Transportation-Related Use of Health Impact Assessments and Similar Tools

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The Caltrans Division of Research and Innovation (DRI) receives and evaluates numerous research problem statements for funding every year. DRI conducts Preliminary Investigations on these problem statements to better scope and prioritize the proposed research in light of existing credible work on the topics nationally and internationally. Online and print sources for Preliminary Investigations include the National Cooperative Highway Research Program (NCHRP) and other Transportation Research Board (TRB) programs, the American Association of State Highway and Transportation Officials (AASHTO), the research and practices of other transportation agencies, and related academic and industry research. The views and conclusions in cited works, while generally peer reviewed or published by authoritative sources, may not be accepted without qualification by all experts in the field.

Executive Summary

Background

Recently there has been an increasing interest by state and federal governments in systematically evaluating the potential health impacts of policies. One approach to this problem involves the use of health impact assessments (HIAs) and similar tools as part of the process of planning urban, transportation and other projects. Such assessments are an emerging practice in the United States, especially in the transportation sector.

Caltrans would like to better understand how other state departments of transportation (DOTs) and other transportation agencies in the United States are planning for health impacts when developing transportation projects.

This Preliminary Investigation focuses on:

- The types of public health issues transportation agencies are reporting on.
- The types of data gathered and analyzed.
- The kinds of reports and other documentation prepared during the planning process.
- Case studies or other outcomes of specific project-related health impact analyses, especially projects with successful HIA mitigation measures.

Summary of Findings

We contacted several state DOTs, two national committees and a major HIA consulting organization concerning the use of HIAs and similar tools for transportation project planning. Results generally show that state DOTs generally have not yet begun to implement HIAs or related tools for transportation planning despite the recent increase in interest to do so. However, some regional agencies—including especially the San Francisco Department of Public Health—have been active in assessing the health impacts of transportation projects. And there are numerous available transportation-related HIA case studies.

Below we summarize specific findings in four topic areas:

- Consultation with Experts.
- Tools and Resources.
- Transportation-Related HIA Case Studies.
- Related Research.

Consultation with Experts

- Jonathan Heller, director and co-founder of Human Impact Partners, noted that state DOTs generally have not yet begun to implement HIAs or related tools for transportation planning despite the recent increase in interest to do so. However, three states are notable for transportation-related HIA activity: Oregon (for a number of transportation-related HIAs), Massachusetts (for a recent law requiring HIAs on new transportation projects) and Washington (for the HIA on its State Route 520 Bridge project).
- Megan Wier of the San Francisco Department of Public Health also pointed to Washington State's use of legislation-mandated HIA for its State Route 520 Bridge project (see **Transportation-Related HIA Case Studies**); however the director of WSDOT's Office of Environmental Services noted that WSDOT did not conduct this HIA. WSDOT does sometimes incorporate health into its environmental reviews, but only when stakeholders have raised concerns.
- Similarly, Oregon DOT rarely incorporates health impacts into its environmental reviews, despite increasing interest in HIAs and the number of HIAs that have been conducted by other agencies in the state.
- New York, Illinois and Maryland similarly do not assess health impacts for transportation projects in any systematic way.
- Ms. Wier and the San Francisco Department of Public Health have done significant work on HIAs of transportation projects; see especially Integrating Health Considerations into Transportation Plans, Projects and Environmental Review (see **Related Research**), Health Impact Assessment Tools (see **Tools and Resources**) and the Still/Lyell Freeway Channel (see **Transportation-Related HIA Case Studies**).

Tools and Resources

- Human Impact Partners (HIP) has a comprehensive resources page: http://www.humanimpact.org/hips-hia-tools-and-resources. See A Health Impact Assessment Toolkit: A Handbook to Conducting HIA, http://www.humanimpact.org/component/jdownloads/finish/11/81, and HIA Practice Standards, http://www.humanimpact.org/doc-lib/finish/11/9, the fundamental standards by which HIP conducts its HIAs.
- The Health Impact Project has an interactive map of HIA case studies, which can be filtered to show only transportation-related projects: http://www.healthimpactproject.org/hia/us. (All relevant studies are described in **Transportation-Related HIA Case Studies**.)
- See also the San Francisco Department of Public Health's Health Impact Assessment Tools: http://www.sfphes.org/HIA_Tools.htm, especially the Healthy Development Measurement Tool (http://www.sfphes.org/enchia/enchia_HDMT.htm), which is a comprehensive evaluation metric that supports the inclusion and consideration of health needs in urban land use plans and projects.

