



NOT FOR DISTRIBUTION – NOT FOR REPRODUCTION

DRAFT FOR REVIEW

**Addressing Emissions-Related Health Issues in Transportation
Planning**

Prepared by the Texas A&M Transportation Institute

Prepared for the Texas Department of Transportation

August 2014

*NOT FOR DISTRIBUTION – NOT FOR
REPRODUCTION*

DRAFT FOR REVIEW

Addressing Emissions-Related Health Issues in Transportation Planning

Air Quality and Conformity Inter-Agency Contract

Subtask 2.1, “TWG Air Quality Planning Technical Issues Analysis”

– FY 2014

Prepared for

Texas Department of Transportation

Prepared by

Texas A&M Transportation Institute

August 2014

©2014 by Texas Department of Transportation.

All rights reserved. Any sale or further use is strictly prohibited without written permission of the Texas Department of Transportation. This material may not be reproduced or transmitted in any form by any means, electronic or mechanical, including photocopying, recording, or by any information and retrieval systems without the written consent of the Texas Department of Transportation, 125 East 11th Street, Austin, TX 78701, (512) 416-2055.

Introduction

There is growing support at the state, federal, and local level for health considerations in transportation policies, programs, and initiatives. Transportation systems are shaped by multiple policy inputs and actions arising from transportation engineers and planners as well as various agencies and organizations. This report provides an overview of the changing landscape in the health and transportation arena, with a particular focus on air quality and emissions-related issues. The findings documented in this memorandum are based on existing literature and publicly available reports, along with telephone interviews with staff from other state Departments of Transportation (DOTs) regarding their existing approaches and practices to integrating health into transportation planning.

Traffic-generated emissions including particulate matter (PM), and ozone precursors such as oxides of nitrogen (NO_x, including nitric oxide [NO] and nitrogen dioxide [NO₂]) and volatile organic compounds (VOC) have been linked to adverse human health impacts. These include increased hospitalizations, chronic diseases such as lung cancer, cardiovascular and cardiopulmonary disease, asthma, etc. There are several publicly-available reports and databases, such as the Center for Disease Control and Prevention's (CDC) National Environmental Public Health Tracking Tool, and the Texas Asthma Burden Report, that provide information regarding the impacts and cost of air pollution, including traffic related air pollution in Texas and the U.S. The Health Effects Institute (HEI) published a comprehensive report summarizing findings regarding health effects of traffic-related air pollution.¹ There are several other studies that also discuss and establish the causal link between mobile source emissions and human health, a selected few of which are listed in Appendix A.

Currently, transportation air quality issues (aimed at protecting human health impacts) are addressed through the framework of transportation conformity requirements, applicable in areas that are in violation of National Ambient Air Quality Standards (NAAQS), i.e. air quality nonattainment areas. Simply put, transportation conformity ensures that network-level transportation emissions (at the transportation plan level) in a region are kept below a certain threshold. Additionally, project-level conformity (in the form of "hot-spot" analyses or other requirements) requirements need to be met in some cases to ensure that there are no localized incidences of high exposure levels.

This report provides a broader outlook on the changing landscape of how various organizations are viewing the linkages between transportation and health, including from an air quality perspective. The report then discusses the role of health impact assessments (HIAs) and environmental justice requirements in the context of transportation and health, and provides findings from case studies of five other DOTs showcasing practices related to health and transportation. The report then concludes with a discussion on the changing paradigm of how air quality and emissions-related health issues are addressed in the transportation sector.

¹ Health Effects Institute HEI Panel on the Health Effects of Traffic-Related Air Pollution. (2010). *Traffic-related air pollution: a critical review of the literature on emissions, exposure, and health effects*. Health Effects Institute, Boston.

Health and Transportation – Concepts and Organizational Positions

The U.S. Department of Transportation’s (USDOT’s) Volpe National Transportation Systems Center recently published a primer on *Statewide Transportation Planning for Healthy Communities*,² which provides a recommended framework for health and transportation planning, as shown in Figure 1.

