, but neither accessibility nor equity. The tool, which was developed by the World Health Organization and partly financed by European Union's Seventh Framework Programme, has primarily been used in Europe, though the literature review used to develop the model drew from studies worldwide. Monetary benefits at the county or regional level are estimated from changes in mortality due to changes in Particular Matter$_{2.5}$ ($PM_{2.5}$) mass concentration, crashes, and carbon emissions, though estimates based solely on mortality are also available. The model considers the combined effect of physical activity and air pollution on health outcomes, and the only input data required are population size and travel characteristics (duration, distance, trips, steps and frequency, mode share, shift) for the different modes (walking and cycling). However, as the model is primarily concerned with walking and bicycling, it does not explicitly consider other modes of transportation; furthermore, traffic injuries and people less than 20 years old are not considered. Model outputs include physical activity, air pollution risk, crash risk, carbon reduction, and economic impacts (U.S. dollars). HEAT was used to model the impact of proposed public transportation fare increases and service cuts in Boston, Massachusetts, by the Metropolitan Area Planning Council.

3.2.2 Urban and Transport Planning Health Impact Assessment

The Urban and Transport Planning Health Impact Assessment (UTOPHIA) tool, which was created by the Centre for Research in Environmental Epidemiology (CREAL) (*35*), estimates the number of deaths preventable through adherence to international recommendations for physical activity, air pollution, noise, heat, and green space access at the census tract level (*32*). Physical activity, air quality, and accessibility are considered, but safety and equality are not included as factors of interest. The model generates the decrease in annual deaths, increase in life expectancy in days, and economic savings (billions of euros) associated with achieving international exposure recommendations, requiring input recommended and current physical activity, air pollution, heat, noise, and access to green space exposures and mortality rates. Developed for use with urban environments, UTOPHIA considers the health impacts of noise and heat exposures unavailable through other models but does not consider traffic injuries, people younger than 20, or traffic-related air pollutants other than $PM_{2.5}$. CREAL has used UTOPHIA to model the health impacts of implementing international public health recommendations in Barcelona, Spain.

3.2.3 Environmental Benefits Analysis and Mapping Program-Community Edition

The Environmental Benefits Analysis and Mapping Program-Community Edition (BenMAP-CE) (*36*) was developed by the U.S. Environmental Protection Agency (EPA) to estimate the monetary value of the health impacts of changes in air quality at variable spatial scales (*32*). The model uses the Global Burden of Disease outdoor air pollution assessment (*37*) to calculate the impacts of ground-level ozone and $PM_{2.5}$ mass concentration and estimates attributable premature deaths, nonfatal heart attacks, aggravated asthma, and lost days of school. From the five factors of interest, only air quality is considered. Datasets for 183 countries containing population (2015), baseline all-cause mortality rates (2013), air quality ($PM_{2.5}$ and ground level ozone) (2013), and grid inputs for both air pollutants are available on the BenMAP-CE website, though more recent data can be attained and input by the user. This tool estimates changes in air quality in $\mu g/m^3$ and the cost of illness (i.e., medical and lost work expense to individuals from air-pollution related conditions) and willingness to pay (i.e., direct Cost of Illness expense and value of suffering, lost satisfaction, and lost time) in U.S. dollars. It uses pollutant distribution, monitor datasets, and incident data as inputs. While BenMAP-CE can model existing air pollution policies and benefits from policy changes, it does not directly capture the impact of traffic patterns or policies; rather, it assesses health outcomes related to changes in air quality. BenMAP-CE has been used by the University of Wisconsin Madison to model the health benefits of decreasing short car trips in the Midwest.

3.2.4 Integrated Transport and Health Impact Modelling Tool

The Integrated Transport and Health Impact Modelling Tool (ITHIM) developed by the Cambridge University's Centre for Diet and Activity Research (CEDAR) (*38*) assesses the health impact of transport scenarios through changes in physical activity, traffic injury risk, and $PM_{2.5}$ air pollution exposure. Accessibility and equity are not considered. Given the resolution of data required, it is generally used at the city or state level (*32*). The tool uses population (including age and gender) data, mean travel distances (miles), and times (minutes) by age, gender, and mode, cycling and walking Metabolic Equivalent (i.e., the ratio of activity energy expenditure to sedentary energy expenditure) values, and Global Burden of Disease (GBD) data to estimate changes in attributable deaths from physical activity, traffic risk, and air pollution, as well as disability-adjusted life years (DALYs), a measure of the number of years of life lost due to the disease burden of disability and disease deaths. ITHIM is flexible in that it can be linked with other transport, health, and economic models or data inventories (e.g., state DPH surveys, travel demand models, etc.), which also allows for higher accuracy in the estimates; however, calibration is time intensive and requires extensive data inputs and processing by professional users. ITHIM has been used by the Nashville Area Metropolitan Planning Organization and by the California Department of Public Health in the San Francisco Bay Area to model the health outcomes of increased active transport. It was recently calibrated by the research team with funding from the MDPH for all MPOs in Massachusetts and is available for use in the Commonwealth.

3.2.5 National Public Health Assessment Model

The National Public Health Assessment Model (N-PHAM) (*39*) was introduced by Urban Design 4 Health at the 2018 Transportation Research Board Annual Meeting. The tool, funded by the EPA, draws from different national databases and expands input modeling capacity, but does not generate outputs on its own. N-PHAM must be linked with an external scenario planning platform to produce outputs, which vary (along with input requirements) with the platforms chosen for pairing (e.g., the EPA mapping tool EnviroAtlas). Factors considered also vary with the paired platform. The tool allows for more complex analysis of physical activity, public health, and natural and built environment data through an application planning interface, connecting with datasets and tools including the EPA Smart Location

Database and the Robert Wood Johnson Foundation National Environmental Database. The capability of the tool is limited by the strength of scenario planning tools it is linked with and the ranges of outputs these tools produce. The tool was used in the health impact assessment of the North Houston Highway Improvement Project, a proposed 25-mile highway expansion project through downtown Houston (*40*).

3.3 Project Scoring Frameworks

A comprehensive review of 11 project scoring frameworks from DOTs and MPOs has revealed some trends with regards to the structure of such frameworks, as well as the types of factors (e.g., accessibility, air quality, equity, physical activity, and safety) that are included and the criteria and measures used to assess those factors.

Many DOTs and MPOs have been engaged in developing project scoring and prioritization frameworks, though some efforts are poorly documented or information is not publicly available. The majority of these have been motivated by the need for transparency in decision making but also in an effort to more effectively communicate decisions to the public and reach set objectives. The need to explicitly consider multiple objectives, meet strategic plan goals, and conduct performance-based planning was also mentioned as a motivating factor for the development of such frameworks.

Many agencies have developed separate project scoring frameworks to prioritize projects based on the mode or facility of interest (e.g., highway, active transportation, or freight corridors, e.g., Minnesota DOT's Corridors of Commerce (*41*)), type of project (e.g., capacity expansion, modernization, etc.), or program (e.g., Sacramento Area Council of Governments (SACOG)'s Active Transportation Program (*42*) and Highway Safety Improvement program).

The project prioritization processes reviewed are numerical but often combine scores based on both quantitative and qualitative criteria; for example, a project is located in a high crash area and is expected to improve safety. Scores to selected criteria are assigned in three ways: (1) using the numerical value of the measure assessed within the criterion, e.g., number of fatal and severe injuries in a year; (2) using a look-up table that assigns scores based on certain project attributes, e.g., complete street features included in a proposed project; or (3) scoring with a range of 0-3 scores based on the level of change or magnitude of a certain measure or the expected changes from the proposed project. Some of these criteria are assessed comparative to others regions or areas, e.g., compared against regional or national averages, such as SACOG's Regional Active Transportation Program (*42*). Combinations of these ways to assess criteria are also included in some frameworks. The scoring process also varies from framework to framework, depending on whether criteria are assessed based on existing conditions within the project area (e.g., Tennessee DOT's Multimodal Suitability Index (*43*)), on changes anticipated due to proposed project alternatives (VDOT's SMARTSCALE (*44*)), or a combination of both within the same criterion (Minnesota DOT's Corridors of Commerce (*41*), Nashville MPO (*45*), MassDOT (*20*,*46*)).

Criteria scores are weighted within each factor (e.g., air quality, equity), and each factor is weighted to produce the overall score. This is common in most frameworks. VDOT's SMARTSCALE has introduced weighting factors that vary by region to account for differences between urban and rural areas (*44*).

When scores are based on absolute numerical values of measures, biases could arise due to magnitude differences, and normalization is implemented. Normalization can be performed in various ways, e.g., based on deciles or quantiles that are associated with a certain number of points (e.g., Minnesota DOT's Corridors of Commerce (*41*)), or by comparing against other projects being scored (VDOT's SMARTSCALE (*44*) and NCDOT (*47*)). Project size differences are accounted for through the estimation of a benefit cost ratio that also facilitates comparison with other projects or project alternatives. In some cases, measures incorporate project size by accounting for mileage or area size in the way these measures are defined.

Ranking of projects resulting from implementation of such frameworks is not definite, in the sense that local rankings (e.g., NCDOT (*47*)) and restrictions on the amount of funding allocated per region (e.g., Minnesota's DOT Corridors of Commerce (*41*)) can affect the final funding decisions. In other cases, justification of any changes for the final decisions needs to be provided, e.g., VDOT's SMARTSCALE, which also requires approval of changes from the Commonwealth Transportation Board (*44*).

Finally, it is common to establish an advisory board, usually consisting of state and MPO representatives that reviews project scores and provides recommendations on changes to be made to achieve established goals. This is commonly performed on an annual basis. Maryland DOT also seeks local input before finalizing decisions (*48*).

3.3.1 Health-Related Scoring Criteria

An overview of the project scoring criteria related to the five categories the team identified as important (accessibility, air quality, equity, physical activity, and safety) has been performed with information from eight state DOTs, two MPOs, and the ActiveTrans Priority Tool. The ActiveTrans Priority Tool has been developed with federal funding to make priority decisions on bicycle and pedestrian improvements (*49*). This tool was included in the review since it has been developed based on similar principles of transparency and can assist in identifying types of criteria for assessing physical activity, equity, and in general criteria that directly relate to active transportation. References to the MassDOT Highway Division project scoring framework are for the version that was current at the onset of this project, i.e., v3.0, which was used as baseline for the team's review and recommendations (*20*).

Table 4 provides a summary of the factors considered by the reviewed frameworks. An immediate observation is that none of them has accounted for noise, which has been associated with anxiety and other psychological health issues. Few have included air quality as an exposure, and the ones that have most often use fuel consumption or GHG emission reduction, which do not directly capture the impact of air quality on health. Safety is included in all the reviewed frameworks, and accessibility is interestingly not present in the SACOG project scoring process. The Ohio and Virginia DOT frameworks do not directly consider transportation impacts on physical activity. This might be a function of the types of projects scored through their respective processes, i.e., Ohio DOT scores only major capacity projects and it is possible that those do not include elements that could motivate physical activity (*50*). However, in the case of VDOT's SMARTSCALE that can be used to assess bicycle and pedestrian projects, the lack of physical activity measures is a limitation. Finally, it is surprising that equity is not captured in frameworks such as those of the California DOT that contain all other exposures of interest.

Table 4. Health-related criteria categories considered in project prioritization frameworks

	Accessi-bility	**Air Quality**	**Equity**	**Noise**	**Physical Activity**	**Safety**
State Department of Transportation						
California	●	●			●	●
Minnesota	●		●		●	●
Massachusetts	●	●	●		●	●
Maryland	●	●	●		●	●
North Carolina	●				●	●
Ohio	●	●				●
Tennessee	●		●		●	●
Virginia	●	●	●			●
Metropolitan Planning Organization						
Nashville	●	●	●		●	●
Sacramento Area Council of Governments		●	●		●	●
Federally Funded						
ActiveTrans Priority Tool	●		●		●	●

The five categories of criteria of interest are assessed through various types of criteria and associated performance measures as indicated in Table 5. Note that existing frameworks often include multiple criteria to assess each category.

Accessibility is most commonly measured for jobs and in some cases for other points of interest, such as schools, businesses, etc. by assessing the number of opportunities that can be reached within a certain travel time threshold (e.g., VDOT's SMARTSCALE). However, these measures are most often developed to assess accessibility by car and less frequently by transit. Accessibility specifically related to active transportation is captured mostly qualitatively via the presence of sidewalks or bicycle infrastructure (e.g., ActiveTrans Priority Tool) and often via assessing access to multimodal facilities or choices (e.g., VDOT's SMARTSCALE, Maryland DOT, and Nashville MPO). Connectivity criteria, such as intersection and roadway density (ActiveTrans Priority Tool), presence of new links improving connections for active modes (e.g., MassDOT), and employment density (NCDOT and TDOT), can also be used to assess accessibility in an indirect way. In some cases, accessibility is captured through mobility-based measures, such as reduction in travel time and increases in speed; however, these have been excluded from Table 5 as they cannot directly capture actual changes in accessibility; rather, they could be capturing capacity improvements that might advance mobility but not necessarily accessibility for all users. The impact of proposed changes on accessibility is mostly assessed qualitatively, e.g., based on whether access to certain types of facilities or more generally points of interest is anticipated to increase after the implementation of a project. Another observation is that accessibility and equity measures frequently overlap, e.g., change in average job accessibility per person within 45 minutes (or within 60 for transit projects) in general but also for disadvantaged populations, as in the case of VDOT's SMARTSCALE.

Air quality is not explicitly assessed in the majority of the frameworks. Environmental impacts is the most common criterion that is related to air quality; however, it most often includes measures that are addressing climate change rather than the impact of air quality on health, (e.g., GHG emission reductions). Although reduction in GHG emissions is a common criterion, it does not capture the detrimental impacts of air pollution at the local scale on health. Another indirect way to measure negative air quality impacts is through fuel consumption that can be used as proxy for the level of pollutants that are emitted from transportation operations. In addition to not capturing local air quality directly, these criteria have the disadvantage of being primarily qualitative, i.e., no emission model is run to assess the impact of the proposed changes. Notably, only two of the reviewed frameworks accounted explicitly for local air quality through the inclusion of ozone, NOx and $PM_{2.5}$ concentrations that have been associated with severe health outcomes (California DOT and Ohio DOT). Impacts on air quality are also often captured within mobility-based criteria. For example, reduction in vehicle-miles travelled or increase in active transportation mode share (e.g., SACOG). Finally, active-transportation related criteria have been introduced, e.g., the number of features that motivate active transportation in combination with levels of air quality (poor, good, etc.) as ways to indirectly assess air quality; see Caltrans health score.