Transportation-Related HIA Case Studies

We have provided a comprehensive list of transportation-related HIA case studies, and in the following select cases highlight the methodology for the HIA report:

- Still/Lyell Freeway Channel in Excelsior District (I-280/PODER): This HIA by the San Francisco Department of Public Health measures the health impacts of air pollution, noise exposures and pedestrian hazards. Analysis methods included surveys; traffic counts; community photography; oral histories; outdoor air quality and noise modeling and exposure assessment; pedestrian environmental quality evaluation; historical document review; and publicly available data from numerous sources including hospitalization data, U.S. Census data and traffic-related injury data.
- The State Route 520 Bridge: The HIA report's appendices include separate papers on demographics, air quality, water quality, noise, physical activity, safety, social connections, mental well-being, green space and emergency medical services. It also includes an analysis of the possible effects on greenhouse gases of three design alternatives for the State Route 520 project, with results showing all three alternatives producing similar levels of emissions.
- Atlanta BeltLine: This HIA uses geographic information systems (GIS), census data, population and travel demand projections, crime rates, survey responses and a literature review to predict the health impacts on affected communities.
- Baltimore Redline: This HIA examines asthma, chronic lower respiratory disease, social cohesion, obesity, physical activity, bicycle and pedestrian risks, mental health, and noise and air pollution impacts on the neighboring communities. It includes interviews with residents, expert input, modeling the health effects of transit, and an extensive literature review and analysis of census and local data about Baltimore health. As a result of this process, the HIA focused on three areas: improving access and opportunities for safe outdoor activity; construction issues; and improving air quality.
- City of Decatur Community Transportation Plan: The HIA project team analyzed demographic and health statistics, performed a literature review to identify potential mitigation strategies and conducted a community workshop to address stakeholder concerns.
- Treasure Island Transportation Plan: This HIA by the San Francisco Department of Public Health made use of its Healthy Development Measurement Tool (see **Tools and Resources**), which uses a set of community-level health indicators along with criteria for healthy development to connect physical and environmental planning to a wider set of social interests and to assess the extent to which urban development projects, plans and policies affect conditions and resources required for optimal health.

Ongoing HIAs of interest (several by HIP) include:

- The I-710 Expansion in Los Angeles: This HIA will explore pathways and health issues such as jobs and economy, pedestrian and motor vehicle safety, air quality, noise and neighborhood resources.
- Lake Merritt BART Station Specific Plan: This HIA will explore jobs, business, economic development, retail (specifically grocery stores), transportation, public safety, parks and housing.
- Ports of Los Angeles and Long Beach: This HIA will explore air quality, noise, displacement of low-income residents, jobs, the economy and neighborhood resources.
- Atlanta Regional Plan 2040: This HIA will examine the plan's potential impact on a range of health issues, such as injury and asthma rates, and the risks of obesity and diabetes.
- San Francisco Road Pricing: The San Francisco Department of Public Health is evaluating a policy under consideration in San Francisco that would charge drivers for use of congested areas for environmental and health impacts, with measures including the effects of air quality and increased physical activity. The HIA will use forecasting methods to study impacts on future pedestrian conditions; active transportation; vehicle collisions; air pollutant exposures and premature mortality; greenhouse gas emissions; and traffic-related noise, annoyance and hypertension.

Related Research

Two studies by Megan Wier of the San Francisco Department of Public Health are of interest:

- Integrating Health Considerations into Transportation Plans, Projects and Environmental Review, which gives an overview of incorporating HIAs into transportation project planning and includes two case studies. (See Appendix A of this report.)
- An Area-Level Model of Vehicle-Pedestrian Injury Collisions with Implications for Land Use and Transportation Planning, which describes a model to predict area-level change in vehicle-pedestrian injury collisions associated with land use development and transportation planning decisions. (See Appendix B of this report.)

Gaps in Findings

Massachusetts recently passed a law requiring HIAs on new transportation projects. However, it is unclear whether any HIAs have taken place or are ongoing. We did not find case studies for transportation-related HIAs in Massachusetts and were not able to get in touch with the Massachusetts DOT. Further, while WSDOT claims to incorporate health impacts into some environmental reviews, we were unable to find examples where such assessments were substantive. We are awaiting a response to a follow-up inquiry as to whether there are examples of WSDOT environmental impact statements (EISs) with more substantive assessments of health impacts.