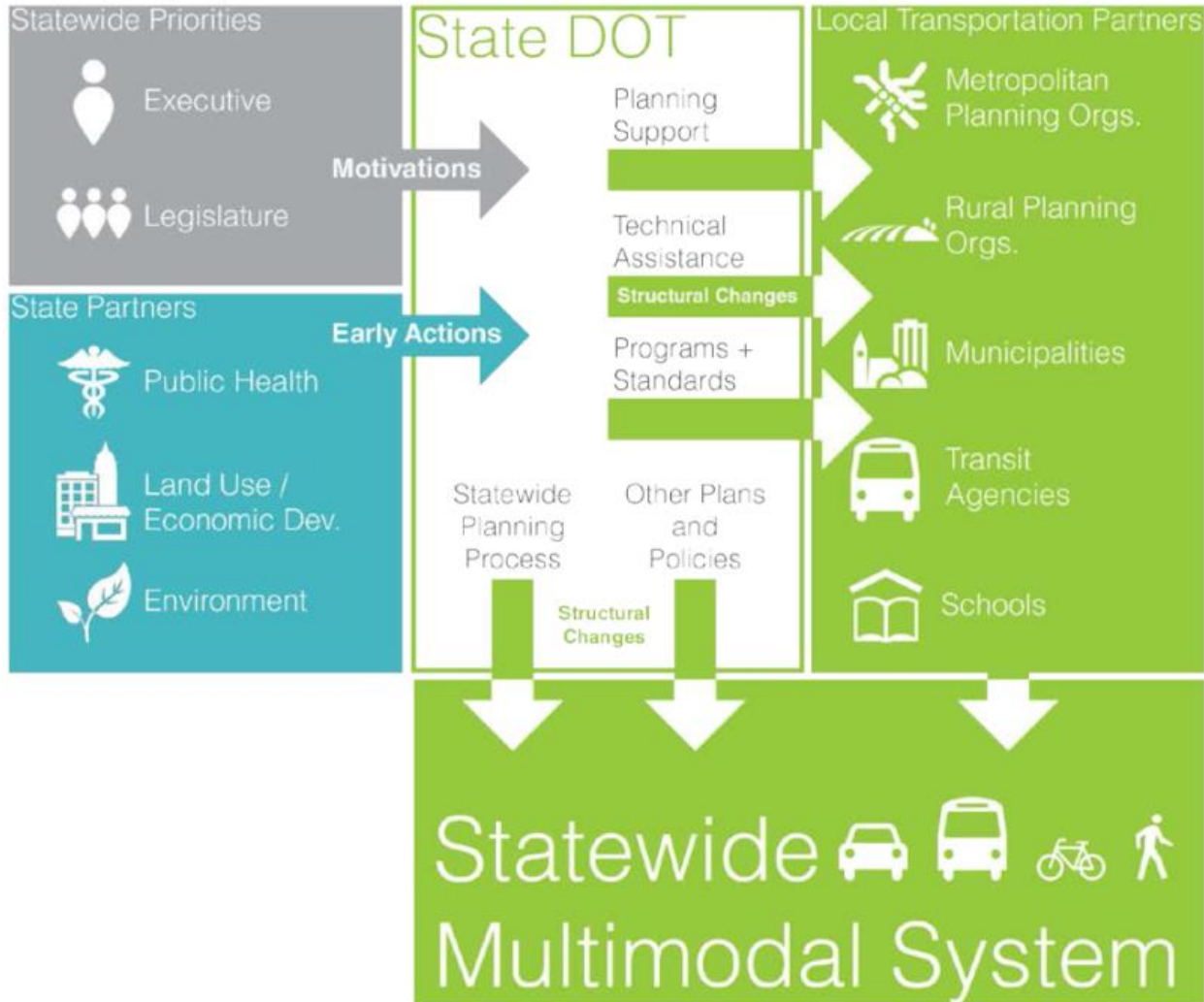


Figure 1: Recommended Framework for Health and Transportation Planning

² Lyons, W., L. Morse, L. Nash, and R. Strauss. *Statewide Transportation Planning for Healthy Communities*. Prepared for the U.S. Department of Transportation, Office of Planning, Environment and Realty, Federal Highway Administration, April 2014.

This document also discussed the need for a holistic approach to health and transportation, covering four key areas:

- Active transportation/changing land use and transportation patterns to promote active living and healthier lifestyle;
- Transportation safety across various modes;
- Accessibility/access to healthcare facilities for all demographics including vulnerable populations; and
- Impact of vehicular emissions on air quality and health.

In 2012, the USDOT had also established a voluntary Health in Transportation Working Group as an initiative to better understand the role of health in transportation, identify aspects of existing USDOT programs related to health and communicate the stakeholder's health-related concerns within the agency.³ The Work Group is focused on two main areas:

- Effects of Transportation on Public Health - The transportation system influences public health both positively and negatively, by way of its effects on air quality, communities, safety, and physical activity, access to jobs, services, healthcare, and recreational opportunities. The negative health impacts could be mitigated in the transportation planning process by reducing air pollution, preventing traffic injuries/deaths, and promoting physical activity.
- Federal Transportation Decision-Making and Health - The federal transportation planning process does not consider health explicitly. However, the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) recognize the impact of transportation infrastructure on public health and support the state DOTs and metropolitan planning organizations (MPOs) that consider health throughout the transportation planning process. Particular tools and opportunities are Bicycle and Pedestrian System Plans, Congestion Management Process (CMP), Long Range Transportation Plan (LRTP), Metropolitan Transportation Plan (MTP) and Strategic Highway Safety Plan (SHSO). While the USDOT does not require HIAs as part of the federal-aid planning process, it states that "practitioners may prepare them voluntarily."

Based on the Moving Ahead for Progress in the 21st Century Act (MAP-21), major federal transportation programs that have important health implications include: Congestion Mitigation and Air Quality Improvement Program (air quality), FTA Capital Investment Program (air quality, active living), Partnership for Sustainable Communities (air quality, safety, active living), Transportation Alternative Program (air quality, safety, active living), and Highway Safety and Improvements Program (safety).

³ Health in Transportation Working Group.
http://www.fhwa.dot.gov/planning/health_in_transportation/workgroup/, accessed July 2014.

There are several other organizations and associations that have put forward statements on health and transportation. Appendix B contains “organization summaries” taken directly from source websites, included to illustrate the paradigm shift that is currently occurring in recognizing the linkages between health and transportation.

Statewide Transportation Planning and Health– Case Studies

Five states, California, Minnesota, North Carolina, Oregon, and Washington were selected as case studies to examine current practices in terms of how health considerations are being addressed in planning, programming, and project development activities. In addition to publicly available data and documentation, the findings from this section were also compiled from telephone interviews conducted with key personnel to assess practices integrating health into transportation planning activities. Key policies, initiatives and programs, and specific emissions-related health issues are described.

California Department of Transportation (Caltrans)⁴

California does not specifically mandate that local governmental agencies integrate transportation planning with developing and/or implementing a healthy community strategy. Instead the state analyzes how transportation projects promote or fail to promote healthy community goals as outlined by Caltrans Regional Transportation Plan (RTP). Although Caltrans defers transportation planning to the regional and/or local governmental agencies, it provides assistance in terms of policy guidance, technical assistance and grant funding. For instance, the Southern California Association of Governments (SCAG) and Santa Barbara County Association of Governments (SBCAG) have both developed regional transportation plans for California through the development of sustainability practices and implementation plans known as the RTP/Sustainable Communities Strategy (SCS) for sub-regions of the state.

The SBCAG Plan is available at:

<http://www.sbcag.org/uploads/2/4/5/5/24540302/final2040rtpscscs-chapters.pdf>; and The SCAG Plan is available at: <http://rtpscscs.scag.ca.gov/Pages/default.aspx>.

Participation in these regional planning programs is voluntary at the local municipal government level, but have been gaining widespread acceptance over the past several years. The award of state and federal funds (public grants opportunities) indirectly promotes the healthy community's initiatives for local transportation projects and transit programs that achieve the state's non-transportation objectives as outlined in the RTP/SCS. Therefore, implementation of RTP/SCS promotes elements that produce healthier communities at the regional level. Some local communities are taking it a step further and integrating sustainable land use practices into their General Plan update, accordingly. Still other cities are using Climate Action Plans (CAPs), HIA, and Active Transportation Plans (ATP) to supplement the state's healthy community agenda. Most of which has been delegated to the local government by the state.

⁴ Contact for Case Study: Kevin Hughes, AICP, Advanced Planner & Environmental Consultant to the City of Beaumont, California, (951) 813-1595, hughesplus2@msn.com.

A key component of Caltrans' health-related activities is an ability to form working partnerships with other agencies. For example, in 2010, Caltrans formed the Active Transportation and Livable Communities Group, which is comprised of Caltrans management personnel and external stakeholders such as the California Department of Public Health, California Department of Housing and Community Development and various advocacy organizations. The group holds quarterly meetings in which Caltrans' policies/programs are reviewed.

Other relevant legislative commitments in California include:

- Assembly Bill (AB) 32: The Global Warming Solutions Act was passed by the California Legislature with the goal of limiting 2020 greenhouse gas (GHG) reduction to the 1990 was set into law. The California Air Resources Board (CARB) adopted cap-and-trade regulation in 2011, and established the market mechanisms in 2012. Transportation fuels were identified as one of the major sources of GHG emissions.
- Senate Bill (SB) 375: The Sustainable Communities and Climate Protection Act was enacted in 2008. Under the SB 375, CARB set regional passenger vehicle use targets for 2020 and 2035 for the California MPO. This bill provides a unique legislative justification for combining land use and transportation planning. Land use is expected to have profound impact on travel behavior, air pollution exposure and health.
- Assembly Bill 441 instructs the California Transportation Commission (CTC) to create a summary of local transportation projects that promote health and equity in the state's RTP Guidance. The bill was adapted from recommendations of the state Strategic Growth Council's Health in All Policies Task Force and co-sponsored by the California Pan-Ethnic Health Network (CPEHN) and TransForm.