Equity often overlaps with economic performance and accessibility criteria, e.g., accessibility to jobs within a certain travel time threshold for disadvantaged populations. In addition to accessibility measures specifically targeted at disadvantaged populations, *equity* is measured by considering demographic characteristics in the area of interest and assessing whether improvements will benefit such populations. Examples of such characteristics include: low income, minority, zero car households, unemployment rate, EJ or Title VI populations, disability, age, and university enrolment (e.g., SACOG, Nashville MPO, and Ohio DOT). In some cases, rates of these characteristics are compared against adjacent areas or with aggregate state averages. Information to assess these criteria is obtained by census data or the American Community Survey. Some frameworks also consider regional equity in how funds are allocated, and projects are scored based on whether they are located in areas where federal funds have already been allocated (e.g., MassDOT).

Physical activity is another factor that hasn't been explicitly captured in the majority of the project prioritization frameworks. Physical activity is primarily captured via the existence of proposed implementation of bicycle and pedestrian accommodations such as complete street features (e.g., Maryland and California DOTs), bike and pedestrian-specific infrastructure (e.g., California, and Maryland DOTs), and through the general criterion of whether a project has the potential to increase biking and walking (e.g., California DOT). In addition, several criteria relating active transportation attributes and access to multimodal options have been developed (e.g., Maryland DOT, VDOT's SMARTSCALE). However, many of the aforementioned criteria are rarely quantitative. Quantitative measures that have been used include: intersection density, bike land and path mileage over total road mileage, and transit vehicle stops per acre (e.g., SACOG). Other quantitative measures have been based on mobility based criteria such as reductions in vehicle miles traveled.

All of the frameworks that were reviewed have established criteria to assess *safety*. Safety criteria most often capture motorized vehicle safety and in some cases they also consider bicycle and pedestrian safety (e.g., MassDOT and SACOG). Safety is primarily assessed via crash-based (e.g., crash frequency for Minnesota DOT's Corridors of Commerce) or crash rate-based criteria (usually per million of VMT; e.g., MassDOT and Ohio DOT) that allow for a quantitative assessment of safety levels. These are often assessed in comparison with statewide or regional averages (e.g., MassDOT) and are combined with assessment of the potential of a project to reduce crashes of various types of users (vehicles, bikes, and pedestrians). Equivalent Property Damage (EPDO) is also used by some frameworks to allow for a monetary assessment of crashes (e.g., VDOT's SMARTSCALE). Other measures include crash severity index (e.g., NCDOT), safety score (i.e., a combination of crash rates and crash modification factors to assess safety improvements), eligibility for Highway Safety Improvement Program (HSIP) (e.g., MassDOT). A novel measure that has been used by the California DOT is worker safety.

Table 5. Project Scoring Criteria of existing frameworks

Accessibility	Air Quality	Equity	Physical Activity	Safety
• Access to employment/jobs o Job/workforce accessibility (general/disadva-ntaged) o Employment density • Access to other opportunities o Proximity to key destinations (1/4-1 mile)/community assets o Access to new growth area o Existence/improvement of bike/ped infrastructure multimodal choices/transit accessibility • Access to multimodal facilities o Access to multimodal choices/transit accessibility	• Emissions o Potential to reduce GHG o GHG emission estimates o Vehicle emissions (general) o Ozone precursors (NO_x and hydrocarbons) o Ozone and PM2.5 (good, fair, poor based on ppm) o Reduction in life-cycle carbon emissions • Fuel consumption • Contribution toward state environmental goals • Health Score (combination of air quality levels and active transportation project attributes) • Mobility (demand)-based o Change in daily household VMT per capita o Predicted walk/bike mode share	• Existing population characteristics-based o Unemployment/poverty rate; percent of households in poverty o % of population with disabilities o % of households with no auto o % of population older than 64 years old and percent of population younger than 18 years old o % of households with no auto o Median household income o Non-white population o Total (%) LIHM population o Number of K-12 and university enrolment by net acre o Census tracts that have more than x% EJ or Title VI population (comparative) o Demographics (age, gender) (comparative) o Disability status (comparative)	• Active transportation attributes o Existence/ improvement of bike/ped infrastructure (sidewalks, bike lanes, etc.), wayfinding, complete streets, etc. o Bike lane & path mileage over total road mileage o Number of active transportation attributes (bicycle lanes, sidewalks, etc.) o Implementation of complete street policies	• Crash frequency/density-based o Crash frequency/density (absolute or in comparison with state, district, or federal functional class) o Bicycle and pedestrian crashes o Fatal and severe bike crashes o Percent of collisions that involve bikes or pedestrians o Project located in high crash area o Project addresses high crash areas through safety improvements o Equivalent Property Damage (EPDO) and EPDO rate of fatal and injury crashes expected to be avoided o Crash severity index

Accessibility	Air Quality	Equity	Physical Activity	Safety

• Connectivity
  o Intersection density
  o Roadway segment density
  o Connections to existing facilities
  o Sidewalk/bicycle facility coverage
  o Bike/ped connectivity to business, amenities, schools, etc.
		• Existing population characteristics-based (continued)
		  o Project location in Health Priority Area based on income, age, and car ownership
		
		• Accessibility-based
		  o Job accessibility for disadvantaged
		  o Accessibility for Low-Income & Minority Communities
		
		• Improvement-based
		  o Improvements in community revitalization and sustainability
		  o Improvements in areas with Environmental Justice or Title VI population
		  o Economic impact development in low income communities
		  o Corrections in areas that are non-ADA compliant
			• Combination of active transportation attributes and transit/multimodal options
			  o Provision of additional nonmotorized and transit capacity
			  o Provision of multimodal options near schools
			  o Improvements in pedestrian, bicycle, and transit mobility and accommodations
			  o Potential to increase walking, biking, transit
			
			• Health Score
			
			• 3 or 4 way intersections per acre/intersection density
				• Crash frequency/density-based (continued)
				  o Bike/ped infrastructure (sidewalks, bike lanes, etc.), wayfinding, complete streets, etc.
				  o Safety benefit (crash severity and improvements)
				
				• Crash rate-based
				  o Safety score (combination of crash rate and crash modification factors)
				  o Crash rate (per millions VMT)
				  o Bicycle and pedestrian crash rate
				
				• Other
				  o Investigative Index (for rail projects; see FHWA’s SARAH Investigative Index)
				  o Worker Safety
				  o Existence of Road Safety Audit
				  o HSIP eligibility

Accessibility	Air Quality	Equity	Physical Activity	Safety
		• Improvement-based (continued) o Provision of alternative transportation choices for underserved groups o Provision of multimodal options near schools o Improvements in accessing Housing Programs o Existence/ improvement of bike/ped infrastructure (sidewalks, bike lanes, etc.), wayfinding, complete streets, etc. • Other o % of Federal funds per eligible roadway	• Transit vehicle stops per acre • Physical activity level (comparative across regions)	• Other (continued) o Improvements in bicycle and pedestrian safety

3.3.2 Project Scoring Framework Health Outcomes

Given the recent interest in incorporating health into decision making and the fact that only a few agencies have implemented targeted criteria adjustments to improve health, there is a need to assess the impacts of those prioritization processes and their criteria on health.

The team's review and interviews with relevant stakeholders revealed only two examples of documented health outcomes of such frameworks: Virginia DOT's SMARTSCALE and Nashville MPO's framework. SMARTSCALE's implementation over three rounds (2016–2020) has resulted in a higher percentage of low-cost projects (<$5 million) that often benefit nonmotorized modes of transportation, as well as of projects related to active transportation and transit (30% for active transportation and 7% for transit during the last round) (*52*). Nashville MPO found similar impacts, with a larger portion of its budget being allocation to active transportation projects since the implementation of its updated scoring process targeted at improving health (*45*). An increase in the inclusion of health-related transportation and planning attributes due to the updated scoring process has also been documented (57%–77% vs. 2% before the implementation of this process).

3.3.3 Conclusions

In summary, the review of existing project scoring and prioritization frameworks has revealed the following:

- Project scoring and prioritization frameworks consist of various categories of scoring criteria, e.g., mobility, safety, economic impact, etc., each of which is weighted by a certain value. Each category usually includes more than one scoring criteria, which in some cases are also weighted differently.
- The magnitude of the measure and weighting factors used significantly affect the final outcome and types of projects that tend to be funded.
- Normalization is a common way to address differences in measure magnitudes when absolute values are utilized. Monetization of benefits that accounts for project size could also be considered to ensure fair comparisons among projects.
- Accessibility is the second most common health-related factor, after safety, that is included in project scoring and prioritization frameworks; however, this occurs often through indirect mobility-based criteria.
- Air quality criteria also exist in most of the reviewed project scoring frameworks but in their majority (~63% of the reviewed frameworks) focus on climate change through GHG emission-related measures. As a result, impacts on local air quality that have more direct and significant impacts on human health are not captured.
- Equity is addressed through criteria developed to assess whether improvements in transportation, e.g., in accessibility or access to active transportation and multimodal facilities, will benefit disadvantaged populations that can be defined in various ways.
- Physical activity is not commonly assessed in a direct way in these frameworks; rather, it is addressed indirectly based on the existence of active transportation or complete street elements.

- Safety is always captured and is easily assessed based on quantitative criteria (e.g., crashes, crash rates); however, the impact of proposed improvements is often hard to capture, especially for improvements related to nonmotorized users, since crash modification factors are limited, e.g., for novel types of bicycle infrastructure treatments.
- It is common for agencies developing these frameworks to have a workgroup that provides recommendation on the scoring process and reviews scoring of projects (usually on an annual basis).
- While the rankings produced by these project scoring frameworks are the basis for funding decisions, they are not binding in any of the reviewed cases. Other factors, such as local input and regional distribution of resources, are also taken into account in final budget allocation.
- Documented outcomes are encouraging in that adjustment made to scoring criteria in an effort to improve health do translate in higher numbers of low-cost projects focused on improving active transportation and therefore, health.
- Overall, changing project scoring criteria is seen as a very cost-effective way of incorporating health in project prioritization and decision making *(38)*.

Recommendations for developing or updating a project prioritization framework include:

- Issues that are of most importance to a region should be identified, and scoring criteria should be adjusted to reflect those priorities. This could result in higher public acceptance. For example, Nashville MPO found that emphasizing quality of life and economic impacts facilitated communication and acceptance by community and elected leaders.
- Some funding should be allocated to increase awareness of the importance of active transportation projects.
- Caution is recommended when assigning weights to different criteria or factors to avoid disproportional impacts of criteria weights on the total score. Different weighting factors should be considered for different areas, districts, and potentially areas with different socioeconomic characteristics/needs.
- Caution is also needed when assigning ranges of values and determining the lowest and highest values that can potentially be assigned to a criterion.
- The overlap of measures or criteria should be minimized.
- Risk management, life-cycle cost analysis, and performance management should be considered in project prioritization.
- Categorical variables should be avoided.
- Benefits should be monetized.
- Different weighting factors should be considered for different areas, districts, and potentially areas with different socioeconomic characteristics/needs.
- VDOT’s SMARTSCALE (*44*) summarizes guiding principles for developing scoring criteria as follows:
    - “Fair and accurate B/C analysis
    - What matters to people and has a meaningful impact
    - Transparent and understandable
    - Work for both urban and rural areas

- Work for all modes of transportation
- Minimize overlap between measures.”

3.4 Collaborations Between DOTs and DPHs

Interviews with relevant stakeholders revealed that there is an increasing trend in the interactions and collaborations of state DPHs with state DOTs. The form of these collaborations varies widely, and many departments are currently actively trying to build that engagement. Regarding the DOT project scoring framework development, no direct involvement of a DPH in any DOT project scoring framework development was documented. Discussions do occur in some cases at the policy and planning level, but the actual project scoring framework development and execution has remained within the DOTs. The health department input has materialized mainly for criteria needed in dedicated programs such as Safe Routes to School or the Transportation Improvement Board Complete Streets Award programs. Some specific examples of collaborations between the two types of departments are described as follows. Notably, the team’s research revealed that there is a high interest by DOTs, most importantly at the higher level of administration, to increase collaborations with DPHs in the near future.

California: The California DOT, Caltrans, has been working very closely with its state public health agency. This collaboration has materialized by inviting the California DPH (CDPH) to provide input to Caltrans on (1) guidelines for transportation grant programs that incentivize local jurisdictions to create more multimodal facilities to encourage public health improvements; (2) guidance documents that inform how Caltrans selects projects, such as the recent update of corridor planning guidance (*52*); and (3) planning documents such as the “Toward an Active California” State Bicycle and Pedestrian Plan (*53*). In some programs, there are more explicit scoring criteria, e.g., “do one of the following to get X points,” from the California Healthy Places Index (HPI) score (*54*). HPI is a tool unique to California, containing a wide range of place-based data intended to help prioritize public and private investments. The collaboration occurs through both formal and informal relationships between the CDPH and Caltrans. CDPH coordinates the state’s Health in All Polices (HIAP) Task Force, established in 2010 by executive order and bringing together 22 departments and agencies. The HIAP emphasis has been on developing the infrastructure to support cross-sector work. CDPH compiled a list of health and transportation metrics for use by these fellow agencies.

Minnesota: The Minnesota Department of Health (MDH) and Department of Transportation (MnDOT) have a memorandum of understanding supporting their collaboration. MDH has two urban planners on staff, who primarily assist with community engagement and Complete Streets. In particular, MDH serves on advisory committees, e.g., for the state Pedestrian Plan. In addition, MDH shares data with MnDOT for local plans (e.g., active transportation, Safe Routes to School) and via committees they sit on such as the Bike Plan committee. However, health data is mainly used for encouragement, i.e., safety campaigns. MDH also trains local health departments to use counting equipment they borrow from MnDOT. Finally, local health departments collaborate with MPOs by participating in MPO distribution and advisory committees.

Oregon: The Oregon Health Authority (OHA) and Oregon DOT have a memorandum of understanding. Through their collaboration, they have attempted to align metrics to measure transportation impact on health but have been challenged due to lack of data common across jurisdictions. As part of its Public Health Modernization Process, OHA has also set outcomes to monitor on its own such as ACS commute to work and process measures such as local public health department participation in federal transportation planning processes. Assistance with development of criteria for programs such as the Safe Routes to School program has also been provided by OHA. Current efforts on the OHA side also include incorporating health and equity language into transportation planning documents. In the case of Oregon, support for health and transportation is higher at the local level than at the state level, due to capacity. Examples include counties inviting local health departments to participate in updating their Transportation System Plans, or providing local data and data analysis to highlight equity issues.