Next Steps

Caltrans might consider:

- Contacting Massachusetts DOT concerning its planned use of HIAs. (See **Gaps in Findings**.)
- Consulting with other contacts recommended by Megan Wier of the San Francisco Department of Public Health but not interviewed within the scope of this investigation:
    - Shari Schaftlein, team leader, Program/Policy Development, for the Federal Highway Administration's (FHWA) Office of Project Development and Environmental Review, (202) 366-5570, shari.schaftlein@fhwa.dot.gov.
    - Aaron Wernham, project director of the Health Impact Project, http://www.healthimpactproject.org/project/staff.
    - Shireen Malekafzali, senior associate at PolicyLink, the contact on an HIA for the St. Paul Light Rail project (see **Transportation-Related HIA Case Studies**), Shireen@policylink.org.

- Contacting Catherine Leslie of the New York State DOT for information about a feasibility study on conducting HIAs: cleslie@dot.state.ny.us.

Contacts

National Committees/Regional Transportation Agencies

San Francisco Department of Public Health
Megan L. Wier
Epidemiologist, Program on Health, Equity and Sustainability
Secretary, TRB Subcommittee on Health and Transportation
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State Departments of Transportation

Illinois Department of Transportation
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Maryland Department of Transportation
Bruce Grey
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New York State Department of Transportation
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Oregon Department of Transportation
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NEPA Program Coordinator
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Washington State Department of Transportation
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Director, Office of Environmental Services
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Nongovernmental Organizations

Jonathan Heller
Director and co-founder
Human Impact Partners
(510) 452-9442, ext. 100, jch@humanimpact.org

Consultation with Experts

San Francisco Department of Public Health/TRB Subcommittee on Health and Transportation
Megan Wier, epidemiologist at the San Francisco Department of Public Health, has worked extensively on transportation-related HIAs and quantitative modeling to predict the effects of transportation projects on pedestrian injuries, the health effects of air quality and noise levels. While checklist approaches have been popular for HIAs related to land use projects, Ms. Wier advocates the use of this more sophisticated quantitative modeling.

She provided numerous links to studies and related resources:

- Health Impact Assessment Tools, San Francisco Department of Public Health (see **Tools and Resources**).
- The case study for the Still/Lyell Freeway Channel (see **Transportation-Related HIA Case Studies**).
- Integrating Health Considerations into Transportation Plans, Projects and Environmental Review (Appendix A); An Area-Level Model of Vehicle-Pedestrian Injury Collisions with Implications for Land Use and Transportation Planning (Appendix B); and Spatial Distribution of Traffic Induced Noise Exposures in A US City: An Analytic Tool for Assessing the Health Impacts of Urban Planning Decisions (Appendix C) (all in **Related Research**).

Ms. Wier also recommended contacting:

- Jonathan Heller, director and co-founder, Human Impact Partners.
- WSDOT, for the HIA on the State Route 520 Bridge (see **Transportation-Related HIA Case Studies**).
- Shari Schaftlein, team leader, Program/Policy Development, Office of Project Development and Environmental Review, FHWA.
- Aaron Wernham, project director, Health Impact Project.
- Shireen Malekafzali, senior associate, PolicyLink, for an HIA on the St. Paul Light Rail project (see **Transportation-Related HIA Case Studies**).

We include feedback from WSDOT and Jonathan Heller in the current section; we were unable to interview other recommended contacts within the scope of the current investigation.

Human Impact Partners
Jonathan Heller, director and co-founder of HIP (see the organization description in **Tools and Resources**), noted that state DOTs are generally not making use of HIAs. Three possible exceptions are:

- WSDOT, for the HIA on the State Route 520 Bridge.
- Oregon, for a number of transportation-related HIAs (see I-5 Columbia River Crossing, Portland to Lake Oswego Transit Project, Commute Options Central Oregon, Oregon Vehicle Miles Traveled Legislation and Transportation Policy Recommendations in the Eugene Climate and Energy Action Plan, all in **Transportation-Related HIA Case Studies**).
- Massachusetts, where a recent law requires HIAs on all transportation projects:
  - **Healthy Transportation Compact**
    http://www.massdot.state.ma.us/main/HealthyTransportationCompact.aspx
    From the web site: This inter-agency initiative is designed to facilitate transportation decisions that balance the needs of all transportation users, expand mobility, improve public health, support a cleaner environment and create stronger communities.
  - **Senate Bill No. 2572, An Act to Create Environmental Justice,** Section 6, April 28, 2008.
    http://www.mass.gov/legis/bills/senate/185/st02/st02572.htm
    From the web site: Within 30 days after the department receives a copy of the environmental notification or notice of a project it shall inform the person if a health impact assessment is required. A health impact assessment is required if the proposed project is in or might affect