Minnesota Department of Transportation (MnDOT)⁵

MnDOT has explicitly stated its policy stance to emphasize the linkage between health and transportation. The vision of MnDOT is set as "Minnesota's multimodal transportation system maximizes the health of people, the environment and our economy."⁶ MnDOT is an active participant in local HIAs for which the Minnesota Department of Health offers technical assistance, training, facilitation and information sharing.⁷ It was noted that there remains considerable debate regarding the timing of an HIA and a transportation project. Environmental planners perceive HIA as somewhat redundant to the existing National Environmental Policy Act (NEPA) processes. MnDOT created the Corridor Investment Management Strategy⁸ initiative to

⁵ Contact for Case Study: Philip Schaffner, Director, MnDOT Policy Planning, (651) 366-3743, Philip.schaffner@state.mn.us.

⁶ MnDOT Transportation Planning and Programming. Available at <http://www.dot.state.mn.us/planning/program/index.html>.

⁷ Minnesota Department of Health (2014). Health Impact Assessment (HIA): Promoting health in all projects and policies. Available at <http://www.health.state.mn.us/divs/hia/>.

⁸ MnDOT Corridor Investment Management Strategy. Available at <http://www.dot.state.mn.us/cims>.

operationalize its long range vision by bringing together local, modal and state partners to identify opportunities for collaborative and innovative investment. The core of this program expands on the traditional cost-benefit and life-cycle analysis, by adding health-related factors such as air quality impacts, safety benefits and access to recreational facilities. Selected projects of this strategy include:

- State-wide Bicycle System Plan, available at <http://www.dot.state.mn.us/bike>;
- State-wide Pedestrian System Plan, available at <http://www.dot.state.mn.us/peds>; and
- Complete Streets (implemented in the fall of 2013).

The goal of MnDOT is to evaluate each transportation project with a proactive risk mitigation plan in mind that assesses the impact of a project on the public's health and not repeating a project in another neighborhood that resulted in negative consequences.

North Carolina Department of Transportation (NCDOT)⁹

NCDOT recognizes that the opportunity to improve health lies in the department's concept of "healthy transportation." As a result, the Healthy Environments Collaborative was created in 2006 as an interagency partnership between NCDOT and the Departments of Health and Human Services (HHS), Environment and Natural Resources, Commerce, and the University of North Carolina, School of Public Health. This joint work group, in partnership with others throughout the state, pulled together a guidance document on integrating health into the comprehensive planning process.¹⁰ In addition, the NCDOT Transportation Public Health Policy was adopted by the Board of Transportation in October 2012.

NCDOT has consistently worked with health professionals to integrate the concept of health into the 25-year comprehensive transportation planning process. Through collaborative efforts NCDOT has worked with the HHS to evaluate, strategize and promote active transportation (e.g., bicycling and walking) within communities. In addition, HHS will provide health indicator data and performance metrics to NCDOT to evaluate the prevalence of chronic disease so that this information can be included in the decision-making process with respect to a particular transportation project. For example, the state's WalkBikeNC plan included a HIA on three communities in which the possible economic benefits from improved health impacts were quantified for three pilot communities (urban, suburban, and rural across the state).

Oregon Department of Transportation (ODOT)¹¹

The ODOT has a long history of working with the public to meet the changing and expanding transportation needs of the population while remaining cognizant of the agency's limited economic resources. ODOT created the Intermodal Oregon initiative to evaluate agency

⁹ Contact for Case Study: Lauren Blackburn, Director, Division of Bike & Pedestrian Transportation, (919) 707-2601, lblackburn2@ncdot.gov; and Julie Hunkins, Director, Office of Environmental Quality, jhunkins@ncdot.gov.

¹⁰ North Carolina Guide to Incorporating Health Considerations into Comprehensive Plans. Available at <http://www.eatsmartmovemorenc.com/HealthConsiderations/HealthConsiderations.html>.

¹¹ Sheila Lyons, PE, Pedestrian and Bicycle Program Manager, (503) 986-3555, sheila.a.lyons@odot.state.or.us.

structures, processes, and policies.¹² In addition, The Oregon Bicycle and Pedestrian Plan (active transportation) “provides direction to ODOT in establishing bicycle and pedestrian facilities on state highways. It also guides cities and counties, as well as other organizations and private citizens, in establishing facilities on local transportation systems.”¹³

In 2007, the Oregon State Legislature passed House Bill (HB) 3543, aimed at reducing global warming emissions including the creation of a Global Warming Commission. The enacted legislation set a 2020 goal to achieve a GHG level at 10 percent less than the established 1990 level and by 2050 to achieve GHG levels 75 percent below the 1990 level. Subsequently, in 2010, the Oregon Sustainable Transportation Initiative (OSTI) was established as an integrated effort to reduce GHG emissions from transportation. Since then, the ODOT and the Department of Land Conservation and Development have worked together to produce relevant rules, guidelines, and tools for reducing GHG emissions to promote healthier, livable communities and greater economic opportunity.

In 2013, ODOT published Oregon Statewide Transportation Strategy for GHG reduction. The strategy calls for the need for more robust and comprehensive economic analysis. In Chapter 4 of the strategy, ODOT outlines the multidimensional impacts of the strategy on public health:

- Reduce air pollution per mile of vehicle travel;
- Encourage compact community development;
- Increase transportation modal options;
- Promoting physical activity; and
- Promote transportation and land use changes that lower vehicle miles of travel (VMT) and emissions.

Washington State Department of Transportation (WSDOT)¹⁴

The Washington State Legislature has put forth six transportation system policy goals¹⁵ that local, regional and state transportation agencies must follow. These policy goals are the basis for establishing detailed and measurable objectives and performance metric of accountability. The policy goals are:

1. “Economic vitality: To promote and develop transportation systems that stimulate, support, and enhance the movement of people and goods to ensure a prosperous economy;

¹²Transforming ODOT through Intermodal Oregon. Available at <http://www.oregon.gov/ODOT/GOVREL/Pages/051613a.aspx>.

¹³Oregon Bicycle and Pedestrian Design Guidelines. Available at <http://www.oregon.gov/ODOT/HWY/BIKEPED/Pages/planproc.aspx>.

¹⁴Contact for case study: Teri Hickey, WSDOT Statewide Transportation Planning, (360) 705-7918, hickeyt@wsdot.wa.gov.

¹⁵Washington State Legislature Transportation System Policy Goals. Available at <http://apps.leg.wa.gov/RCW/default.aspx?cite=47.04.280>.