Tennessee: The Tennessee DPH works with its local health departments to address built environment overall and are not actively engaged with the Tennessee DOT.

Washington State: The Washington State Department of Health (WSDOH) and Washington Department of Transportation (WSDOT) have a strong relationship. The Active Community Environments program is the primary mechanism, but they are trying to build on that. WSDOT has developed guidance for local governments through the transportation efficient communities program in collaboration with the Departments of Public Health, Commerce, and Ecology. In addition, WSDOT is influencing grant programs that are funded by the DPH with CDC money, such as the Transportation Improvement Board Complete Streets Award program. These grants are given to planning organizations to work on complete streets and active community environment, and WSDOT, in collaboration with WSDOH, checks whether they are in line with thinking about the linkages of health and transportation. WSDOT has also been participating in discussions with WSDOH through the FHWA's initiative Planning & Environment Linkages to discuss how to best incorporate health in their decision making. Some efforts in that direction have been made by using health data in the Safe Routes to School and bicycle/pedestrian funding programs. WSDOT and other agencies have access to health data via the Washington Tracking Network (comparable to the Massachusetts Environmental Public Health Tracking (EPHT)).

3.5 Challenges and Research Needs

Interviews with representatives from DOTs and MPOs have revealed several challenges and research questions related to transportation and health, as follows.

- Representative Data: While new technologies have been providing more and more data, one can never have enough data. In addition, data are often not representative of real-world conditions. For example, some of the crowdsourcing methods for bicycle demand provide data from mostly recreational users, leaving out behavioral characteristics of commuting bicyclists. There is also the issue of underreported crashes and accidents or near-misses, which affect disproportionately nonmotorized users. Finally, data for new modes such as scooters are hard to obtain, especially when these modes are first introduced. Ways to obtain accurate and representative data are a major research need.

- Model accuracy and assumptions: The issue with existing models capturing the impact of build environment on user behavior is that they are based on collected data and assumptions. Data issues were discussed previously. At the same time, model assumptions do not always represent reality, especially when implemented in various regions.
- Resolution of transportation vs. health data: There is a mismatch in the resolution that transportation and health data are available. While transportation and demographic data can often be obtained at the census block level, health data tend to be much more aggregated, mainly due to the need for privacy protection. There is a need for criteria and measures that accurately capture health outcomes without compromising their privacy.
- Health impacts attributable to transportation vs. other factors: This is another issue that was mentioned by many of the interviewees. Given the fact that transportation systems are integrated within cities or regions in general, where there are multiple other factors that could be affecting one's health, it is hard to accurately attribute certain health impacts on transportation alone. For example, air pollution could be attributed to traffic operations but also industrial activities within the same area. Although a very challenging problem, future research could attempt to develop ways to differentiate the contribution of transportation vs. other sources on health outcomes.
- Complexities of different regions: Another issue related to project scoring frameworks and their ability to accurately assess and compare projects is the challenge of quantifying health benefits, given the complexities of different regions. Several ways that develop more objective measures have been proposed, e.g., benefit/cost ratio or return on investment, but as discussed previously, those could also be resulting in biases toward certain types of projects, e.g., low-cost projects that also have low benefits, or projects in particular areas, e.g., urban. Caution is needed when such measures are utilized for funding decision making.
- Scalability of tools for statewide purposes: Related to the regional complexities that make a fair comparison of projects challenging is the need for tools focusing on assessing health outcomes that can be scaled to different area sizes.
- Technology: In addition to improved data, technological advancements have brought changes in the way people travel and even in the number of trips they take (e.g., telecommuting, online shopping, etc.). Future research could focus on the impacts of automated vehicles on health. In addition, there is an interest in assessing the impacts of technology, such as the internet, on health economy; for example, does improved access to information cause travelers to make healthier decisions, have access to better health care, etc.

- Resources: Staff availability with expertise in epidemiology has been mentioned as a primary obstacle in moving toward a more direct assessment of transportation impacts on health.
- Interviews with representatives from DPHs, as well as the literature review, revealed a set of challenges, some of which overlap with ones mentioned previously.
- Complexity of transportation-health relationships: Substantial variation exists in the relationship between specific transportation facilities and their use by different populations. For example, perceptions of safety matter more for some populations than for others.
- Balancing perspectives of different agencies: Timelines and requirements frequently do not align. Collaboration requires learning and respecting obligations of fellow agencies.
- Time frame (cost-benefit): Health benefits will only become evident after many years.
- Use of indicators: Many valuable systems of performance measures exist but are too broad for use in scoring individual projects.
- Integration of community feedback in project scoring: Public health has embraced health equity as a core principle. One of the basic tenets of equity is meaningful engagement of impacted communities, particularly vulnerable populations. Innovative methods and relationship development followed by meaningful integration of input from these communities is needed.
- Measurement/surveillance and link between infrastructure change and user behavior-health outcomes: There is a lack of models capturing the impact of many types of transportation projects and changes projects on traveler behavior. Examples are the introduction of a bike lane on bicycle mode share or the introduction of real-time transit information on transit and non-transit traveler behavior. Even when such models exist, it is hard to make the connection between traveler behavior and health outcomes, mainly due to the multitude of other factors affecting one’s health.
- Attention to unintended consequences: There is growing evidence that transportation improvements can worsen existing inequalities. Examples include increased housing costs when active transportation improvements attract new, more affluent residents or decreased food or park access when displaced residents move to an area with fewer connections that do not require a motor vehicle.

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4.0 Massachusetts Department of Transportation Highway Division Project Scoring

4.1 MassDOT Highway Division Project Scoring

The current procedures that are part of MassDOT's project selection process were developed by the MassDOT Project Selection Advisory Council (PSAC) in 2015. This was the product of an 18-month process with public hearings across Massachusetts, public testimonies and input, and incorporation of legislative elements in the final scoring criteria (*55*) As in many other states, the development of project selection criteria was motivated by the need for transparent and data-driven capital investment decisions while meeting the Commonwealth's policy goals and needs. In addition, there is interest in maximizing return on investment (ROI).

While each MassDOT division and the Massachusetts Bay Transit Authority (MBTA) have developed their own project scoring systems to comply with the PSAC's recommendations, the focus of this study has been on the MassDOT Highway Division's project scoring process.

The Highway Division's process includes eight categories, referred to as sections in this report: (1) System Preservation; (2) Mobility; (3) Safety; (4) Economic Impact; (5) Social Equity and Health Effects; (6) Environmental; (7) Policy Support and Project Risk; and (8) Cost Effectiveness. Each of these factors contains multiple related criteria that are scored with values from a range of -1 to 3. Some of these criteria are data-driven, and others are qualitative. Criteria related to health are discussed in detail in Section 4.2 for both version 3.0 (*20*) of the scoring process that was used as the baseline for the proposed criteria the team developed, as well as for the most updated 4.0 version (*46*) that has already incorporated some of these recommendations. Depending on the criterion, scoring is performed based on changes anticipated due to the proposed project or on both existing conditions and changes anticipated from the proposed project. The eight categories included in the process are weighed differently, with mobility (20%), system preservation (15%), and safety (15%) receiving the highest weights. All other sections receive weights of 10%. The highest overall project score is 100 points.

Rankings obtained from this process are not the only factor considered in decision making. Project readiness, types of funding, and regional and asset/mode distribution of projects to ensure regional and socioeconomic equity and cost effectiveness are also considered following the project scoring process. Recent updates were proposed to the scoring process to accommodate changes in how economic development aspects were captured and introduce additional criteria within the same factors as a result of a recently completed study (*56*).

An advantage of this framework is the wide scope of factors that it considers, capturing aspects of all five health-related factors (accessibility, air quality, equity, physical activity, and safety) that are of interest in this project. The framework also includes various criteria within each factor capturing elements that are relevant to most modes. Major advantages are its simplicity and limited redundancy, as well as the inclusion of criteria that can be easily used to differentiate between projects.

However, limitations exist in directly incorporating health outcomes. Air quality is only assessed via reduction to GHG emissions, which is a criterion best suited for assessing climate change rather than health outcomes due to air pollution. In addition, crash rates are not assessed separately for bicyclists and pedestrians, and the severity of crashes is not captured. Physical activity is not explicitly addressed. Many of the criteria are scored based on whether an improvement is substantial or not, introducing subjectivity into the scoring process. Finally, Mobility, Safety, and System Preservation receive the highest weighting factors. This could have implications on the types of projects being prioritized.

4.2 Proposed Project Scoring Criteria to Account for Health

This section presents the proposed project scoring criteria grouped in five categories based on the health-related factors they address: (1) air quality, (2) accessibility, (3) equity, (4) physical activity, and (5) safety. Two scoring criteria are proposed for each of the accessibility, equity, and safety factors. For air quality, the team proposes a single criterion, which includes two air quality exposure measures, specifically particulate matter of 2.5μm or smaller diameter ($PM_{2.5}$) and nitrogen dioxide (NO_2). A single criterion is proposed for the physical activity category, as well. This criterion is a composite one in the sense that it pairs physical activity-related chronic disease health outcomes with project characteristics.

This section includes a brief description of the relevant scoring criteria per category that were included in an earlier version of the scoresheet (version 3.0), which was primarily used as the baseline for developing the team's recommendations. This is used to justify the selection of the proposed scoring criteria. The most recent version of the scoresheet (version 4.0) has incorporated many of the proposed changes, which is also noted when relevant. Each subsection describing one of the proposed scoring criteria includes a discussion of evidence found in the literature that shows a correlation between the performance measures included in that criterion and health outcomes. The methodology, standards, and data needed to score each of the criteria are also discussed, along with limitations for each proposed criterion.

4.2.1 Air Quality

The baseline version of the highway project scoresheet used for developing the team's recommendations (version 3.0 (*20*)) incorporated air quality under the Social Equity category. This criterion was assessed qualitatively based on reductions in GHG emissions expected from the proposed project due to improvements in capacity, mobility, or in general congestion reduction. Another issue with this criterion was that it was assessing GHG emission reductions, which places the focus on addressing climate change rather than local air quality problems; the latter affects health more directly. More recent versions of the scoresheet, including the most recently updated version 4.0 (*46*), have incorporated the recommendations of this research project that are described as follows.

The team proposes to include concentrations of $PM_{2.5}$ and NO_2 as part of the criterion for assessing health outcomes related to air quality. This can be done by comparing the existing levels of $PM_{2.5}$ and NO_2 with the statewide average concentrations of these pollutants. The comparison is coupled with a qualitative assessment of whether the proposed project is expected to result in emission reductions due to mobility improvements. The latest revisions of the scoresheet have also included other means for scoring points under this criterion, for example through alternative ways that could lead to air quality improvements such as green technology, design elements that would protect pedestrians from being exposed to air pollutants, or by showing air quality improvements through a Congestion Mitigation and Air Quality (CMAQ) analysis.

4.2.1.1 Evidence base

$PM_{2.5}$ mass concentration is a common air quality exposure metric because it is associated with a wide range of health outcomes at all ages, including low birth weight, decreased lung function and growth, numerous respiratory and cardiovascular outcomes, high blood pressure, and stroke. Environmentally, $PM_{2.5}$ is responsible for reduced visibility (*57*). NO_2 is often used as a traffic emissions indicator due to its positive association with negative environmental effects such as acid rain and its contribution to forming both particulate matter and ozone (*58*). In addition, with regard to its environmental impacts, NO_2 can lead to increased respiratory and cardiovascular health risks, including increased risk of cardiac disease, stroke, and chronic obstructive pulmonary disease deaths, increased brachial artery diameter and brachial artery flow-mediated dilatation, heightened sensitivity of children with mild to moderate asthma to inhaled allergens, and increased risk of mortality by at least 0.05% for all ages following acute exposure (*59*,*60*,*61*).

The high variability of $PM_{2.5}$ and NO_2 can also result in negative equity impacts furthering the health impacts associated with air quality. Disparities in exposure and related (previously detailed) health outcomes from these air pollutants have been associated with demographic characteristics including race, ethnicity, and socioeconomic status (*62*). This is often because individuals of minority and low socioeconomic statuses are more likely to live and work near sources of pollutant emissions and farther from open and green spaces. The use of local measures of air pollution allows for assessment of impacts in areas with vulnerable populations that are often underrepresented when using air pollution-related medical outcome metrics.

4.2.1.2 Methodology

The following steps describe the process for scoring this criterion:

1. Calculate the average concentration of ambient $PM_{2.5}$ and NO_2 of the area (using grid cell data) included within a 500-meter buffer from the proposed project, as described in the Project Need Form. Vehicle emissions decay to background levels within 500 meters of major roadways (*63*).

2. Compare these ambient concentrations with the statewide average $PM_{2.5}$ and NO_2 concentrations. The statewide averages used should be over the same time period as the time period used for calculating the average concentrations of the project area as described in Step 1.

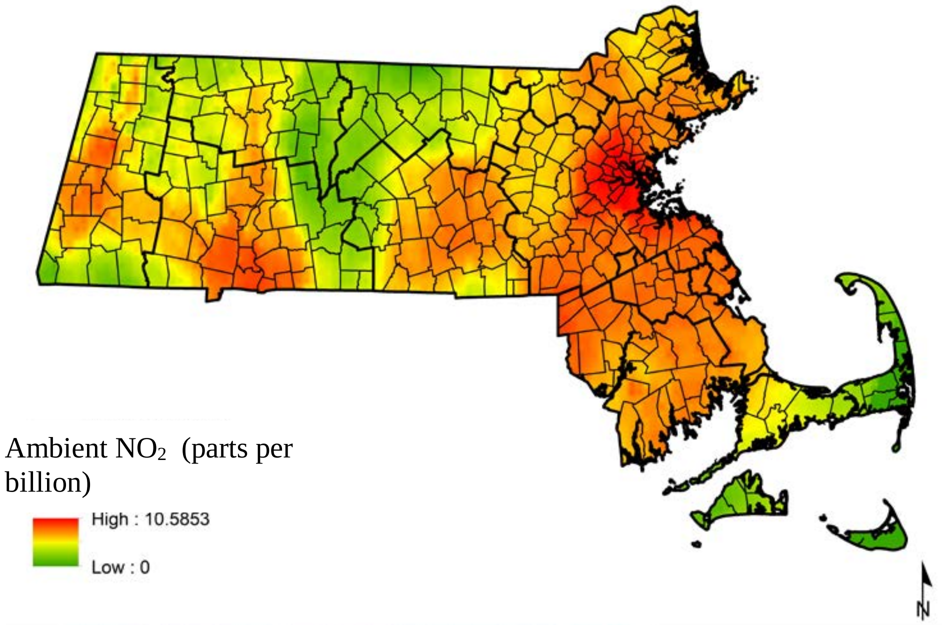
3. Assess whether the proposed project is expected to result in substantial reductions in $PM_{2.5}$ and NO_2 emissions due to mobility improvements. Assessing whether the resulting outcome is substantial or not can be facilitated by creating a list of project types that have been shown to result in significant reduction of those types of emissions.