a most vulnerable community, unless the department waives the requirement upon a finding that the project would have no potential impact on any of the indicators used to create the communities health index. If the department intends to waive the requirement for a project in a most vulnerable community, it first shall provide notice to the public and the opportunity for written public comment within 30 days after the notice, and shall provide its decision of whether a health impact assessment is required within 30 days of the close of the public comment period.

- **Senate Bill No. 2087, An Act Modernizing the Transportation Systems of the Commonwealth**, June 26, 2009.
  http://www.malegislature.gov/Laws/SessionLaws/Acts/2009/Chapter25
  This bill calls for establishing methods to implement the use of HIAs to determine the effect of transportation projects on public health and vulnerable populations.

Mr. Heller noted that it is not feasible to expect to do HIAs on all transportation projects, and so the Massachusetts bill may not be realistic. It is unclear whether Massachusetts has actually performed any HIAs for transportation projects; there are no publically available case studies, and requests for an interview were not returned. Feedback from Washington and Oregon is included in this section.

Mr. Heller also noted that:

- The FHWA's fiscal year 2011 Research Plan includes HIAs for transportation projects. (See http://www.fhwa.dot.gov/hep/step/resources/research_plans/fy11rp.cfm.)
- HIP uses the North American Practice Standards as a model for its HIAs. (See **Tools and Resources.**)

State Departments of Transportation

Washington

Carol Lee Roalkvam, director of WSDOT's Office of Environmental Services, noted that WSDOT incorporates health into its National Environmental Policy Act (NEPA) and State Environmental Policy Act (SEPA) analysis if it is an issue of concern (identified through scoping). There is no separate HIA process; WSDOT follows its environmental procedures, all available online at http://www.wsdot.wa.gov/environment/:

- **Environmental Procedures Manual**, Washington State Department of Transportation, June 2011, pages 411-6, 452-2, 447-16.
  http://www.wsdot.wa.gov/publications/manuals/fulltext/M31-11/epm.pdf
- NEPA/SEPA Guidance: http://www.wsdot.wa.gov/Environment/Compliance/NEPA_SEPA.htm.
  - Checklists and templates:
    http://www.wsdot.wa.gov/Environment/Compliance/techguidance.htm.
    - Environmental Justice Discipline Report Template:
      http://www.wsdot.wa.gov/NR/rdonlyres/DD911090-F3E1-4E23-BEFF-920DA66E3882/0/EJ_Template.pdf
      Although it doesn't mention the word "health," this template includes elements that generally resemble a simple HIA. It includes placeholders for existing conditions (including demographics, pedestrian facilities, etc.) and possible project effects on community cohesion, safety, transit, noise and air quality.
  - Sample Environmental Justice Discipline Reports (containing only general discussions of health):
    - **405 Corridor Program**, Washington State Department of Transportation, January 2006.
      http://www.wsdot.wa.gov/NR/rdonlyres/802C0761-915E-4E58-B367-092A5D0BE468/18530/BellEJDRv3_012006.pdf
    - **SR 167 Southbound HOT Lane**, Washington State Department of Transportation, August 2008.