2. Preservation: To maintain, preserve, and extend the life and utility of prior investments in transportation systems and services;
3. Safety: To provide for and improve the safety and security of transportation customers and the transportation system;
4. Mobility: To improve the predictable movement of goods and people throughout Washington state;
5. Environment: To enhance Washington's quality of life through transportation investments that promote energy conservation, enhance healthy communities, and protect the environment; and
6. Stewardship: To continuously improve the quality, effectiveness, and efficiency of the transportation system.”

The 2007-2026 WSDOT Transportation Plan identifies “Environmental Quality and Health” as one of the top priority areas for transportation investment.¹⁶ The plan recognizes that local communities have taken the initiative to develop transportation infrastructure projects that consider health in conjunction with economic and environmental benefits.¹⁷ In early 2014, WSDOT published the results of the FHWA’s Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) pilot program. WSDOT concludes that with some modifications, INVEST could provide a bridge between the NEPA and HIA by identifying stakeholder concerns in early stages of project development.¹⁸

Health Impact Assessments

The NEPA is the regulatory process that guides the evaluation and disclosure of potential environmental impacts of a proposed action on humans and the environment. This is especially true for transportation infrastructure actions that use federal money or require federal permits; projects such as new highways, passenger rail lines, major bridges and airports. Traditional social, economic, and environmental analyses include assessments of noise, air quality and potential exposure to hazardous waste. In addition, environmental justice factors such as livability, community culture, neighborhood cohesion, and public place-making have been important considerations during the assessment of the impacts and benefits of infrastructure projects.

HIAs have become increasingly prominent as a data driven tool to assess transportation projects. The World Health Organization (WHO) defines HIA as a means of assessing the health impacts of policies, plans and projects in diverse economic sectors using quantitative, qualitative and

¹⁶ Washington State Transportation Commission and Washington State Department of Transportation (2006). Washington Transportation Plan 2007-2026. Retrieved from <http://www.wsdot.wa.gov/NR/rdonlyres/083D185B-7B1F-49F5-B865-C0A21D0DCE32/0/FinalWTP111406.pdf>.

¹⁷ WSDOT Health and Environment. Available at <http://www.wsdot.wa.gov/planning/wtp/documents/HealthEnvironment.htm>.

¹⁸ Washington State Department of Transportation (2014). Washington State Department of Transportation INVEST Study. Retrieved from <http://www.wsdot.wa.gov/NR/rdonlyres/3DA93461-B374-4795-9503-B094C8E5FFAF/0/FinalINVESTandAppendices.pdf>.

participatory techniques. The key to HIA is to understand the manner in which the individual elements, factors and performance measures are packaged to reflect the impact of a project on the affected community.

There are many similarities between HIAs and environmental review and environmental impact assessment processes, as well as Context Sensitive Solutions (CSS). Table 1 illustrates the similarities between HIA and Environmental Impact Assessments (EIAs). In September 2011, the National Research Council (NRC) published recommendations on HIA. The main premise of these broad recommendations is to demonstrate that HIA can be implemented as a tool in instances in which there is “added value” to a project.

Table 1: Contrasting Health Impact Assessments and Environmental Impact Assessments

Health Impact Assessment	Environmental Impact Assessment
1. Screening	1. Initiating Project
2. Scoping	2. Scoping
3. Assessing Risks and Benefits	3. Developing Alternatives and Assessing Environmental Impacts
4. Recommending Changes to Mitigate Health Effects	4. Recommending Measures to Mitigate Impacts
5. Reporting	5. Preparing Environmental Assessment or Environmental Impact Assessment
6. Evaluating HIA Effects	6. Finding of No Significant Impact (FONSI) or Record of Decision (ROD)

Emissions and Health Impacts Analysis Spectrum – Changing Paradigm

Figure 2 (adapted from the Health Effects Institute Report cited on Page 3) shows the spectrum of issues from an analytical/research perspective linking emissions to health. The relationship between transportation emissions and health is not straightforward — the linkages between transportation and air quality deal with what is emitted by vehicles (emissions), how they disperse into the atmosphere, how the dispersed pollutants result in exposure levels for different populations/regions, following which inferences could be made regarding health impacts, or actions taken to mitigate impacts.

The first step, i.e., characterization of emissions, is usually performed through measurement and modeling exercises. Measurement is done through laboratory or field testing using sophisticated sensors and equipment. Models based on large sample of measured data are also available to

estimate emissions based on various factors and inputs. The U.S. Environmental Protection Agency’s (EPA) Motor Vehicle Emissions Simulator (MOVES) model is an example that is used in the U.S. for generating emissions rates for various vehicle types and different model years, or to generate network-level transportation emissions for use in conformity analyses in nonattainment areas. Dispersion deals with how vehicular emissions are dispersed (i.e., distributed into the atmosphere) in terms of concentrations. This not only depends on the location and quantity of emissions, but also on geographic and meteorological factors that may affect how the pollutants are dispersed, as well as other factors that may affect pollutant formation in the case of secondary pollutants. Dispersion modeling and photochemical modeling are models used to understand dispersion. Ambient measurements of pollutant concentrations can also provide information on pollutant dispersion. Ambient air quality measurements also form the basis for designation of nonattainment areas (i.e., areas in the U.S. that do not meet the NAAQS). Receptor-based modeling and land-use regression are approaches that discuss dispersion from a source apportionment perspective.