4. Document whether the proposed project: (1) has implemented CMAQ and shown that there will be improvements in air quality, and (2) includes green technology or design elements that buffer pedestrians from pollutants.

5. Assign the score based on standards described in Section 4.2.1.4.

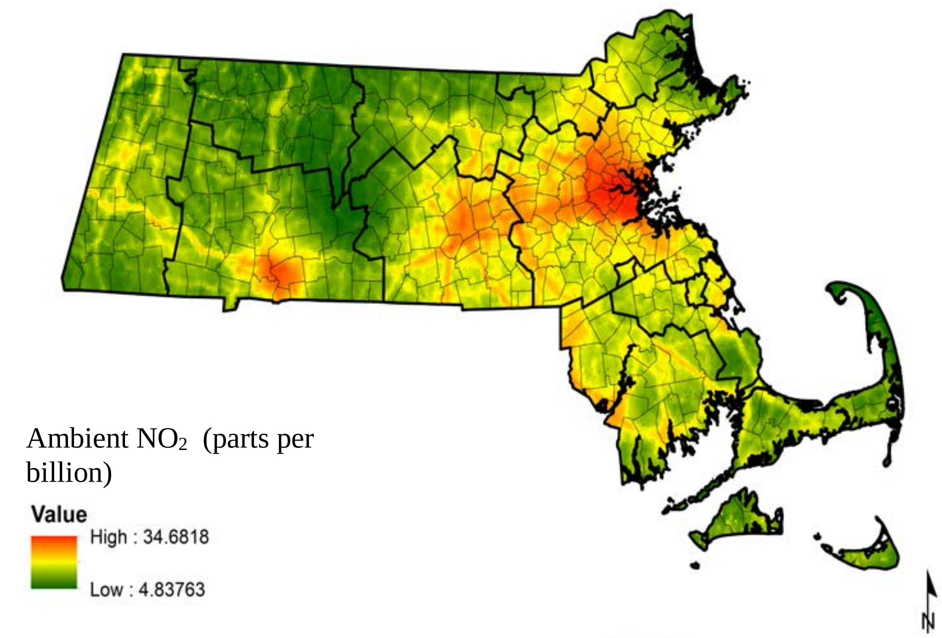
4.2.1.3 Data

$PM_{2.5}$ and NO_2 concentrations are highly spatially variable and dissipate rapidly with distance from emission sources, requiring relatively high resolution data. Grid data of minimum 2.5km resolution for $PM_{2.5}$ and 1km resolution for NO_2 are recommended. Datasets of annual modeled $PM_{2.5}$ and NO_2 at the suggested resolutions (2.5km grid $PM_{2.5}$, 1km grid NO_2) are available from the Joel Schwartz research group at Harvard for the period of 2000 to 2016 (*64*) and have been provided to the research team; see Figures 2 and 3 for maps of these concentrations across Massachusetts. Air pollution generally exhibits minimal temporal variation, so these data do not need to be updated continuously; updates every 5–10 years should be sufficient.



Source: Schwartz, J. (2019). *Modeled Annual Ambient NO_2* [data file and codebook]. Boston, MA: Harvard University. (*64*)

Figure 2. Map of modeled ambient $PM_{2.5}$ across Massachusetts for 2016



Source: Schwartz, J. (2019). *Modeled Annual Ambient NO_2* [data file and codebook]. Boston, MA: Harvard University. (*64*)

Figure 3. Map of modeled ambient NO_2 across Massachusetts for 2016

4.2.1.4 Standards

The proposed project will be assigned scores based on the existing levels of NO_2 and $PM_{2.5}$ concentrations for the project area (within a 500-meter buffer), the statewide averages for those pollutants, and the expected changes in air quality for the project area as follows:

2 points: The existing average concentrations of $PM_{2.5}$ and NO_2 for the project area exceed the corresponding statewide averages for both pollutants, and a quantified decrease in emissions is expected due to mobility improvements, OR CMAQ analysis has been performed showing that the project will provide quantified air quality improvements.

1 point: The existing average concentrations of $PM_{2.5}$ and NO_2 for the project area exceed the corresponding statewide average for one of the two pollutants, and a quantified decrease in emissions is expected due to mobility improvements, OR presence of green technology or design elements that buffer pedestrians from pollutants.

0 points: The existing average concentrations of $PM_{2.5}$ and NO_2 for the project area are below statewide averages for both pollutants, OR no improvements in air quality or pedestrian buffers are expected to materialize due to the proposed project.

-1 point: The existing average concentrations of $PM_{2.5}$ and NO_2 for the project area exceed the corresponding statewide average for one of the two pollutants, but no air quality or mobility improvements are anticipated as a result of the proposed project, OR project is expected to result in impairments to air quality.

These standards maintain the -1 to 2 point range and, therefore, can seamlessly replace the Air Quality and GHG Reduction criterion that was present in the Social Equity category of version 3.0 of the scoresheet.

4.2.1.5 Limitations

The grid resolutions recommended for $PM_{2.5}$ and NO_2 reflect data availability but do not directly capture the effects of traffic conditions on specific roadways, because there may be multiple roadway or industrial sources of emissions within each data pixel. However, the data are sufficient for assessing local changes within project extent areas. Another limitation is that using annual data does not reflect seasonal variability in ambient $PM_{2.5}$ and NO_2, though annual average is likely sufficient for assessing most long-term health outcomes. Finally, it is possible that $PM_{2.5}$ and NO_2 concentrations do not capture true human exposures, given the fact that most individuals spend the majority of their time inside, where pollution concentrations diverge from outdoor estimates, and individual travel between areas is not captured through regional assessments. However, they do provide informative local estimates that can be used as proxies for the health impacts of transportation operations close to roadways.

4.2.2 Accessibility

The baseline version of the highway project scoresheet (*20*) incorporated accessibility through the existence of bike or pedestrian connections to points of interest in the proposed project. This connectivity criterion was housed under the Mobility category but was moved under the Social Equity category in version 4.0 of the scoresheet. Accessibility was also assessed through a criterion incorporating commute travel time improvements for areas with high job density under the Economic Impact category. While accessibility to jobs during commuting hours is very important for both mobility and health outcomes, improvement in commuting travel time does not necessarily reflect improved accessibility for the whole population or during all times of day. As a result, this Workforce Commuting and Accessibility criterion was updated in more recent versions of the scoresheet (v3.1 and v4.0) based on the team’s recommendations to more directly assess accessibility by scoring projects based on both existing job accessibility levels and anticipated improvements in commute time or job access. However, the updated criterion is still based only on automobile access to job and does not consider the potential of other modes in helping individuals reach destinations or the need for access to other opportunities.

The team proposes two accessibility criteria, in an effort to consider both access to jobs and other opportunities while accounting for access by different modes. In particular, the team proposes a criterion that assesses job accessibility within a certain time budget using car or transit, and a second one assessing access to opportunities (other than jobs, e.g., health care, food, education) within a certain time budget using bike or walking. The first criterion could be included under the Economic Impact category and has been implemented in the most recent versions of the scoresheet (by updating the Workforce Commuting and Accessibility criterion), while the second one could replace the existing Connectivity criterion and, therefore, be included under the Mobility category in version 3.0 or the Social Equity and Health Effects category in version 4.0 of the scoresheet.

Both of these criteria are assessed based on both existing conditions and proposed improvements. In order to account for existing conditions and avoid additional modeling burden, the team suggests that the two proposed measures are assessed for existing conditions while accounting for how they compare against adjacent areas, averages of other projects, or statewide averages. The advantages of the proposed criteria is that they directly capture job accessibility, which is a social health determinant as well as a distance-based measure to goods and services in close proximity to the project using nonmotorized modes of transportation. A third accessibility criterion is presented as part of the equity criteria next, to capture accessibility specifically for disadvantaged populations.

When measuring accessibility, it is important to consider (1) a reasonable timeframe; (2) different travel modes; (3) different activities or opportunities; and (4) share of population that has access to a mode or opportunities (*65*). The three proposed criteria ensure that all of these aspects are taken into consideration when scoring projects.

4.2.2.1 Job accessibility

4.2.2.1.1 Evidence base

Access to jobs is a social determinant of health, as it can influence a household’s income. This in turn can affect access to numerous other goods and services, including transportation options, health care, and education, all of which contribute to health outcomes as described in Section 4.2.2.2.1.

4.2.2.1.2 Methodology

The following steps describe the process for scoring this criterion.

1. Calculate the number of jobs that are accessible by car or transit within a 45-minute commute during the morning commute peak hour. This can be done by averaging job accessibility for all census blocks included within or adjacent to the proposed project. Alternatively, travel time thresholds can be adjusted to reflect different standards; for example, a 60-minute commute in certain areas might be a more reasonable threshold for the area's traffic conditions and jobs-housing balance. The adjustment could also vary by mode, e.g., 45-minute commute travel time threshold by automobile and 60-minute commute travel time threshold for transit. The commute time period can also be revisited to reflect specific goals. Another way this scoring criterion can be adjusted is by accounting for the Relative Loss in Access to Jobs (RLAJ) instead of number of jobs to assess existing conditions of job accessibility via automobile for the census blocks of interest. This is calculated as the number of jobs accessible via automobile within a certain travel time threshold that are lost during the peak commute period compared to the number of jobs that are accessible within the same travel time threshold when free-flow traffic conditions are present. MassDOT has developed a separate scoring for this that can also be utilized, e.g., "a score of 2 indicates that relative to its larger Metropolitan Planning Organization (MPO) region, residents in that census block group lose access to higher than the 75th percentile of all jobs lost across all block groups in the region" (*66*).

2. Job accessibility by transit can also be revisited based on MBTA's connectivity to employment centers metric. This metric is assessed by receiving values of 1–2, based on a comparison against the median number of accessible jobs (i.e., the project receives a value of 2 if it is within an area that has below the median number of accessible jobs and 1 if it is in an area with above the median number of accessible jobs.

3. Averages for all census blocks of interest should also be calculated when RLAJ or MBTA's connectivity to employment centers metric are utilized instead of the average number of jobs that are accessible by car or transit within a 45-minute commute during the morning commute peak hour.

4. Calculate that statewide average number of jobs that are accessible by car or transit within a 45-minute commute during the morning commute peak hour. This can be done by averaging job accessibility for the same modes, travel time threshold, and time for all census blocks in the state. Alternatively, the comparison can be performed using the average job accessibility of other proposed projects being considered in the scoring process, all other communities within the state, or the MPO the project belongs to, instead of the statewide average.

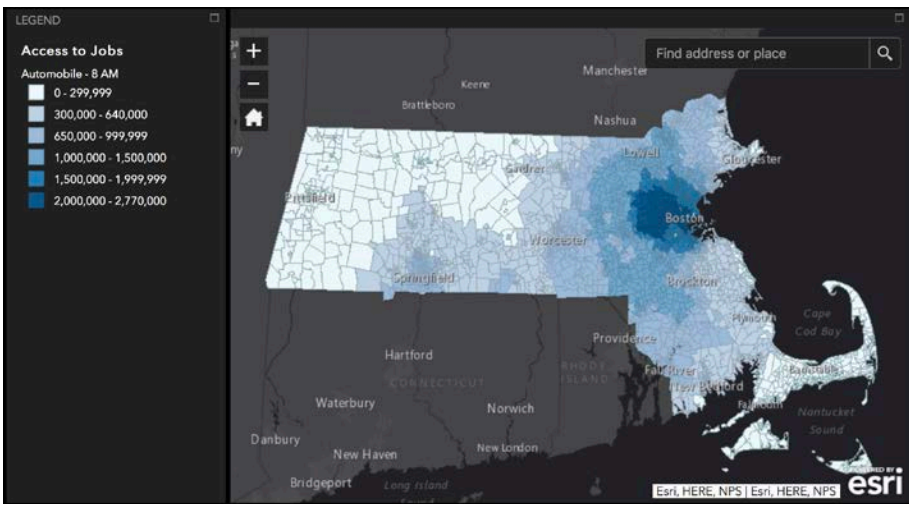
5. Assess whether the proposed project is expected to substantially improve job accessibility for the same census blocks that are included within or are adjacent to the proposed project. Assessing whether the resulting outcome is substantial or not can be facilitated by creating a list of project types that have been shown to result in significant job accessibility improvements.

6. Assign the score based on standards described in Section 4.2.2.1.4.

4.2.2.1.3 Data

Job accessibility data by mode (bike, walk, automobile, and transit) for various time periods by census block for 60 minutes by automobile and walk and various travel time thresholds by transit can be obtained through the Massachusetts Jobs Access Data Dashboard, which maps data obtained from the University of Minnesota's Accessibility Observatory; see Figure 4 (*66*). This dashboard also includes data on Relative Loss in Access to Jobs (RLAJ) and the MBTA Connectivity Employment Centers Scoring.

The team's recommendation is that these datasets are incorporated in the geoDOT database in the highest resolution possible, e.g., in five-minute intervals, to allow for different aggregations of job accessibility metrics. This would facilitate the incorporation of such data in the submission of the proposed project by the proponent, as well as the scoring process for MassDOT.



Source: Massachusetts Department of Transportation (MassDOT). (2020). *Massachusetts Job Access Data Dashboard*. (*66*)

Figure 4. Job accessibility by automobile for 8AM

4.2.2.1.4 Standards

The proposed project will be assigned scores based on the existing levels of job accessibility by car and transit for the proposed project area and the statewide average job accessibility, both by car and transit within a 45-minute commute for the morning peak hour. Anticipated improvements in job accessibility from the proposed project are also accounted for in the scoring as follows:

2 points: The project area has lower job accessibility than the area against which it is compared, and the proposed project is expected to improve it.

1 point: The project area has similar job accessibility (e.g., within 5%) than the area against which it is compared, and the proposed project is expected to improve it.