http://www.wsdot.wa.gov/NR/rdonlyres/80352212-F081-4099-A726-9EB932E10146/0/SOCIALECONOMICENVIRONMENTALJUSTICE.pdf
        - **SR 509: Corridor Completion/I-5/South Access Road, Final Environmental Impact Statement**, Appendix F: Environmental Justice, Washington State Department of Transportation, undated.
        - http://www.wsdot.wa.gov/NR/rdonlyres/F34D3E0B-0577-4376-801D-45D348E24F38/0/appendix_f.pdf
            - Environmental Impact Statement page: http://www.wsdot.wa.gov/Projects/I5/SR509FreightCongestionRelief/Library.htm
    - More environmental justice guidance: http://www.wsdot.wa.gov/LocalPrograms/Environment/EJ.htm and http://www.wsdot.wa.gov/environment/ej/envirojustice.htm.
- Environmental Impact Statement for the Alaskan Way Viaduct and Seawall Replacement, October 2008. http://www.wsdot.wa.gov/Projects/Viaduct/library-environmental.htm#bstsepa This statement includes a general discussion of health:
    - Environmental Checklist, pages 11 and 20 of the PDF. http://www.wsdot.wa.gov/NR/rdonlyres/AFE78B95-FFFF-413B-B711-BDE0D635123D/0/BST_Checklist_100708.pdf
    - Air Quality Discipline Report, July 2006, page 7 of the report. http://www.wsdot.wa.gov/NR/rdonlyres/A5DF6BBE-3826-4E0F-BF45-948DAA4748FD/0/SDEISAppendixQAirQuality.pdf

A review of these documents suggests that health impacts are assessed only at a general level, as in ensuring that pollutants are below concentrations known to affect human health.

Ms. Roalkvam also pointed to the legally required health assessment of State Route 520. (See State Route 520 Bridge in **Transportation-Related HIA Case Studies**.) This HIA was conducted not by WSDOT but by public health agencies. WSDOT incorporated it into its EIS (http://www.wsdot.wa.gov/Projects/SR520Bridge/EIS.htm).

Oregon

Michael G. Holthoff, NEPA program coordinator for ODOT, noted that the agency does not currently assess the health impacts of transportation projects. In 2009, ODOT (with the FHWA Oregon Division) developed an EIS annotated template, but according to Mr. Holthoff "the concept of HIA is not in there." Further:

> "There have been a few EAs or EISs in the past where health impacts were raised (by stakeholders, and as related to air quality and/or environmental justice) and made their way into the NEPA analysis, but we do not currently address health impacts as an everyday practice or in a comprehensive way. I have seen an increasing number of HIA-oriented webinars and publications, so I believe it's coming to FHWA NEPA eventually. We're just not there yet."

Hal Gard, Manager for the Geo-Environmental section concurred, adding that "there has been increased interest by our Department of Environmental Quality and some Environmental Justice interest groups in seeing them done."

New York

According to John Zamurs, head of the New York State Department of Transportation's Air Quality Section, NYSDOT does not perform health impact assessments for our projects. However, we have begun an SPR study to look at developing NYSDOT-specific MSAT analysis guidelines/procedures. One element of that study is to evaluate the feasibility of doing health impact assessments.

The project manager for this study, Catherine Leslie, can be reached at cleslie@dot.state.ny.us.

Illinois

Barbara Stevens, chief of the Environmental Section of the Illinois Department of Transportation, noted that Illinois DOT does not currently include health impact assessments in planning or project development. However, during the reconstruction of the Dan Ryan Expressway in Chicago a few years ago, area residents expressed concerns about impacts to air quality during construction. Illinois DOT included mitigation measures to help reduce emissions from construction equipment and reported the air data that was gathered using special equipment installed at various stations along the alignment.

Maryland

According to Bruce Grey, deputy director of the Maryland Department of Transportation's Office of Planning and Preliminary Engineering, the agency does not assess health impacts when planning transportation projects.

Tools and Resources

Human Impact Partners

http://www.humanimpact.org

This organization promotes the use of HIAs and claims to be "the only organization in the United States focused on capacity building for HIAs — offering policymakers, project leaders, public agencies, community groups and advocacy organizations the support they need to conduct HIAs and use the results to make informed choices." HIP has been involved in HIA-related activities, often in collaboration with the Los Angeles County Department of Public Health, for a number of transportation projects (http://www.humanimpact.org/projects), including the I-710 Expansion in California, the Lake Merrit BART Station Specific Plan and the Ports of Los Angeles and Long Beach (included in **Transportation-Related HIA Case Studies**).