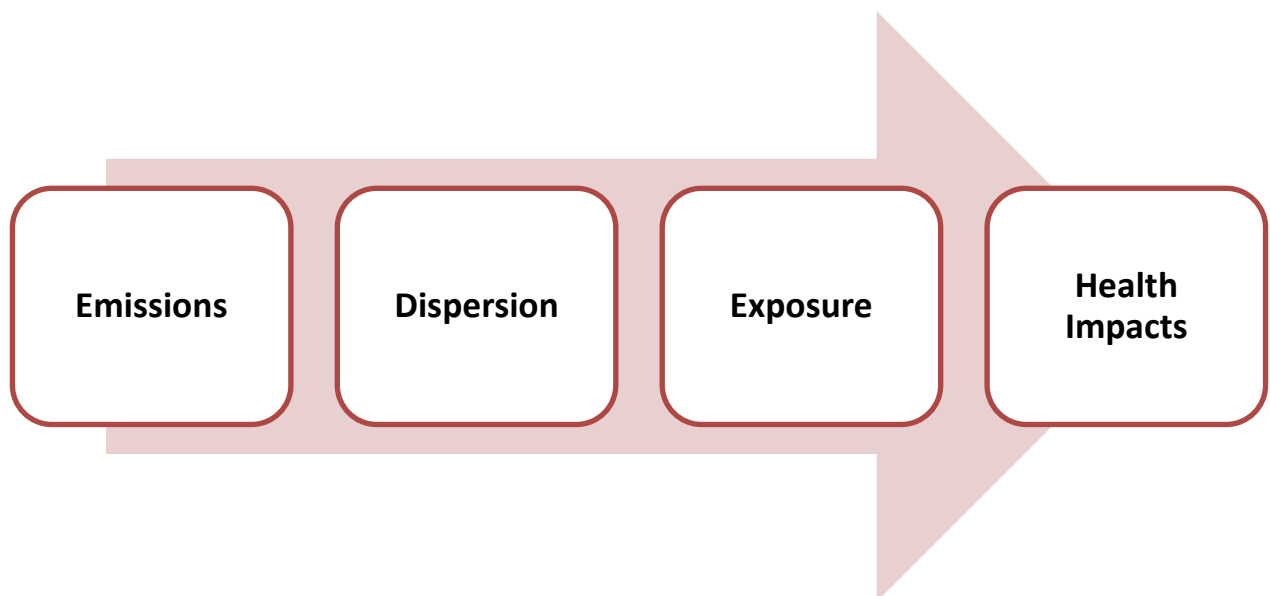


Figure 2: The Transportation Emissions to Health Impact Spectrum

The study of exposures can be viewed as an extension of the dispersion aspect, which additionally considers population exposures in terms of durations, levels (i.e., concentrations of exposure), and number of persons exposed to levels above certain thresholds, etc. While traditionally, exposures were often handled through distance-based proxies (i.e., “x miles from a high-traffic roadway”), and using GIS-based spatial analyses to take into account geographic and demographic data can provide more sophisticated assessments of exposures.

Personal/wearable/real-time monitoring of exposures is another means of obtaining exposure data that has been increasingly used as well, as well as medical studies looking at biomarkers of exposure. Finally, at the end of the spectrum is the study of health impacts, where findings with regard to exposures are translated into tangible results in terms of health outcomes, as well as interventions/solutions to mitigate health impacts.

As discussed previously, among state DOTs, transportation conformity requirements are generally viewed as the means of addressing emissions-related issues and their health implications. However, as the broader movement to address health in the transportation sector gains traction, there has also been a paradigm shift in how transportation emissions and conformity related issues are viewed. Figure 3 illustrates this shift by contrasting the existing and new paradigms. As seen in the figure, there is a shift from only looking at nonattainment areas. In addition to criteria pollutants that have associated NAAQS, there is a shift to additionally examine ultrafine particles, black carbon, air toxics, particle-bound polycyclic aromatic hydrocarbons, and other pollutants, as well as GHGs. Moving beyond the transportation conformity concept that examines network-level emissions, more work is being performed studying near-roadway dispersions (for example, the EPA is currently working on a large near-roadway research program, which has already resulted in near-road air quality monitoring requirements in large urban areas), and more rigorous hot-spot analyses (such as the quantitative hot-spot analysis requirements for PM and carbon monoxide [CO]). Finally, even in studying concentrations (i.e., dispersion of pollutants), there has been a paradigm shift looking at more fine-grained studies of exposures as a means to better understand health impacts and outcomes.

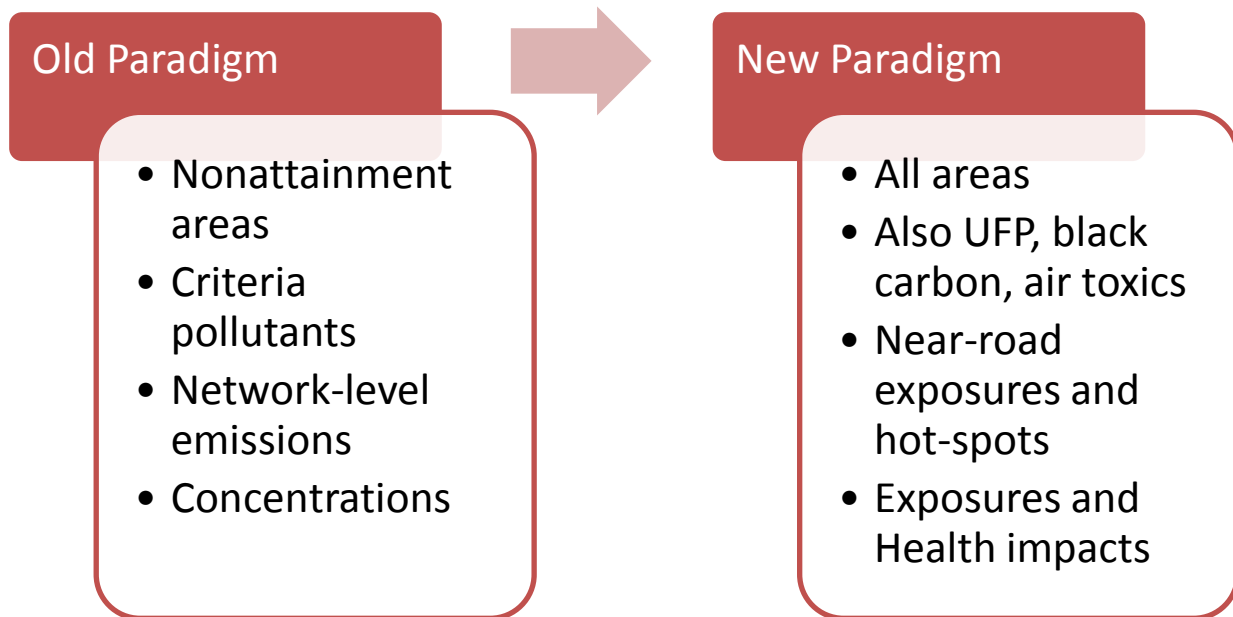


Figure 3: The Changing Paradigm in Understanding Transportation Emissions and Health

Concluding Remarks

This memorandum discussed the broader context of how the issue of health is being addressed in the transportation sector, with case studies, organizational perspectives, and the relevance of existing programs and practices discussed. Following this, a more specific discussion of emerging issues from an air quality and transportation conformity perspective was also provided.

There is growing federal support for health considerations in local, regional, and state transportation policies, programs, and initiatives. While emissions related health issues will continue to primarily be addressed through transportation conformity by DOTs, it is seen that there is a shift in how these issues are being addressed at the state, federal and local levels. As health considerations (including those specific to transportation emissions) are incorporated into the transportation planning process, it is expected that an integrated and holistic approach, taking into account cross-disciplinary partnerships can serve the Texas Department of Transportation (TxDOT) and its partner agencies well.