0 points: The project area has a higher job accessibility than the area against which it is compared, or no improvements are expected from the proposed project.

These standards maintain the 0 to 2 point range and, therefore, can seamlessly replace the Workforce Commuting and Accessibility criterion that is present in the Economic Impacts category of version 3.0 of the scoresheet.

4.2.2.1.5 Limitations

This criterion does not consider job accessibility by nonmotorized modes of transportation or other potential inequities for parts of the population that do necessarily have access to a car or even transit. In addition, it does not account for job accessibility during non-peak commuting hours or job type. For example, health care and hospitality service jobs are organized around shifts; therefore, they do not necessarily benefit from improved job accessibility during peak hours. Finally, improved job accessibility does not necessarily lead to improved health, as it does not directly encourage physical activity or provide access to health care or other points of interest that could have a direct impact, such as schools.

4.2.2.2 Accessibility to other points of interest

4.2.2.2.1 Evidence base

Access to goods and services is another major determinant of health. Lack of proximity and transportation options to access hospitals/medical centers or health care providers have been documented as obstacles to receiving sufficient health care services (*67*,*68*). Access to education not only improves one's potential for job access and sufficient income, which are also strongly correlated with health outcomes, but it has also been found to influence people's behaviors toward a healthier lifestyle. Educated individuals are more likely to engage in physical activity and receive preventative care (*69*). Access to recreational activities encourages physical activity, as well as social interactions that benefit mental health. Access to transit motivates physical activity but also has some indirect health benefits through the reduction in air pollution and traffic accidents from reduced car demand (*70*). In addition, it improves overall accessibility for disadvantaged populations, bringing additional health benefits. Finally, lack of access to high-quality food has been correlated with chronic disease such as diabetes, cardiovascular disease, and obesity (*69*,*71*).

4.2.2.2.2 Methodology

The following steps describe the process for scoring this criterion:

1. Calculate distances from the centroids of the census blocks that are within or adjacent to the project area to points of interest (destinations) in the area, using the Geographic Information System (GIS) network analyst. Points of interest include schools, recreational areas, food retail, hospitals, and medical centers.

2. Assuming certain levels of walking and bicycling speeds (e.g., 3 mph for walking and 12 mph for bicycling), calculate the travel times from the census block centroids that are within or adjacent to the project area to these points of interest. These speeds are

assumed to remain constant throughout the day, as they are usually not affected by traffic conditions.

3. Using the GIS network analyst, calculate the number and type of points of interest (destinations) that are within a 20-minute walk or bike trip for the project area of interest. This can be done by averaging the number of points of interest accessible within 20 minutes by either bike or walk, for all census blocks that are included within or adjacent to the proposed project. This scoring criterion can either focus on one type of destination or utilize the summation of points of interest that are accessible via walking or biking within the determined travel time threshold. Another way this criterion could be altered is by adjusting travel time thresholds to reflect different standards for different types of destinations (e.g., education vs. medical) or nonmotorized modes (walk vs. bike) or focus on accessibility using either walk or bike (not both, as phrased above). For example, a 15-minute walk to elementary schools could be a good indication of an area with good accessibility and potential for students' commuting by walking.

4. Calculate that statewide number of points of interest that are accessible by walking or biking within 20 minutes. This can be done by averaging the number of points of interest that can be reached for the same modes (e.g., walk and bike), travel time threshold, and time for all census blocks in the state. Alternatively, the comparison can be performed using the accessibility of other points of interest for the other proposed projects being considered in the scoring process, all other communities within the state, or the MPO the project belongs to, instead of census blocks.

5. Assess whether the proposed project is expected to substantially improve accessibility to other points of interest for the same census blocks that are included within or adjacent to the proposed project. Assessing whether the resulting outcome is substantial or not can be facilitated by creating a list of project types that have been shown to result in significant improvements for accessibility to points of interest (other than jobs).

6. Assign the score based on standards described in Section 4.2.2.2.4.

4.2.2.2.3 Data

Road inventory is already available in geoDOT and can be used for measuring actual travel distances. However, the only services that have already been mapped in geoDOT are schools, and open space-protected and recreational open space. Locations of acute and non-acute health care centers, community health centers, and rapid transit stations are also available via MassGIS (*72*).

The team proposes that datasets available in MassGIS be incorporated in the geoDOT database. As before, this would facilitate the utilization of such data for the submission of the proposed project by the proponent, as well as the scoring process for MassDOT. Additional points of interest that should be incorporated when data become available are transit stops and food retail, such as grocery stores and restaurants. Access to transit stops would capture the potential of multimodal transportation options and food retail to impact access to high-quality food that can affect health within the project area. Typically, coordinates for these types of locations are available; if that is not the case, a resolution at the census block level should be sufficient. Until additional datasets of services become available in GIS format for Massachusetts, the team recommends utilizing the already existing geoDOT points of interest.

4.2.2.2.4 Standards

The proposed project will be assigned scores based on the existing levels of accessibility to other points of interest by walk and bike for the proposed project area, and the statewide average level of accessibility, community average, or other project average to those destinations, both by walk and bike within a 20-minute travel time. Anticipated improvements in accessibility to destinations other than jobs from the proposed project are also accounted for in the scoring as follows.

2 points: The project area has lower accessibility to the points of interest than the area against which it is compared, and the proposed project is expected to improve it.

1 point: The project area has similar accessibility to the points of interest (e.g., within 5%) than the area against which it is compared, and the proposed project is expected to improve it.

0 points: The project area has higher accessibility to the points of interest than the area against which it is compared, or no improvements are expected from the proposed project.

These standards maintain the 0 to 2 point range and, therefore, can seamlessly replace the Connectivity criterion that is present in the Mobility category of version 3.0 of the scoresheet and currently in the Social Equity and Health category of version 4.0 of the scoresheet.

4.2.2.2.5 Limitations

While this criterion assesses accessibility based on distance, which is commonly done, it does not directly promote equity or physical activity. That is because proximity does not necessarily lead to improved accessibility (*73*). Not everyone within the same area has the same level of access to goods and services, often due to language and cultural barriers. In addition, an area’s topography in combination with physical ability and availability of modes can affect the true estimation of accessibility (*74*).

4.2.3 Equity

The baseline version of the highway project scoresheet (*20*) incorporated equity primarily through criteria included under the Social Equity category. While several criteria were included in this section, not all of them were addressing social equity as it relates to health impacts; for example, some of the criteria were addressing air quality or regional equity, in terms of funding allocation. Social equity was primarily assessed based on a project’s proximity (within ¼ mile) to EJ areas and Title VI communities and anticipated impact (positive or negative), as well as based on a housing criterion related to whether the proposed project utilizes housing grants or provides access to housing programs. The 4.0 version of the scoresheet (*46*) has maintained all of these equity criteria, primarily assessing social equity.

While EJ and Title VI communities can serve as indicators of health inequities, they are currently subjective regarding the expected impact of a proposed project on those communities. The Policy Support category of both the baseline and current versions of the scoresheets also includes the public outreach criterion, which could be used to assess equity. However, this criterion was assessed only on whether public outreach was performed or not with positive or neutral feedback or opposition and no distinction between information provision and engagement that can determine the level of public outreach was incorporated.

Interest in incorporating equity more explicitly into transportation planning is accelerating, and greater consensus on high-priority criteria is likely to become evident within the next few years. The team proposes two criteria consistent with a vertical equity approach supplementing and strengthening the EJ criterion while awaiting this consensus. This is explained in Section 4.2.3.1.1. The first is a composite equity score that expresses a project's potential to (1) increase *accessibility* to essential services for (2) *transportation-disadvantaged* populations via (3) increased *walk, bicycle, or transit* options. This score also addresses accessibility. Increased walk, bicycle, and transit mobility are addressed under the Mobility category in the current scoring framework, but the team recommends adding distance standards for a more quantitative equity evaluation. This criterion can be included under Social Equity in place of the EJ criterion.

The second criterion evaluates the record of community engagement during the development stage of the project, with a focus on the engagement of transportation-disadvantaged populations. This criterion is based on the "Community Engagement Standards for Community Health Planning Guideline" (*75*) produced by the Massachusetts Department of Public Health. This guideline presents a continuum of public involvement from low to high level: inform, consult, involve, collaborate, delegate, and community-driven/-led. This criterion can be included either under the Social Equity category, if general restructuring of the scoresheet were to be implemented to relax the restriction of a maximum of 10 points per category, or could replace the Public Outreach criterion under the Policy Support category. The proposed criterion presented here is developed assuming no restrictions on the number of points that it can allocate, but alternative scoring standards are also proposed in section 4.2.3.2.4 to allow for a seamless replacement of the Public Outreach criterion under the existing scoresheet structure.

The team recommends no change to the Title VI criterion at this time.

4.2.3.1 Transportation disadvantage access (composite indicator)

4.2.3.1.1 Evidence base

Current transportation planning processes emphasize protection of underrepresented and low-income EJ communities from disparate and adverse effects, as well as meaningful participation by these groups in the planning process. Key dimensions of transportation equity include (1) equity definition; (2) definitions of *transportation disadvantage*; (3) inclusion of impacted populations in transportation decision making processes; and (4) priority on basic *access* rather than *mobility*, particularly via more affordable modes such as walking, bicycling, and transit, and by identifying essential services (*76*,*77*). The historical emphasis on "horizontal equity" (equal allocation to or treatment of all users) has benefited more advantaged groups traveling by vehicle. By contrast, "vertical equity" indicators (1) are progressive with respect to income, meaning lower-income households pay less or receive more benefits including more affordable forms of transportation such as walking, biking, and transit; (2) benefit transportation-disadvantaged populations with improved access via these affordable modes; and (3) emphasize basic access to essential services rather than prioritizing traditional mobility measures such as travel time savings that benefit more advantaged groups (*78*,*79*). Factors contributing to transportation disadvantage include low-income nondriver/carless households, disability, language barriers, isolation, caregiver for child or adult, and obligations (such as frequent medical treatment) (*76*).

The FHWA "Guidebook for Developing Pedestrian & Bicycle Performance Measures" (*80*) suggests metrics for assessing transportation-disadvantaged populations served based on distance to walking, bicycling, or transit facilities that can be adapted for project prioritization. These distances are ¼ mile walking distance to a sidewalk, trail, or shared use path, ½ mile bicycling distance to an on-street bicycle facility, and ½ mile walking distance or 2-mile bicycling distance to a transit stop.

4.2.3.1.2 Methodology

The following steps describe the process for scoring this criterion:

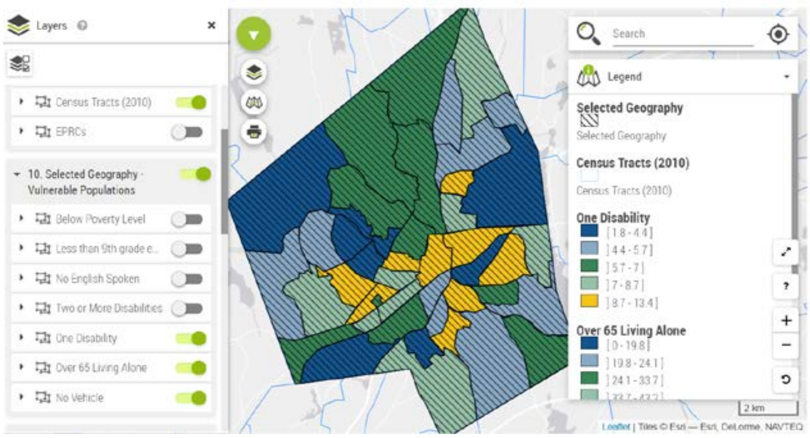
1. Determine the census tracts that will be affected by the proposed project. This can be done by capturing all census tracts within a 2-mile radius from the census tract(s) within the project area.

2. Determine whether these census tracts include transportation-disadvantaged populations per the MassDOT EJ definitions and GIS layers and per the EPHT based on the highest quantile for persons with one or more disabilities, percentage of those 65 and over living alone, and percentage of zero-vehicle households. The MassDOT GIS layers are on a census block resolution but can be aggregated to obtain census tracts that satisfy the MassDOT EJ definition (see Section 4.2.3.1.3). This is proposed in order for the resolution of the two datasets used to determine disadvantaged populations to be the same as EPHT, which provides the data on a census tract level.

3. Assess whether the proposed project will benefit a transportation-disadvantaged population. This can be done as follows:
   a. Using the centroid(s) of the census tract(s) within the project area, create buffer zones using the following radii: ¼ mile walking distance if sidewalks or trails are proposed, ½ mile bicycling distance if on-street bicycle facilities or shared use paths are proposed, and ½ mile walking distance or 2-mile bicycling distance if transit stops are proposed.
   b. Assess whether the defined buffer zones include at least one census tract that was characterized as having transportation-disadvantaged populations, per Step 2.

4.2.3.1.3 Data

Existing EJ layers in geoDOT will be utilized for determining minority, low-income, and limited English proficiency. The Massachusetts Executive Office of Energy and Environmental Affairs defines EJ as census blocks for which one of the following is true: (1) Median annual household income is at or below the statewide median income; (2) 25% or more of the residents are a minority; or (3) 25% or more of the residents are not fluent in the English language (*81*). In addition, the EPHT portal of the Massachusetts Department of Public Health (*82*) can be utilized to assess which census tracts include disadvantaged populations based on persons over 65 living alone, people with disabilities, and zero-vehicle households, among other characteristics. EPHT, which utilizes American Community Survey data, enables users to map and display quintiles of characteristics, in this case percentage of persons with one or more disabilities, percentage of those 65 and over living alone, and percentage of zero-vehicle households, for areas of interest. Figure 5 provides an example of the EPHT interface for vulnerable population data by census tract. Both geoDOT and the Massachusetts EPHT portal are updated by the respective state agencies when new ACS or census data are available.



Source: Massachusetts Department of Public Health. (2019). *Massachusetts Environmental Public Health Tracking*. (*82*)

Figure 5. Vulnerable population data by census tract, Environmental Public Health Tracking System

4.2.3.1.4 Standards

The proposed project will be assigned scores based on whether it is expected to improve accessibility for a disadvantaged population by improving access to pedestrian, bicycle, or transit facilities, as follows.

2 points: The project improves two or more new facilities meeting the distance criteria (¼ mile walking distance to a sidewalk or trail, ½ mile bicycling distance to an on-street bicycle facility or a shared use path, and ½ mile walking distance or 2-mile bicycling distance to a transit stop) for an identified transportation-disadvantaged population in any census tract of interest.