HIP has a useful tools and resources page at http://www.humanimpact.org/hips-hia-tools-and-resources. Selected links include:

> **A Health Impact Assessment Toolkit: A Handbook to Conducting HIA**, Third Edition, February 2011.
> http://www.humanimpact.org/component/jdownloads/finish/11/81
> Developed by HIP, this toolkit introduces and defines HIA, describes each step of the HIA process and discusses other aspects of HIA such as collaboration and when to use HIA.
>
> **Minimum Elements and Practice Standards for Health Impact Assessment**, Version 2, November 2010.
> http://www.humanimpact.org/doc-lib/finish/11/9
> These standards for application of HIA were developed by the North American HIA Practice Standards Working Group and are used by HIP when conducting HIAs.
>
> **HIA Summary Guides**, December 2010.
> http://www.humanimpact.org/component/jdownloads/finish/11/44
> These two-page summaries describe each of the five steps of HIA.
>
> **Frequently Asked Questions about Integrating Health Impact Assessment into Environmental Impact Assessment**, undated.
> http://www.humanimpact.org/component/jdownloads/finish/11/42

This guide answers common questions about integrating HIA into environmental impact assessments.

The Merseyside Guidelines for Health Impact Assessment, International Health IMPACT Assessment Consortium, Second Edition, May 2001.
http://www.humanimpact.org/component/jdownloads/finish/11/24
This report provides guidelines for HIAs from the United Kingdom.

Health Impact Assessment: A Screening Tool for the Greater London Authority, London Health Commission, May 2001.
http://www.humanimpact.org/component/jdownloads/finish/12/25
This tool provides a systematic method of identifying key ways in which a particular policy or strategy may affect health.

Concord Naval Weapons Station HIA Scope, August 14, 2008.
http://www.humanimpact.org/component/jdownloads/finish/13/4
This resource is an example of a completed HIA scope.

HIA Data Sources and Related Resources, March 2010.
http://www.humanimpact.org/component/jdownloads/finish/14/40
This table provides a list of commonly used data sources in HIA.

HIA Report Guide, December 2010.
http://www.humanimpact.org/doc-lib/finish/13/100
This guide provides a template and information about what to include in an HIA report.

Health Impact Project
http://www.healthimpactproject.org
This organization is a national initiative promoting the use of an HIA as a decision-making tool for policymakers. The web site includes:

- An interactive map of case studies at http://www.healthimpactproject.org/hia/us. (All relevant studies are described in **Transportation-Related HIA Case Studies**.)
- A useful list of resources at http://www.healthimpactproject.org/resources.

Health Impact Assessment Tools, Program on Health, Equity and Sustainability, San Francisco Department of Public Health, August 3, 2011.
http://www.sfphes.org/HIA_Tools.htm
From the web site: [The department uses] these tools and our general public health expertise to work with community stakeholders and government agencies to inform project development and policy-making and to improve the consideration of health and health inequities in decision-making.

Healthy Development Measurement Tool, Program on Health, Equity and Sustainability, Environmental Health Section, San Francisco Department of Public Health, January 11, 2011.
http://www.sfphes.org/enchia/enchia_HDMT.htm
The Healthy Development Measurement Tool (HDMT) is a comprehensive evaluation metric that supports the inclusion and consideration of health needs in urban land use plans and projects. The HDMT comprises three core components: a community health indicator system to evaluate community health objectives and baseline neighborhood conditions; a healthy development checklist that is used to evaluate land use plans and projects; and a menu of policy and design strategies that can be used to make recommendations on how to improve baseline conditions and/or meet checklist targets. The HDMT explicitly connects public health to urban development planning in efforts to achieve a higher quality social and physical environment that advances

health. See also http://www.thehdmt.org/; HDMT Case Studies, http://thehdmt.org/case_studies.php; and the Treasure Island Transportation Plan case study (page 22 of this report), which uses this tool.

Other Tools

Pedestrian Injury Forecasting Model, May 10, 2010.
http://www.sfphes.org/HIA_Tools_Ped_Injury_Model.htm

The San Francisco Noise Model, March 25, 2010.
http://www.sfphes.org/HIA_Tools_Noise.htm

Air Quality: Assessment, Planning, Policy Development, and Regulation, undated.
http://www.sfdph.org/dph/EH/Air/default.asp

Air Quality Measurement and Modeling, March 25, 2010.
http://www.sfphes.org/HIA_Tools_Air_Quality.htm

Pedestrian and Bicycle Environmental Quality Assessment Tools, undated.
http://www.sfphes.org/HIA_Tools_PEQI.htm
http://www.sfphes.org/HIA_Tools_BEQI.htm

A Guide for Health Impact Assessment, California Department of Public Health, October 2010.
http://www.cdph.ca.gov/pubsforms/Guidelines/Documents/HIA%20Guide%20FINAL%2010-19-10.pdf
This guide outlines key steps, activities and issues in the HIA process. It provides a brief background on HIA, an outline of essential and common tasks in the HIA process, discussion of common issues and challenges encountered in the HIA process, and examples of and links to resources for practice. It also provides suggestions for integrating health analysis within the regulatory environmental impact assessment process, obtaining inclusion from diverse stakeholders, and evaluating the HIA process.