Appendix A – Additional References Related to Health Effects and Transportation Emissions

1. Center for Disease Control and Prevention, National Environmental Public Health Tracking Tool (June 2, 2014). Retrieved from: <http://www.cdc.gov/nceh/tracking/>.
2. Texas Department of Health and Human Services. Data and Surveillance for Asthma, June 9, 2014. Retrieved from <https://www.dshs.state.tx.us/asthma/data.shtm>.
3. Verhoeven, M. (2010). Modelling life trajectories and mode choice using Bayesian belief networks (doctoral degree dissertation): <http://repository.tue.nl/667904>. Eindhoven: Technische Universiteit Eindhoven. ((Co-) promot.: prof.dr. H.J.P. Timmermans & dr. T.A. Arentze).
4. World Health Organization. Health Effects of Transport-Related Air Pollution (June 9, 2014). Retrieved from http://www.euro.who.int/_data/assets/pdf_file/0006/74715/E86650.pdf.
5. Valavanidis, A, K. Fiotakis, and T. Vlachogianni. Airborne particulate matter and human health: toxicological assessment and importance of size and composition of particles for oxidative damage and carcinogenic mechanisms. *Journal of Environ Sci Health C Environ Carcinog Ecotoxicol Rev.* 2008 Oct-Dec; 26(4):339-62.
6. Cassee, F.R., M.E. Héroux, M.E. Gerlofs-Nijland, and F.J. Kelly. Particulate matter beyond mass: recent health evidence on the role of fractions, chemical constituents and sources of emission. *Inhal Toxicol.* 2013 Dec; 25(14):802-12.
7. Thorpe, A, and R.M. Harrison. Sources and properties of non-exhaust particulate matter from road traffic: a review. *Sci Total Environ.* 2008 Aug 1; 400(1-3):270-82. Epub 2008 Jul 16.
8. Klems, J.P., M.R. Pennington, C.A. Zordan, and M.V. Johnston. Ultrafine particles near a roadway intersection: origin and apportionment of fast changes in concentration. *Environ Sci Technol.* 2010 Oct 15; 44(20):7903-7.
9. Klems, J.P., M.R. Pennington, C.A. Zordan, L. McFadden, and M.V. Johnston. Apportionment of motor vehicle emissions from fast changes in number concentration and chemical composition of ultrafine particles near a roadway intersection. *Environ Sci Technol.* 2011 Jul 1; 45(13):5637-43.
10. Johnston, M.V., J.P. Klems, C.A. Zordan, M.R. Pennington, J.N. Smith, and HEI Health Review Committee. Selective detection and characterization of nanoparticles from motor vehicles. *Res Rep Health Eff Inst.* 2013 Feb; (173):3-45.
11. Gertler, A.W., J.A. Gillies, W.R. Pierson, C.F. Rogers, J.C. Sagebiel, M. Abu-Allaban, W. Coulombe, L. Tarnay, and T.A. Cahill. Real-world particulate matter and gaseous emissions from motor vehicles in a highway tunnel. *Res Rep Health Eff Inst.* 2002 Jan; (107):5-56; discussion 79-92.
12. Health Effects of Diesel Exhaust: A fact sheet by Cal/EPA's Office of Environmental Health Hazard Assessment (OEHHA 2001) and the American Lung Association (April 10, 2014). Retrieved from http://oehha.ca.gov/public_info/facts/dieselfacts.html.
13. Canagaratna, M.R., T.B.O nasch, E.C. Wood, S.C. Herndon, J.T. Jayne, E.S. Cross, R.C. Miake-Lye, C.E. Kolb, and D.R. Worsnop. Evolution of vehicle exhaust particles in the atmosphere. *J Air Waste Manag Assoc.* 2010 Oct; 60(10):1192-203.

14. Environmental Protection Agency, Health Science (April 8, 2014). Retrieved from <http://www2.epa.gov/science-and-technology/health-science>.
15. America's Health Rankings: State of Texas (June 10, 2014). Retrieved from <http://americashealthrankings.org/states>.
16. World Population Review: State of Texas (June 10, 2014). Retrieved from <http://worldpopulationreview.com/states/texas-population/>.
17. Final Guidance For Incorporating Environmental Justice Concerns in EPA's NEPA Compliance Analyses (April 20, 2012). Retrieved from http://www.epa.gov/compliance/ej/resources/policy/ej_guidance_nepa_epa0498.pdf.
18. National Research Council Provides Guidance on Use of Health Impact Assessment (November 5, 2011). Retrieved from <http://www.rwjf.org/publichealth/product.jsp?id=72817>.
19. Milken Institute Chronic Disease Index (June 10, 2014). Retrieved from <http://www.chronicdiseaseimpact.com/>.
20. Bell, J., L. Cohen, and S. Malekafzali (2009). Health effects of transportation policy. In S. Malekafzali (Ed.), *Healthy, equitable, transportation policy: recommendations and research*.
21. CDC (2011). *CDC Transportation Recommendations*. Retrieved from <http://www.cdc.gov/transportation/recommendation.htm>.
22. CDC (2014). *Transportation and Health*. Retrieved from <http://www.cdc.gov/healthyplaces/healthtopics/transportation/default.htm>.
23. Conti Jr., E.A., P.F. Morris, and J.A. Hunkins (2012). The North Carolina Department of Transportation's vision for healthy communities through sustainable transportation. *NC Med J*, 73(4), pp.274-277.
24. Emerson, Donald J., and Christine Hoeffner (2006). *Improved Linkage Between Transportation Systems Planning and the National Environmental Policy Act*. NCHRP Project 8-36, Task 48: National Cooperative Highway Research Program.
25. Malekafzali, S. (2009). *Healthy, equitable transportation policy: recommendations and research*. Retrieved from http://www.convergencepartnership.org/atf/cf/%7B245a9b44-6ded-4abd-a392-ae583809e350%7D/HEALTHTRANS_FULLBOOK_FINAL.PDF.
26. Petersen, Ruth, and Julie Hunkins (2013). *North Carolina: Transportation, Commerce and Environment are Integral in Building Healthy Communities*. Retrieved from http://healthyamericans.org/health-issues/prevention_story/north-carolina-transportation-commerce-and-environment-are-integral-in-building-healthy-communities.
27. Ragland, David R, and Phyllis Orrick (2011). *Transportation and Health: Policy Interventions for Safer, Healthier People and Communities*. Retrieved from <http://www.prevent.org/data/files/transportation/transportationandhealthpolicycomplete.pdf>.

Appendix B – Organizational Summaries/Statements on Health and Transportation

American Association of Retired Persons (AARP)

“Older adults need transportation to the places and services that support their independence. As federal, state, and local policymakers consider transportation investments, they should take into account older adults’ mobility requirements and desire for mobility options, including travel on foot or bicycle and by car, bus, train, plane, and, in some areas, boat. Because of physical limitations, many older adults need specialized transportation services such as door-to-door paratransit and escorts to doctor’s offices. All of these options must be safe, affordable, accessible, dependable, and user-friendly. Policies that encourage adequate, safe and accessible transportation infrastructure and services help people of all ages stay active and engaged in their communities”

(Source: <http://www.aarp.org/research/ppi/liv-com2/policy/transportation>).

American Lung Association

“The American Lung Association strongly supports a safe, healthful environment for all. Environmental policies must protect the public against acute and chronic adverse health effects. The American Lung Association is especially concerned about the effect of air pollution on the health of vulnerable populations, including people with lung diseases such as asthma, the elderly and children. All available strategies, including public education and outreach, research, legislation, regulation and litigation, should be employed as necessary to protect the public health.”