1 point: The project improves one existing facility meeting the distance criteria for an identified transportation-disadvantaged population.

0 points: The project does not impact an identified transportation-disadvantaged population or provides no facilities meeting the distance criteria.

-1 point: The project has a negative impact on an identified transportation-disadvantaged population through degradation of a pedestrian, bicycle, or transit facility.

These standards maintain the -1 to 2 point range and, therefore, can seamlessly replace the Environmental Justice criterion that is present in the Social Equity category of version 3.0 of the scoresheet.

4.2.3.1.5 Limitations
The primary limitation of this criterion is related to the uncertainty of the population distribution when using the census tract centroid for assessing distances to pedestrian, bicycle, and transit facilities.

4.2.3.2 Community engagement

4.2.3.2.1 Evidence base
Federal transportation planning guidelines include public involvement recommendations (*83*), but project-level accountability may lag. Community engagement is a key principle of community empowerment. Greater input and participation by populations, particularly transportation-disadvantaged populations, who would be impacted by a transportation project is recommended (*8*,*10*,*76*). Key to greater engagement is asking potentially impacted community members about their needs and experiences and utilizing venues unique to the population and innovative techniques that go beyond traditional transportation planning, such as videos and conducting outreach at nontraditional locations (*84*). However, limited project scoring frameworks among state and regional transportation agencies have incorporated criteria for community engagement. Two sources were located with frameworks or suggestions for community engagement measures that are or could be quantifiable (*10, 85*).

4.2.3.2.2 Methodology
This criterion is based on the “Community Engagement Standards for Community Health Planning Guideline” (*75*) produced by the Massachusetts DPH. This guideline presents a continuum of public involvement from low to high level: inform, consult, involve, collaborate, delegate, and community-driven/-led. The guide provides examples for each level. The top levels, Delegate and Community-driven/-led, are not relevant for scoring projects. All projects are required to have a Design Public Hearing at the 25% level. However, the hearing is a one-time event, and many critical decisions have already been made and design money spent by the time of the hearing.

Proponents will provide documentation of their efforts to (1) inform and (2) consult, involve, or collaborate with community stakeholders. Table 6 provides examples of such efforts to assist the proponent with both engaging with the affected community and assessing its level of engagement for project-scoring purposes.

Table 6. Examples of engagement level

Engagement Level			
Inform	**Consult**	**Involve**	**Collaborate**
Fact sheets	Public comments	Workshops	Advisory groups
Websites	Focus groups	Deliberative polling	Consensus building
Open houses	Surveys	Advisory bodies	Participatory decision making
	Community meetings		

4.2.3.2.3 Data
The proponent will provide documentation of all activities pursued to inform and actively engage community stakeholders.

4.2.3.2.4 Standards
The proposed project will be assigned scores based on the highest level of engagement it demonstrates (Inform is the lowest and Collaborate is the highest), as follows.

2 points: Proponent shows evidence of utilizing at least one community engagement activity at the Consult, Involve, or Collaborate level.

1 point: Proponent shows evidence of utilizing at least one community engagement activity at the Inform level.

0 point: Proponent shows no evidence of community engagement activities at the Inform, Consult, Involve, or Collaborate levels.

In order to seamlessly replace the existing Public Outreach criterion that uses a range of -1 to 1 for point allocation, the team proposes the following alternative point allocation.

1 point: Proponent shows evidence of utilizing at least one community engagement activity at the Consult, Involve, or Collaborate level.

0 points: Proponent shows evidence of utilizing at least one community engagement activity at the Inform level.

-1 point: Proponent shows no evidence of community engagement activities at the Inform, Consult, Involve, or Collaborate levels.

4.2.3.2.5 Limitations
Activity counts may not capture all dimensions of community engagement for a project. In addition, it is expected that transitioning the engineering workforce to initiate community engagement earlier in project development might require additional time.

4.2.4 Physical Activity

The baseline version of the highway project scoresheet (*20*) indirectly incorporated physical activity through criteria included under the Mobility category. These criteria included assessment of the project's impact on pedestrian, bicycle, and transit accommodation and mobility via improvements in pedestrian, bicycle, and transit-related infrastructure, as well as connectivity based on a project's ability to create or complete connections for other modes of travel (e.g., bike and pedestrian connections to transit or other opportunities). However, these criteria, which are still present in the most recent version of the scoresheet (v4.0) (*46*), do not explicitly consider physical activity or the impacts of it on health. Another change is that the connectivity criterion has moved to the Social Equity category in this most recent scoresheet version.

The team proposes a composite criterion pairing a physical activity-related chronic disease health outcome with project characteristics as defined in the existing physical activity-related Mobility category criteria. Projects in areas with higher current levels of chronic diseases strongly associated with physical activity would score higher for physical activity if the design includes new or improves existing pedestrian or bicycle facilities as described in the Mobility category. This criterion could be placed under Social Equity if general restructuring of the scoresheet were to be implemented to relax the restriction of a maximum of 10 points per category. The intent is not to replace the pedestrian and bicycle scores under Mobility, but rather to supplement them, because value for physical activity is only one aspect of active transportation infrastructure, i.e., there is a mobility benefit as well. Alternatively, without a general restructuring of the scoresheet or a removal of other criteria, it could replace the Effect on Pedestrian Mobility and Accommodations and Effect on Bicycle Mobility and Accommodations criteria under the Mobility category; alternative scoring standards are presented in section 4.2.4.1.4 for this case.

4.2.4.1 Physical activity-related chronic disease

4.2.4.1.1 Evidence base

Physical activity level reflects frequency, duration, and intensity of activity. Recently updated U.S. physical activity guidelines call for adults to accumulate at least 150 minutes of moderate intensity aerobic activity per week (*12*). A large body of research documents that minority and low-income populations experience lower physical activity levels (*86*) and higher rates of chronic diseases correlated with the lack of physical activity (*87*). Areas with higher concentrations of these populations have historically received lower levels of transportation investment, particularly for more affordable modes that could increase access to critical services while providing opportunity for physical activity (*9*). An emerging area in physical activity and health research is the study of unintended consequences of built environment improvements that support active transportation, as there is growing evidence these improvements may further benefit already advantaged populations and widen inequities (*88*).

Scoring for physical activity should therefore assess not only project characteristics but also existing physical activity-related health outcomes. The FHWA "Guidebook for Developing Pedestrian and Bicycle Performance Measures" suggests use of physical activity or chronic disease metrics for project prioritization and provides example measures such as current levels of physical activity or activity-related health indicators (*80*). The only population-level physical activity measurement in the United States is the Behavioral Risk Factor Surveillance System (BRFSS) (*89*) administered by the Massachusetts DPH on behalf of the U.S. Centers for Disease Control and Prevention. However, BRFSS participation continues to decline significantly over time across the United States, and physical activity estimates are no longer available at the community level for Massachusetts.

The recent publication "Physical Activity: Built Environment Approaches Combining Transportation System Interventions with Land Use and Environmental Design" (*90*) from the Community Preventive Services Task Force recommends deploying land use and transportation strategies in tandem to increase physical activity opportunity, and presents four types of strategies: pedestrian infrastructure; bicycle infrastructure; connectivity; and access to transit. However, most of the physical activity and health literature research on specific facilities does not translate easily to differential scoring.

4.2.4.1.2 Methodology

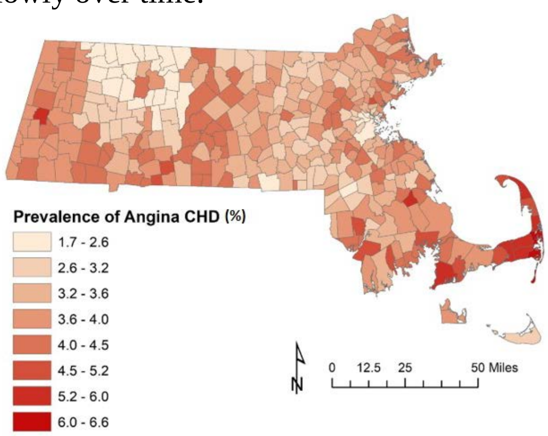
The prevalence of three physical activity-related chronic conditions will be utilized for this criterion: (1) percentage of adults in the municipality categorized as obese based on height and weight data; (2) percentage of adults in the municipality who report ever being told by a doctor, nurse, or other health professional they had diabetes; and (3) percentage of adults in the municipality who report ever being told by a doctor, nurse, or other health professional they had angina or coronary heart disease (CHD). Prevalence is the number of cases of disease present in a population, in this case represented by percentage. Scoring prioritizes the top quintile, i.e., municipalities reporting the highest percentages of these physical activity-related chronic conditions. The following steps describe the process for scoring this criterion.

1. Determine and report prevalence quintiles for each of the following three physical activity-related chronic conditions: obesity, diabetes, and angina or coronary heart disease at the community or municipality level. If a project affects multiple communities, use the highest quantile for the affected communities for each of the health outcomes. The selection of the community and municipality level is because population estimates of health conditions at a higher resolution (i.e., below the community level) are not available for privacy reasons. Lower resolutions could be used in the absence of community-level data but would result in less accurate chronic-condition assessments.

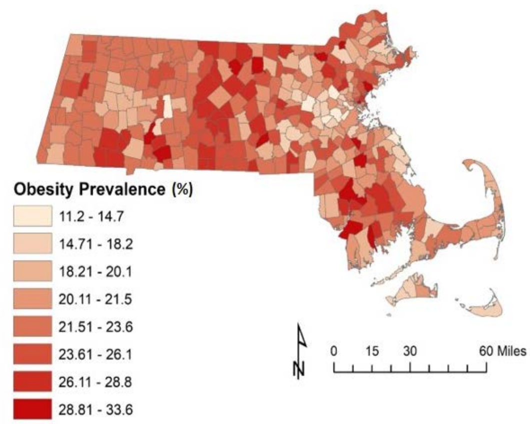
2. Assess whether the proposed project substantially improves pedestrian and/or bicycle mobility through improved or new walk or bicycle-specific infrastructure (same as those reported in the most recent version of the scoresheet, v4.0). Alternatively, a list of project types that have been shown to result in significant improvements for physical activity can be created to replace or supplement the ones mentioned in the most recent version of the scoresheet.

4.2.4.1.3 Data

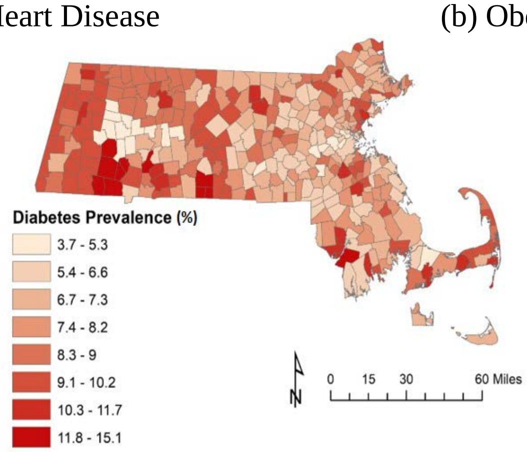
Community-level estimates based on BRFSS data are publicly available via the Public Health Information Tool (PHIT) (*91*) web portal maintained by the Massachusetts DPH. PHIT contains hundreds of datasets, including selected BRFSS direct estimates and some small area estimates (community-level data) as well as mortality data. Small area estimation is a process that uses population data to derive estimates from limited samples (*92*). PHIT currently includes small area estimates (based on 2012–2015 data) for percentage of adults (1) categorized as obese, based on height and weight data collected as part of BRFSS; (2) who report ever being told by a doctor, nurse, or other health professional they had diabetes; and (3) who report ever being told by a doctor, nurse, or other health professional they had angina or coronary heart disease. Community (municipality)-level estimates are available for 259 Massachusetts municipalities (74%), while the remaining 92 communities (26%) did not have sufficient respondents to permit reporting. PHIT also includes county-level data estimates, so the corresponding county-level estimate was substituted for each of the municipalities lacking a community-level estimate. All Massachusetts municipalities were then divided into quintiles (i.e., five equal groups) of prevalence for each of the three health outcomes. These three datasets are illustrated in Figure 6 (*89*). These estimates will not be updated due to the declining BRFSS participation, but chronic disease rates change only slowly over time.



(a) Angina or Coronary Heart Disease



(b) Obesity



(c) Diabetes

Source: Commonwealth of Massachusetts. (2020). *PHIT Data: Behavioral Risk Factor Surveillance System (BRFSS)*. (*89*)

Figure 6. Prevalence of physical activity-related chronic conditions (2012–2015)

4.2.4.1.4 Standards

The proposed project will be assigned scores based on whether it is in an area that presents high levels of the three chronic conditions associated with physical activity (i.e., obesity, diabetes, or angina/CHD) and the potential of the project to improve infrastructure that would benefit physical activity levels, as follows.

2 points: The project is in an area that is in the highest quintile for at least one of the three chronic conditions (obesity, diabetes, or angina/CHD) AND adds new or improves existing Pedestrian Mobility and Accommodations and/or Bicycle Mobility and Accommodations AND improves connectivity by creating new bike and pedestrian connections to transit stops, transportation hubs, and other opportunities, completing a link between existing pedestrian and bicycle facilities or creating new connections to recreational or open space.

1 point: The project is in an area that is in the highest quintile for at least one of the three chronic conditions (obesity, diabetes, or angina/CHD) and EITHER adds new/improves existing Pedestrian Mobility and Accommodations or Bicycle Mobility OR improves connectivity by creating new bike and pedestrian connections to transit stops, transportation hubs, and other opportunities, completing a link between existing pedestrian and bicycle facilities or creating new connections to recreational or open space.

0 points: No improvements to Pedestrian Mobility and Accommodations or Bicycle Mobility and Accommodations are proposed.

-1 points: The project is an area that is in the highest quintile for at least one of the three chronic conditions (obesity, diabetes, or angina/CHD) and will have negative effects on Pedestrian Mobility and Accommodations or Bicycle Mobility and Accommodations.

In order to seamlessly replace the existing Effect on Pedestrian Mobility and Accommodations and Effect on Bicycle Mobility and Accommodations criteria, each of which use a range of -1 to 2 for point allocation, the team proposes the following alternative point allocations.

Physical activity-related chronic disease—pedestrian mobility and accommodations

2 points: The project is in an area that is in the highest quintile for at least one of the three chronic conditions (obesity, diabetes, or angina/CHD) AND adds new or improves existing Pedestrian Mobility and Accommodations.