The guide outlines the following steps in the HIA process:

1. **Screening** involves determining whether HIA is valuable and feasible in a particular decision-making context. (The document includes a sample screening checklist on pages 13-16 of the report.)
2. **Scoping** involves determining health issues for analysis, the temporal and spatial boundaries for analysis, and the data and research methods employed in the analysis. (A sample is given on pages 19-20 of the report.)
3. **Assessment** involves using data, expertise, and qualitative and quantitative research methods to judge the magnitude and likelihood of potential health impacts and their significance, and to identify appropriate mitigations and design alternatives. Objectives include:
    a. Developing a conceptual model linking the decision at hand to human health effects using epidemiological and empirical research. (See page 25 of the report for links to searchable databases.)
    b. Determining the baseline health status, health-relevant conditions and vulnerabilities in the population or area potentially impacted by the decision. (See page 27 of the report for examples of baseline indicators.)
    c. Judging prospective health impacts using available data, qualitative and quantitative analysis, and expert and experiential knowledge. (See pages 27-29 of the report for possible data sources, and page 34 for examples of uses of quantitative data in HIAs to estimate health impacts.)

d. Identifying strategies for policy, program or project design; mitigations; and alternatives to protect and promote health.

4. **Reporting** involves documenting and synthesizing the assessment findings and communicating the results and recommendations of the assessment. (See page 48 of the report for key elements of HIA reports.)
5. **Monitoring** involves tracking the decision and implementation effect on health determinants and health status.

The guide also encourages "meaningful participation of affected residents and other stakeholders in the policy making process" in order to "help identify relevant research questions, sources of data and information, and proposals for alternatives and mitigations." Further, "[m]eaningful and inclusive public participation can also ensure that the HIA addresses community priorities and makes judgments that take into account community values." (See page 52 of the report for examples of possible community roles in stages of the HIA process.)

FHWA Process and State Examples (scroll down to Health Impact Assessment)
http://www.fhwa.dot.gov/hep/climate/sustainability/sustain05.cfm
From the web site: A Health Impact Assessment (HIA) is a methodology to assess transportation in terms of impacts on public health and wellness, with a focus on underserved or vulnerable populations. At least 27 HIAs were conducted in the US from 1999-2007 and an additional ten HIAs in progress. Most of the studies were sponsored by local health departments, private foundations, or federal agencies, and covered a range of polices and projects including after-school programs, power plants, land use planning, commercial redevelopment, parks and trails, public subsidies for housing, and public transit. Nine of the HIAs investigated transportation-related health impacts. The HIAs used a variety of assessment methods such as literature review, expert panels, GIS mapping, public involvement (interviews or surveys), analysis/forecasting of travel and census data, and review of existing programs or planning documents. Most of the HIAs included recommendations for changing the proposed policy or program. However, there was little documentation of the impacts on implementation.

The page includes three case studies: New Zealand Transport Agency's Applications to Land Transport, Atlanta BeltLine HIA and City of Decatur Community Transportation Plan. The FHWA concludes that the effectiveness of HIAs is often a function of commitment, in terms of time and monetary resources and buy-in from transportation officials, the public and politicians.

Transportation-Related HIA Case Studies

The following is a comprehensive list of transportation-related HIA case studies. In select cases, we have highlighted the background, methodology and findings for the HIA report. In other cases, we have included a briefer summary or the synopsis from the Health Impact Project case study page.

International

"Applying Health Impact Assessment to Land Transport Planning," J. Ball, M. Ward, L. Thornley, R. Quigley, *NZ Transport Agency Research Report 375*, 2009.
http://210.48.109.8/resources/research/reports/375/docs/375.pdf
The New Zealand Transport Agency conducted a review of HIA that included three case studies of completed HIAs:

- Greater Wellington Regional Land Transport Strategy HIA: This assessment included stakeholder workshops during the scoping and appraisal/evaluation stages.