National Air Quality Standards

The NAAQS must be set solely on the basis of the protection of public health. The American Lung Association supports the NAAQS development and revision process as delineated in the Clean Air Act of 1970 and amended through the 1990 Amendments, and opposes the use of cost/benefit analysis or technological feasibility in the standard-setting process. The American Lung Association recognizes and supports the Clean Air Act delegation of the nation’s standard-setting responsibility to the EPA.

Land Use and Transportation

“The American Lung Association believes that in order to improve the health and welfare of the American people and to begin to solve the interrelated problems of energy and air pollution, transportation and land use policies must not continue to foster the dependence on the motor vehicle. The American Lung Association supports policies that encourage appropriate mixed-use development, mass transit and alternative transportation options. The American Lung Association recommends land use development that is organized and coordinated to protect the environment.”

(Source: <http://www.lung.org/associations/charters/plains-gulf/advocacy/environmental.html>).

American Planning Association (APA) and Texas Chapter

“The Transportation Planning Division of the American Planning Association exists to facilitate technical information sharing among member professionals who deal with the ways transportation effectively and efficiently moves people and goods, shapes urban form, affects economic vitality and impacts quality of life. The Division promotes professional communication among its own members, with other APA divisions and with other professional groups. We assess and make recommendations on policies and programs so as to derive the full public benefits of comprehensive and community-based planning that promote personal mobility and travel choices.”

(Source: <https://www.planning.org/divisions/transportation>).

APA’s National Centers for Planning are dedicated to helping planners create communities of lasting value.

- Green Communities – APA’s Green Communities Research Center has the expertise and influence to help planners and citizens create greener, more sustainable communities.
- Hazards Planning – APA’s Hazards Planning Research Center identifies practices that protect communities from natural and manmade hazards and educates planners and allied professionals about those practices.
- Planning and Community Health - By working with policymakers, public health professionals, environmental scientists, transportation engineers, educators, and others, planners work to create healthier communities.”

Center for Disease Control and Prevention (CDC)

“The U.S. transportation system has been shaped by multiple policy inputs and concrete actions which have arisen from transportation and community planners, funding agencies and others at federal, state, and local levels. The system is designed to move people and goods efficiently; however, there is a growing awareness across communities that transportation systems impact quality of life and health. Government and non-government agencies are seeking innovative policies and programs that protect and promote health while accomplishing the primary transportation objectives.”

“Expanding the availability of, safety for, and access to a variety of transportation options and integrating health-enhancing choices into transportation policy has the potential to save lives by preventing chronic diseases, reducing and preventing motor-vehicle-related injury and deaths, improving environmental health, while stimulating economic development, and ensuring access for all people. With this goal in mind, the CDC and Prevention has identified transportation policies that can have profound positive impact on health. The CDC supports strategies that can provide a balanced portfolio of transportation choices that supports health and reduces health care costs. Transportation policy can:

- Reduce injuries associated with motor vehicle crashes;

- Encourage healthy community design;
- Promote safe and convenient opportunities for physical activity by supporting active transportation infrastructure;
- Reduce human exposure to air pollution and adverse health impacts associated with these pollutants; and
- Ensure that all people have access to safe, healthy, convenient, and affordable transportation.”

“The CDC recognizes that transportation is one of the largest contributors to air pollution. In urban areas, motor vehicles are regarded as a significant source of air pollution. Exposure to traffic emissions is linked to adverse health effects such as premature mortality, cardiac symptoms, exacerbation of asthma symptoms, diminished lung function, and increased hospitalization. The CDC has made three specific recommendations to address the negative health effects:

1. Reduce human exposure to transportation-related air pollution by retrofitting existing diesel vehicles with current pollution control measures, requiring effective inspection and maintenance programs for medium- and heavy-duty vehicles, providing incentive for motor vehicle drivers to purchase vehicles with technologies to control and pollution and reduce emissions, strengthening congestion mitigation and air quality programs, and seeking solutions to reduce pollution generated by ports, high-volume roadways and railroads.
2. Improve air quality and hence the respiratory and cardiovascular health by promoting transportation choices and innovative transportation measures that reduce emissions, shifting to active transportation and public transportation modes, and reducing vehicle miles traveled per capita.
3. Support the following policies/programs that aim to promoting renewable energy sources and strengthening fuel efficiency.”

Source: <http://www.cdc.gov/transportation/>.

U.S. Environmental Protection Agency (EPA)

The NEPA is the regulatory process that guides the evaluation and disclosure of potential environmental impacts of a proposed action on humans and the environment. This is especially true for transportation infrastructure actions that use federal money or require federal permits; projects such as new highways, passenger rail lines, major bridges and airports. Traditional social, economic, and environmental analyses include assessments of noise, air quality and potential exposure to hazardous waste. In addition, environmental justice factors such as livability, community culture, neighborhood cohesion, and public place-making have been important considerations during the assessment of the impacts and benefits of infrastructure

projects. Only through the assessment of health impacts can the linkages between the public's health and sound transportation decisions can be made.

Environmental Sustainability and Health Research

Accordingly, the EPA has established the National Health and Environmental Effects Research Laboratory (NHEERL), as its focal point for focal point for scientific research on the effects of contaminants and environmental stressors on human health and ecosystems integrity. EPA Research Recommendations:

- People who live, work, or attend school near major roads are at increased risk of health problems related to roadway air pollution such as asthma, cardiovascular disease, low birth weight, pre-term birth, premature death, reduced lung function, and impaired lung development in children.
- Breathing high levels of polluted air (containing PM_{2.5}) and ground-level ozone can cause lung inflammation, decreased lung function, and an increase in asthma attacks (airway constriction of smooth muscles and mucus plugging).
- >5 percent of heart disease deaths could be associated with air pollution and ozone exposure (vasoconstriction). Heart attack survivors who live <100 meters (328 feet) from a major road have a 27 percent increased risk of dying over 10 years than those living at least 1,000 meters (3,280 feet) away.

EPA Smart Growth and Economic Success: Benefits for Real Estate Developers, Investors, Businesses, and Local Governments

Smart growth development is compact and walkable and provides a diverse range of choices in land uses, building types, transportation, homes, workplace locations, and stores. Such development projects are attractive to private-sector interests because they can find a ready market and compete financially. They appeal to local governments because they can be the building blocks of a growing economy and high-quality, economically sustainable neighborhoods and communities while also helping to create a cleaner, healthier environment. Some of the advantages for developers, communities, and local governments associated with smart growth include:

- Compact Development - Using land and resources more efficiently and redeveloping old or neglected areas while retaining existing infrastructure can create economic advantages for real estate developers and investors, businesses, and local governments. Compact development can generate more revenue per acre because it uses land more efficiently. It can reduce the costs of land and infrastructure for individual projects and the costs of providing fire and police protection, utilities, schools, and other public amenities. By locating companies closer together, compact development can create a

density of employment that increases economic productivity and attracts additional investment.