1 point: The project is in an area that is NOT in the highest quintile for any of the three chronic conditions (obesity, diabetes, or angina/CHD) BUT adds new or improves existing Pedestrian Mobility and Accommodations.

0 points: No improvements to Pedestrian Mobility and Accommodations or Bicycle Mobility and Accommodations are proposed.

-1 points: The project is an area that is in the highest quintile for at least one of the three chronic conditions (obesity, diabetes, or angina/CHD) AND will have negative effects on Pedestrian Mobility and Accommodations.

Physical activity-related chronic disease—bicycle mobility and accommodations

2 points: The project is in an area that is in the highest quintile for at least one of the three chronic conditions (obesity, diabetes, or angina/CHD) AND adds new or improves existing Bicycle Mobility and Accommodations.

1 point: The project is in an area that is NOT in the highest quintile any of the three chronic conditions (obesity, diabetes, or angina/CHD) BUT adds new or improves existing Bicycle Mobility and Accommodations.

0 points: No improvements to Pedestrian Mobility and Accommodations or Bicycle Mobility and Accommodations are proposed.

-1 point: The project is an area that is in the highest quintile for at least one of the three chronic conditions (obesity, diabetes, or angina/CHD) and will have negative effects on Bicycle Mobility and Accommodations.

4.2.4.1.5 Limitations
Chronic disease risk is affected by a wide range of factors, of which physical activity is only one. While minutes of transportation or total physical activity would provide a more direct metric, data limitations prevent its use at this time. The most recent Massachusetts Travel Survey was administered in 2010, and the sample size for walking and bicycling trips is small and mainly concentrated on the eastern part of the state. Physical activity behavioral data is routinely collected by the Massachusetts DPH as part of the BRFSS, but sharply declining participation prevent community-level estimates. BRFSS data are self-reported. Another consideration related to this criterion is the potential for double-counting improvements in bicycle and pedestrian mobility through improved infrastructure that is already included in the Mobility criteria. This could be resolved by replacing the bicycle and pedestrian mobility criteria with the proposed ones as discussed in 4.2.4.1.4. Finally, the recommended indicator has not been previously tested by any other DOT.

4.2.5 Safety

Safety has been incorporated in both the baseline v. 3.0 highway project scoresheet (*20*) and the most updated v. 4.0 scoresheet (*46*) through multiple criteria. These include (1) existence of road safety audit; (2) improvements on safety anticipated due to proposed project; (3) improvements specific for bicyclists and pedestrians; and (4) comparison of crashes or crash rates with state, district, or federal averages. With the exception of the last one, these measures are not quantitative; rather, they are based on qualitative criteria and assumptions on whether a project improves safety for all users or specifically for nonmotorized users. Crashes and crash rates are used, but they are not directly accounting for bike and pedestrian safety or crash severity. In addition, scores for the existing motor vehicle safety conditions criterion are allocated based on three different measures, Highway Safety Improvement

Program, crashes, and crash rates. This not only requires additional resources, since it is more time intensive to estimate three different measures, but it also can create confusion and have unintended consequences in the types of projects to be scored, obscuring transparency.

In the most recent version of the scoresheet, the safety criteria categories have stayed the same, with the exception of the road safety audit that was removed. However, the standards used to assess each criterion have changed to become more quantitative; for example, improvements in motor vehicle safety are now assessed using Crash Modification Factors and estimating whether a proposed project is expected to reduce crash rates by more than 50%. The baseline version was assessing the same criterion based on qualitative improvements in Strategic Emphasis Areas or areas included in the Strategic Highway Safety Plan or inclusion of recommendations from a road safety audit. Yet, the two safety criteria related to pedestrian and bicyclist safety still base their assessment on documented needs for pedestrian and bicycling safety improvements rather than directly accounting for crashes or crash rates, and they lack a focus on crash severity.

Two safety criteria are proposed: (1) crash rate for nonmotorized users (separated into two: one for each type of nonmotorized user, i.e., pedestrian and bicyclists, which is consistent with the existing pedestrian and bicycle safety criteria in the 4.0 version of the scoresheet; and (2) annual number of fatal and injury crashes, both under the Safety criteria group. While the extent of fatal and injury crashes is often mentioned as part of the "identified safety issues" and is often described in detail in road safety audits (RSA), it is not explicitly and quantitatively considered in any of the safety criteria included in v. 3.0. The 3.0 version of the scoresheet included points for when improvements are made due to the recommendations from an RSA, but did not consider the exact number of fatal and injury crashes. The most updated version of the scoresheet, v4.0, does not consider the results of RSAs.

To avoid extensive modeling exercises any time a project needs to be scored, these two measures will be assessed for existing conditions, and the criteria will be formulated by comparing against state, MPO, or other areas of interest, averages. These criteria will also be combined with expectations on how the proposed projects will affect safety levels for bicyclists and pedestrians. The second measure captures crash severity, which is also very important and greatly affects nonmotorized users as well. The first criterion is expected to replace the Existing Pedestrian Conditions and Proposed Improvements and Existing Bicycle Conditions and Proposed Improvements criteria and the second to replace the Existing Motor Vehicle Safety Conditions, both under the Safety category.

4.2.5.1 Crash rate for nonmotorized users

4.2.5.1.1 Evidence base

Pedestrians and bicyclists are particularly vulnerable to crashes due to the limited protection they have compared to motorized vehicles. Safety risks associated with bicycling and walking are often seen as deterrents to nonmotorized mode choices and therefore, physical activity. In addition, crashes disproportionally impact ethnic and racial minority populations as well as low income individuals, adversely affecting the equity of transportation systems (*93*,*94*,*95*). Pedestrian mortality rates are higher for people of color and driver yielding behavior is impacted by pedestrian race, indicating that certain minorities are prone to more severe injuries when involved in crashes.

According to the 2018 traffic safety data released by the National Highway Traffic Safety Administration (NHTSA) (*96*) there has been an increase in both pedestrian and bicyclist fatalities compared to 2017. While this information is alerting, it does not consider the changes in travel patterns (if any), e.g., do people drive more or walk more than before? Changes in travel patterns result in changes in the exposure nonmotorized users experience.

Crash rate is a ratio that expresses the risk to crashes; the numerator is the average number of crashes per year during a n-years' time period, and the denominator expresses the exposure over the same period. Exposure metrics could vary depending on project location, e.g., intersection vs road segment as well as the mode for which crash rates are estimated. Motor vehicle crash rates are usually estimated using vehicle miles traveled (VMT) as the exposure metric, while for nonmotorized users the demand of both motorized vehicles and nonmotorized users has been proposed as both of these values are affecting crash frequency (*97*). The use of exposure metrics when dealing with crash data allows for a more accurate safety quantification compared to crash frequency (i.e., number of crashes).

4.2.5.1.2 Methodology

Two criteria are proposed, one focusing on pedestrian and the other on bicycle safety and improvements, but they are described together for brevity. The following steps describe the process for scoring each of these two criteria.

1. Obtain the 5-year annual average number of bicycle/pedestrian crashes for the project area.

2. Obtain the Annual Average Daily Traffic (AADT), Annual Average Daily Bicycle (AADB) traffic, or Annual Average Daily Pedestrian (AADP) demand for the project site (e.g., intersection or segment, or average if larger area). Alternatively, miles traveled by each mode can be used as proxies for demand to replace the aforementioned AADT, AADB, and AADP, but only when the interest is to obtain crash rates for an area (e.g., census block or community) rather than an intersection or segment.

3. *For an intersection*: calculate bicycle or pedestrian crash rate as follows (*97*):

$$\boldsymbol{CR_b = \left(\frac{1000000}{365}\right)^2 \frac{\overline{C_{b,5}}}{AADT \times AADB}} \tag{1}$$

CR_b: crash rate for bikes for the area of interest
$\overline{C_{b,5}}$: 5-year annual average number of crashes for the area of interest
AADT: Annual Average Daily Traffic for the area of interest
AADB: Annual Average Daily Bicycles for the area of interest

For a segment: calculate bicycle (or pedestrian) crash rate as follows:

$$\boldsymbol{CR_b = \left(\frac{1000000}{365}\right)^2 \frac{\overline{C_{b,5}}}{AADT \times AADB \times L}} \tag{2}$$

L: segment length.

4. Calculate the same bicycle/pedestrian crash rate for the state by averaging bicycle/pedestrian crash rates over all census tracts, communities, or MPOs, depending on data availability. This can be done by either averaging already calculated crash rates over the area of interest, or by calculating an average crash rate by dividing the total number of crashes in the area by total AADT. Alternatively, the comparison can be performed with average bicycle/pedestrian crash rates for the areas of the other proposed projects being considered in the scoring process, for all census tracts in a community that the proposed project belongs to, or all communities within the MPO the proposed project belongs to.

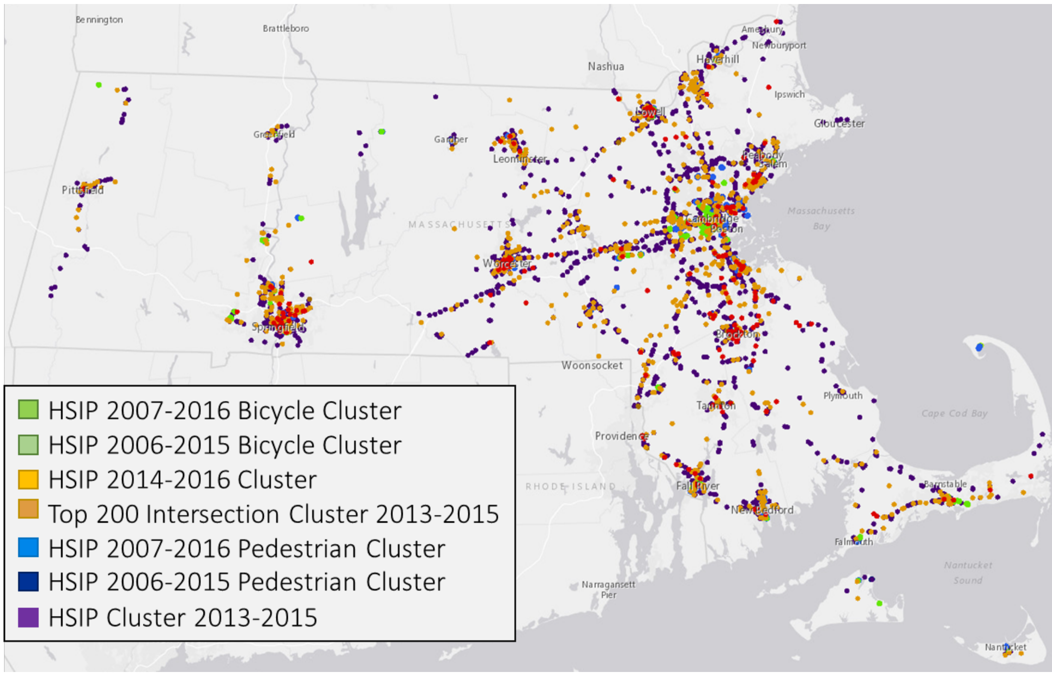
5. Assess whether the proposed project is expected to improve safety (i.e., reduce crashes) for bicyclists/pedestrians.

6. Assign the score based on standards described in Section 4.2.5.1.4.

4.2.5.1.3 Data

Severe injury and fatal crashes involving bicycles and pedestrians for 2006–2016 have been grouped in crash clusters and are available in geoDOT; see Figure 7. The most recent five years can be utilized to estimate crash rates for nonmotorized users. AADTs can be obtained from the MassDOT Transportation Management System (*98*) at the segment level and can be combined to produce intersection-level AADT. These data are available since 1962; however, not all locations have data available for the same years.

Bike or pedestrian demand data, i.e., annual average daily bicycle or pedestrian demand, could be useful in order to produce a more representative exposure measure; however, these data are currently limited to a few locations. Data updates are necessary every two to three years or whenever big investments in bicycle and pedestrian projects are implemented to capture the effect on nonmotorized user demand.



Source: geoDOT

Figure 7. Pedestrian, bicycle, and motor vehicle crash clusters for fatal and severe injury crashes

4.2.5.1.4 Standards

The proposed project will be assigned scores based on whether it is in an area that presents high nonmotorized user (i.e., bicycle or pedestrian) crash rates compared to the areas of interest and the potential of the project to improve safety, i.e., reduce these crash rates, as follows.

2 points: The project area has higher bicycle/pedestrian crash rates compared to the area of interest AND reductions in bicycle/pedestrian crashes are expected from the proposed project.

1 point: The project area has similar bicycle/pedestrian crash rates compared to the area of interest (e.g., within 5%) AND reductions in bicycle/pedestrian crashes are expected from the proposed project.

0 points: The project area has lower bicycle/pedestrian crash rates than the area of interest it is compared against and the proposed project is not expected to deteriorate these crash rates, OR no change in bicycle/pedestrian crashes is expected.

-1 point: The project is expected to increase nonmotorized user crashes.

While these standards do not maintain the 0 to 2 point range needed to replace existing safety criteria that are relevant, they do maintain a maximum of 2 points. As a result, they can seamlessly replace the Existing Pedestrian Safety Conditions and Proposed Improvements and Existing Bicycle Safety Conditions and Proposed Improvements criteria that are present in the Safety category of version 3.0 of the scoresheet.

4.2.5.1.5 Limitations

Estimation of crash rates depends on the availability of crash data and demand data, usually AADT, AADB, and AADP. Given that crashes are often not reported, a fact that this is disproportionately true for crashes involving nonmotorized users, it is likely that the obtained crash rates are not representative. In addition, a lot of near-misses might exist in a segment or intersection with a low number of crashes, which would be impossible to capture, given that only data from formal reports are used when estimating crash rates. The lack of bicycle and pedestrian demand studies and data collection efforts also limit the availability of AADB and AADP that are essential for the estimation of the respective bicycle and pedestrian crash rates. Finally, crash rates are only appropriate for comparisons of project sites with similar characteristics, as they cannot capture the impact of geometric or other attributes on crashes. Ideally, Safety Performance Functions (SPF) should be used in place of crash rates, since they are capable of (1) capturing the impact of different design components that can lead to crashes, (2) considering a nonlinear relationship between number of crashes and exposure that is more realistic. However, SPFs have not been developed for many safety countermeasures, in particular for pedestrian and bicycle-specific treatments.

4.2.5.2 Annual average number of fatal and severe injury crashes

4.2.5.2.1 Evidence base

Car crashes are the leading cause of death for ages 5–34 in the United States (*99*). Severe injury and fatal crashes have been associated with high economic costs that range from damaged property to medical service, insurance, legal court costs, reduced productivity, and workplace losses (*100*). However, if in addition to these costs, one considers the societal harm of human lives, the total cost in monetary terms can be three times higher (*100*). While several safety criteria can indirectly capture the impact on health, severe crash frequency (i.e., number of fatal and severe injury crashes) has the additional advantage of doing so in a more direct way. This is not to discount low safety conditions associated with areas with many noninjury crashes, or near-misses, but it is used as a metric to account for areas that can have detrimental impacts on human health. An additional advantage of considering this performance measure is the availability of data, as severe crashes are always reported by both police and medical professionals.

4.2.5.2.2 Methodology

The following steps describe the process for scoring this criterion:

1. Obtain the 5-year annual average number of fatal and severe injury crashes for the project area.

2. Obtain the statewide 5-year annual average number of fatal and severe injury crashes. Alternatively, the comparison can be performed with 5-year annual average number of fatal and severe injury crashes of the other proposed projects being considered in the scoring process, or of the community or municipality or MPO the proposed project belongs to.

3. Assess whether the proposed project is expected to reduce severe crashes for all users.

4. Assign the score based on standards described in Section 4.2.5.2.4.

Alternatively, this criterion can be incorporated within the Existing Motor Vehicle Safety Conditions criterion of the latest v. 4.0 scoresheet, by replacing the focus on crashes or crash clusters in general to severe crashes or clusters. The existing criterion is scored based on a project area being included within the Top 200 MassDOT Motor Vehicle Crash Cluster, the existence and number of motor vehicle clusters within the project area, whether the project is eligible for non-MassDOT HSIP, the difference between observed and predicted crashes based on the Highway Safety Manual, and the comparison with state, district, or federal numbers of crashes for the same functional class in combination with whether the project will improve safety.

4.2.5.2.3 Data

Crash severity is reported for all crashes that have been formally reported in crash reports. These data are available in geoDOT for the period of 2013–2015. Additional years of data are available in the MassDOT Open Data Portal (*101*). However, crashes are currently grouped by location to create crash clusters. For motor vehicle crashes, a cluster is created to contain crashes within a distance of 25 meters. For nonmotorized user crashes, the respective distance is 100 meters. This information exists in geoDOT, and for every cluster, the number, location, and severity level of each individual crash is known.

4.2.5.2.4 Standards

The proposed project will be assigned scores based on whether it is in an area that presents high frequency of fatal and severe injury crashes (of all modes) compared to the areas of interest and the potential of the project to improve safety, i.e., reduce crash frequencies, as follows.

2 points: The project area has higher annual number of fatal and severe injury crashes (5-year average) compared to the areas of interest AND the proposed project is expected to result in safety improvements.

1 point: The project area has similar annual number of fatal and severe injury crashes (5-year average) (e.g., within 5%) compared to the areas of interest, AND the proposed project is expected to result in safety improvements.

0 point: The project area has lower annual number of fatal and severe injury crashes (5-year average) compared to the areas of interest OR no safety improvements are expected from proposed project.

-1 point: The proposed project is expected to deteriorate safety.

The inclusion of -1 point as an option in the proposed criterion does not affect the maximum score that can be assigned for the Safety category. However, in order for this criterion to seamlessly replace the Existing Motor Vehicle Safety Conditions (in either v. 3.0 or v. 4.0) and maintain a maximum of 10 points for the Safety category, a 3-point option needs to be added, which could be similar to the ones from the existing scoresheets that are utilizing the presence of Crash Clusters, adjusting them to focus on only fatal and severe injury crashes, as follows.

3 points: Project area contains a Top 200 Motor Motor Vehicle Crash Cluster for fatal and severe injury crashes AND project will improve safety.

4.2.5.2.5 Limitations
Crash frequency does not account for exposure; therefore, a location might appear more unsafe than another, even if it is characterized by higher motor vehicle or bicycle demand. When sites with similar characteristics, e.g., similar traffic volumes, are compared, this becomes less relevant. This could be addressed by estimating fatal and injury crash rates instead of frequencies for these types of crashes. In addition, there is a lack of modeling techniques that can assist with quantification of a project's impact, specifically on the severity of crashes.

4.3 Summary of Proposed Changes

Table 7 presents a summary of the recommended added criteria and, in general, changes to the existing MassDOT Highway Division project prioritization scoresheet. Note that the baseline for these proposed criteria was v. 3.0 of the scoresheet. Existing criteria in italic font represent criteria to be replaced or supplemented based on the proposed project scoring criteria. The suggestion is that the rest of the criteria remain unaltered.

Table 7. Proposed criteria

Factor	Existing Criteria (v3.0)	New Criteria
Air Quality	• *Air Quality and GHG reduction*[1]	• **$PM_{2.5}$ and NO_2 concentration**[2]
Accessibility	• *Workforce commuting and accessibility* • *Connectivity (new bike/ped connections to transit stops, etc.)*	• **Job accessibility** • Accessibility by walk/bike to other points of interest • Transportation disadvantaged access (composite indicator)
Equity	• *Improvements in EJ communities* • Improvements in Environmental Title VI communities • Improves access to housing programs • Regional Equity (% of federal funds per eligible roadway mile) • *Public outreach*	• Transportation disadvantaged access (composite indicator) • Community engagement[3]
Physical Activity	• Sidewalk improvements • *Effect on pedestrian, and bicycle mobility and accommodations (Improvements in pedestrian and bicycle, mobility and accommodations)* • Effect on transit mobility and accommodations (Improvements in transit mobility and accommodations)	• Physical activity-related chronic disease[4]
Safety	• *Existing pedestrian safety conditions and proposed improvements* • *Existing bicycle safety conditions and proposed improvements* • *Existing motor vehicle safety conditions* • Road safety audits • Improvements to motor vehicle safety	• Bicycle/Pedestrian crash rate • Annual number of fatal and severe injury crashes

[1]Existing criteria in italics indicate those that are being replaced.
[2]Criteria in bold indicate the criteria that have already been included in version 4.0 of the MassDOT Highway Division project scoring framework.
[3]This criterion can be either included under the Social Equity category if general restructuring of the scoresheet were to be implemented to relax the restriction of a maximum of 10 points per category, or replace the Public Outreach criterion under the Policy Support category.
[4]This criterion could be placed under Social Equity category if general restructuring of the scoresheet were to be implemented to relax the restriction of a maximum of 10 points per criteria category or replace the Effect on Pedestrian Mobility and Accommodations and Effect on Bicycle Mobility and Accommodations criteria under the Mobility category.

Based on the research team's recommendations, the most recent version of the scoresheet has incorporated some of the proposed project scoring criteria as indicated by the ones in bold font. In particular, $PM_{2.5}$ mass and NO_2 concentration criterion was included as the Air Quality and GHG reduction criterion under Social Equity and was supplemented by additional standards related to the implementation of CMAQ analysis, presence of green technology, or buffers to protect pedestrians. Section 4.2.1.2 describes this criterion exactly as it has been implemented in version 4.0 of the scoresheet. The proposed job accessibility criterion has been partially incorporated (i.e., focus only on car access to jobs) as part of the Workforce Commuting and Accessibility criterion under Economic Impacts, supplemented by standards related to the introduction of motor vehicle or bicycle connections and the reduction in automobile commute times.

The second accessibility criterion is proposed to replace the Connectivity criterion currently under Social Equity, in version 4.0 of the scoresheet. The proposed transportation disadvantage access criterion replaces the Environmental Justice criterion under Social Equity, while the community engagement criterion could replace the Public Outreach criterion under the Policy Support category. The physical activity-related chronic disease criterion could replace the Effect on Pedestrian Mobility and Accommodations and Effect on Bicycle Mobility and Accommodations under Mobility. Alternatively, if a restructuring of the whole scoresheet were to be considered, the community engagement and physical activity-related chronic disease criteria could be placed under the Social Equity category. Finally, the Bicycle/Pedestrian crash rate criteria are proposed to replace the Effect on Bicycle/Pedestrian, Mobility and Accommodations criteria, while the annual number of fatal and severe injuries could replace the Existing Motor Vehicle Safety Conditions, both under the Safety category.

In order to maintain a total of 10 points per criteria category, the air quality, both of the accessibility, and transportation disadvantage access criteria are replacing existing criteria under the same categories using a compatible scoring range (0 to 2 points, -1 to 2 points, etc.). In the case of the crash rate for nonmotorized users, the proposed standards do not maintain the 0 to 2 point range needed to replace existing safety criteria that are relevant, but they do maintain a maximum of 2 points, which is sufficient for maintaining a maximum of 10 points for the Safety category. For the rest of the proposed criteria, alternative scoring standards have been proposed to allow for a seamless incorporation into the existing structure of the scoresheet. The alternative standards can allow for a seamless replacement of existing scoring criteria without the need for restructuring the scoring process (i.e., maintaining 10 points for each criteria category) or removing other existing criteria.

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5.0 Conclusions

Transportation affects health through multiple pathways, including air quality, accessibility, equity, physical activity, and safety. This research project has investigated the state of practice in assessing health for transportation projects and its impact on decision making, and has identified the following main takeaways.

- Changing project prioritization criteria is a cost-effective way to incorporate health in transportation decision making (*38*).
- Agencies that have updated their project scoring processes have observed increases in low-cost projects and projects targeted at improving active transportation.
- Allocation of weights warrants attention, and it should reflect priorities set by relevant stakeholders. For example, if improving active transportation to enhance health in a region is considered to be a policy goal, criteria related to physical activity and nonmotorized transportation modes should be weighed higher.
- Different criteria or weights should be considered for rural and urban areas and potentially for areas with different socioeconomic characteristics.
- Normalization of criteria scores should be implemented when criteria magnitudes vary substantially, to allow for a fair comparison of scored projects.
- New data sources (e.g., those related to physical activity) are likely to become available in the near future and could influence the overall assessment of how transportation affects health or facilitate the development of new performance measures and criteria.
- The importance of incorporating health in project prioritization and decision making is also documented within the recently published "National Highway Cooperative Research Program (NCHRP) Report 20-112: A Research Roadmap for Transportation and Public Health" (*102*), which has identified the following as the first problem that warrants research: "Problem Statement 1: Synthesis of Best Practices for Including Health Outcomes in Transportation Project Prioritization."

Given the state of practice of understanding and addressing the connection between transportation and health, the research team proposes the following.

Updates/additions to the MassDOT highway project criteria: As discussed in Chapter 4, the team proposes eight criteria to address health impacts related to air quality, accessibility, equity, physical activity, and safety. The recommendation is that these criteria are included under various criteria categories, but primarily under the Social Equity, Safety, and Mobility categories.

Criteria weight adjustments: Changes to the weighting factors in the MassDOT Highway Division project scoring process should be considered to more explicitly account for exposures affecting health and to emphasize nonmotorized projects. Although many of the existing criteria are related to health, as well as the proposed criteria within the Social Equity category, social equity considerations are only weighted as 10% of the overall score. Moving criteria from other higher-weighted categories to the Social Equity factor without increasing the weight for this category could have the unintended effect of decreasing the consideration of health. In addition, adding more criteria to this category also reduces the impact of each of the criteria on the overall score.

Seamlessly incorporate project scoring with geoDOT: Scoring projects can be facilitated by developing a single platform for project initiation and scoring that also contains all of the data needed to score a project. While the interactive part of the scoresheet that is used to score projects includes links to relevant datasets, a combined platform that automatically provides the user with necessary data would improve efficiency in proposing and scoring projects.

Conduct a travel survey: The last travel survey performed for the state took place in 2011. Limitations of this study include (1) new shared and micromobility options, which are not represented in the sample; and (2) limited data for areas outside the Greater Boston region. The team recommends that MassDOT and MDPH closely collaborate so that questions about active travel trips and behavior can be incorporated.

Bicycle and pedestrian data collection: Physical activity surveillance has been identified as a critical need nationally (*103*). With new technological means such as smartphone applications, data collection is becoming more streamlined. The recommendation is that state agencies perform bicycle and pedestrian data collection efforts in order to obtain demand data, and also invest in technology that will allow them to obtain information on high-risk areas where crashes are not necessarily observed (e.g., applications through which one can report near-misses or bad pavement conditions).

Identify improvements with significant impact: Future research could investigate research findings and real-world implementation outcomes to develop a list of project types that have been found to significantly affect (positively or negatively) the criteria of interest (e.g., accessibility, air quality, safety, etc.). A list should be developed separately for each of the criteria of interest and should be based on project characteristics and outcomes that are quantifiable to the extent possible (e.g., yielding rates when flashing beacons are installed at crosswalks).

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7.0 Appendices

7.1 Departments of Transportation and Metropolitan Planning Organizations Interview Questions

1. Is project scoring part of your DOT's resource allocation process?
    a. If so, what tools do you use?
    b. Do these project scoring methods/tools differ by the type of project (e.g., highway vs transit projects, construction vs maintenance)?
2. What models do you use to assess changes in demand, safety, air quality, mobility, accessibility, equity that are potentially used as inputs to those tools?
3. Are you aware of efforts to incorporate health into transportation decision making at your DOT? (e.g., frameworks, models).
4. How, if at all, have you worked on developing and/or implementing project evaluation criteria (including accessibility and equity) to account for the impact of health on transportation at the state level?
    a. What data are needed to assess such criteria?
    b. How are these data obtained?
5. What public health project scoring criteria are you aware of that we should review? Do you recommend them?
6. Does your agency use Health Impact Assessments for transportation projects?
7. Does your DOT work with the state DPH on transportation and health generally? If so, please summarize your experience.
8. What are some research needs that you deem necessary for incorporating health outcomes in project decision making?
9. Are there any reports/publications that document your project evaluation decision-making process that we could get access to?

7.2 Departments of Public Health Interview Questions

1. Summarize your experience working with your state transportation department on transportation and health.

PROBES:
HIA
Project scoring / Project evaluation
Performance measures
Other

2. What frameworks, models or tools for incorporating health into transportation decision making are you aware of or would like to see implemented in your state?

3. What public health or equity performance measures or project scoring criteria relevant to transportation is your department interested in?
   a. Health (e.g. physical activity, traffic injuries and fatalities / safety, air quality)

   b. Equity (e.g. access to jobs, goods, and services; emissions impact/ environmental pollution; general transportation; future growth; economic)

4. What examples from other states of incorporating health into transportation decision making should we review?

PROBES:
Project scoring
Performance measures