- **Walkability** - Walkable neighborhoods have well-connected streets and a mix of land uses near each other, making not only walking but also bicycling and transit more convenient and appealing. Projects in walkable neighborhoods command a price premium, earning real estate developers and investors a higher return on investment. Improvements to streets and sidewalks to make them more appealing to pedestrians can benefit local businesses by attracting more customers. In turn, local governments benefit through additional property and sales tax revenue.
- **Range of Choices** - People and businesses value places that bring together a variety of activities to create vibrant environments. The demand for such places exceeds the supply. Many people in the two largest demographic cohorts, baby boomers and their children, are particularly interested in lively neighborhoods with their daily needs close by. Communities with access to transit also help people reduce their transportation costs, enabling them to save money or spend more on their homes, entertainment, or other things they value. Changing demographics will likely further increase the demand for smart growth development over the coming decades; developers, investors, businesses, and local governments who respond to these market preferences could reap economic advantages.

Partnership for Prevention

Partnership for Prevention is a nonpartisan organization of business, nonprofit and government leaders working to make evidence based disease prevention and health promotion a national priority. While seeking to support the development of transportation policies that also promote the nation's health, this organization published a report in 2011, "Transportation and Health: Policy Interventions for Safer, Healthier People and Communities," to examine the three areas where transportation policies may promote public health: environment and environmental health, community design and active transportation, and motor vehicle-related injuries and fatalities.

Source: <http://www.prevent.org/Additional-Pages/Transportation-and-Health.aspx>.

Prevention Institute

The Prevention Institute is a national non-profit organization promoting policies, organizational practices, and collaborative efforts that improve health and quality of life. In 2009, it published a report titled "Healthy, Equitable Transportation Policy: Recommendations and Research," which illustrates the opportunities and barriers transportation policy creates for building healthy communities. The direct health effects of transportation policy, as identified in this report, include pollution, climate change, physical activity, mental health and safety; the indirect health effects include the housing and employment barriers encountered by those without a car and the senior and disabled populations.

Source: <http://www.preventioninstitute.org/component/jlibrary/article/id-107/127.html>.

Rockefeller Foundation

“The kind of transportation we invest in determines the shape of our communities, our access to jobs and services, and how much of our time and money we spend on getting around. In the United States, there isn’t enough attention focused on getting a return on our transportation investments or even maintaining the infrastructure we already have – both of which provide people with the options that connect them to jobs and opportunity. We believe that coordinated intervention is needed to ensure that transportation planning and infrastructure policy serves the needs of 21st century America.”

“The Rockefeller Foundation's transportation work aims to encourage economic growth and improve quality of life by helping communities to make better investments in modern, efficient, and effective transit solutions.”

“Key Outcomes include:

- Greater prosperity and social mobility as a result of smart infrastructure choices that create communities with safe, convenient and affordable transportation options;
- Communities that encourage and sustain active and healthy living through well-designed streets, paths, and an abundance of options;
- Metropolitan regions served by integrated, comprehensive transportation systems that support economic growth and encourage smart development patterns; and
- Bus Rapid Transit viewed as a solution for mass transit problems by key stakeholders at the city, state, and national level.”

Source: <http://www.rockefellerfoundation.org/our-work/current-work/transportation>.

World Health Organization (WHO)

“The effects on health of transport-related air pollution have become one of the leading concerns about transport. In the next few decades, road transport will remain a significant contributor to air pollution in cities across the European Region, and estimates indicate that 100,000 deaths a year in these cities could be linked to ambient air pollution, shortening life expectancy by an average of a year. A significant fraction of these deaths and a range of other adverse effects on health are attributable to transport-related air pollution.”

“In 2010, 90 percent of the urban population in the 15 countries that belonged to the European Union (EU) before 1 May 2004 are expected to be living in areas meeting the EU hourly air-quality limit value for nitrogen dioxide, carbon monoxide, benzene and lead. Also, exposure to particulate matter is expected to decrease, though it will still cause significant effects on health. The eastern half of the WHO European Region, however, is expected to have more difficulties in meeting air quality standards. In this part of the region, the rapid increase in private cars and in goods transported by lorries, in combination with a decline in public transport, have turned road transport into an increasing contributor to air pollution.”

“The WHO 2005 report documenting health effects of transport-related air pollution provides the first comprehensive assessment of air pollution related to road transport and of the risks it presents to human health. Furthermore, it considers the entire chain of relevant issues: from patterns and trends in activities that determine the intensity of emissions from transport, to contribution of traffic to pollution levels, and finally to patterns of human exposure to such pollutants.”

Source: <http://www.euro.who.int/en/data-and-evidence/evidence-informed-policy-making/publications/hen-summaries-of-network-members-reports/what-are-the-effects-on-health-of-transport-related-air-pollution>.

World Bank

“Transport is a crucial driver of development, bringing socio-economic opportunities within the reach of the poor and enabling economies to be more competitive. Transport infrastructure connects people to jobs, education, and health services; it enables the supply of goods and services around the world; and allows people to interact and generate the knowledge that creates long-term growth. Rural roads, for example, can help prevent maternal deaths through timely access to childbirth-related care, boost girls’ enrolment in school, and increase and diversify farmers’ income by connecting them to markets.”

“Although the sector is crucial to reducing poverty, sharing prosperity and achieving development goals, transport is also at the heart of critical development challenges:

- Rapid urbanization and motorization: Cities are expected to hold 5.2 billion residents by 2050. Over the next 20 years, more cars may be built than in the auto industry’s 110-year history;
- Accessibility and affordability: An estimated one billion people in low-income countries still lack access to an all-weather road. In cities, time lost to congestion erodes prosperity. High mobility costs cut the disposable income of the poor in many cities that lack formal and affordable public transportation;
- Air pollution and road safety: More than 1.2 million people are killed and up to 50 million are injured on the world’s roads every year. Low and middle-income countries account for 90 percent of the deaths although they own just half the world’s motor vehicles. Urban air pollution, largely linked to transport, leads to the death of an estimated 800,000 people each year;
- Climate change: Transport contributes about 15 percent of global greenhouse gas emissions. With motorization on the rise, that share is expected to grow.”

Source: <http://www.worldbank.org/en/topic/transport/overview>.

Transportation Research Board of the National Academies (TRB)

The TRB has established a Health and Transportation subcommittee (ADD50-01) to improve understanding and evaluation of how transportation systems influence public health, maximize

the health benefits of transportation systems and limit their adverse effects on travelers, neighbors, and vulnerable groups, and integrate transportation and health issues through planning, policy, engineering, design, interdisciplinary collaboration, and community participation. The committee has identified gaps in the knowledge about transportation and health, for example, auto use and parking, data and methods for health and transportation research and practice, economics and policy, transportation impact assessments, and strategies for integrating health and transportation planning.

Source: Transportation Research Board (2014). Areas of Needed Research in Health and Transportation. Retrieved from <http://www.trbhealth.org/research/research-needs>.