- North Nelson to Brightwater Corridor Study HIA: A form of rapid HIA informed the corridor study, which was needed to accommodate projected growth and relieve congestion. The primary recommendation was to conduct a full HIA for project alternatives.
- Wairau-Taharoto Corridor Upgrade HIA: The project-level HIA followed the steps of screening, scoping, evaluation and reporting with input from a multidisciplinary expert panel at each stage. There was limited public involvement because of time and budget constraints. The HIA took place late in the planning process and lacked buy-in from the project manager, and so the recommendations had little impact on final design.

Road and Bridge Redevelopments

Interstate 75 Focus Area Study Health Impact Assessment, City of Cincinnati Health Department, December 2010.
HIA Report:
www.cincinnati-oh.gov/health/downloads/health_word40614.doc
This HIA focused on the Ohio Department of Transportation's plan to add lanes to and replace a bridge on I-75, a major north-south corridor that bisects the city of Cincinnati. It was concerned specifically with evaluating the health impacts of recommendations in the *Revive Cincinnati* study, which made recommendations for neighborhoods adjacent to I-75 concerning economic development and redevelopment, neighborhood investment, green initiatives, transportation infrastructure and transportation modes and urban design. The HIA Committee evaluated three neighborhoods—Avondale, Spring Grove Village and Queensgate—for the following impacts:

- **Air quality related to construction**, with the committee recommending that air quality data for particulate matter and volatile organic compounds be collected before, during and after construction. The methodology for this evaluation will be developed by faculty and students at the Center for Health Related Aerosol Studies and Industrial Hygiene at the University of Cincinnati in collaboration with the Cincinnati Health Department staff. To mitigate the effects of the project on air quality, the committee recommends:
  - Promoting landscaping and green space, lowering the health risk factors for inactivity.
  - Restoring the Mill Creek to its natural state in collaboration with the Millcreek Restoration Project.
  - Promoting alternatives to vehicle transportation by working with the Planning and Transportation divisions and through support letters to city council when roadway changes are made in the neighborhood.
  - Utilizing plants and trees that produce a low level of allergens.
  - Monitoring air quality at schools, day care centers and senior housing during and after construction.
- **Traffic, crashes and air quality related to traffic changes** during the project. Recommendations include:
  - Creating connectivity across the barriers such as I-75, large arterial streets and the Mill Creek.
  - Creating safe, efficient ways to connect neighborhoods to businesses and public services.
  - Creating walkable streets using wide sidewalks, crosswalks and traffic calming devices.
  - Promoting safe neighborhood streets.
- **Displacement of residents**, with recommendations including a housing program to assist displaced residents in finding and financing LEED-certified housing.

The HIA also recommends:

- Putting its recommendations for collecting air quality data into construction contracts (such as the air quality data the contractor will pay to collect, how to collect the data and how the contractor will make the data available to the public). Contracts should also list how dirt tire tracks,

crushers, noise, debris disposal and recycling, dust control, lead control and asbestos will be handled and controlled to minimize environmental and health impacts.

- A **community education program** to inform residents about rights to lodge a complaint about noise, air quality, bad odors and dirt on the road.
- **During construction**, real-time traffic and road construction information to help area residents, transit, freight, Emergency Medical Services and other users navigate construction-related detours.

Overall, this HIA concludes that the *Revive Cincinnati* plan's recommendations will positively impact air quality and population health by encouraging walking, biking and use of public transit. These recommendations include:

1. Linking existing cemeteries, parks and trails to create a connected green space.
2. Naturalizing the Mill Creek through the removal of channel walls and the creation of natural flood plains to enhance water quality issues and advance Metropolitan Sewer District storm water drainage solutions.
3. Creating a multiuse trail and park space along the Mill Creek and link it to existing trail and park network from the Mill Creek to Lower Price Hill, the Banks, and points east and west along the Ohio River.
4. Preserving potential alignments for future passenger rail.
5. Studying traffic and street design for Mitchell Avenue and Vine Street to determine the best solution for traffic flow.
6. Enhancing connectivity across the Mill Creek with the addition of pedestrian bridges.

Ultimately, the HIA concludes that the I-75 project will also improve air quality by improving traffic flow and reducing traffic congestion.

Still/Lyell Freeway Channel in Excelsior District (I-280/PODER), San Francisco Department of Public Health, UC Berkeley, People Organizing to Demand Environmental and Economic Rights.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/stilllyell-freeway-channel-in-excelsior-district.
- HIA web site: http://www.sfphes.org/HIA_PODER.htm.
- HIA report: http://www.healthimpactproject.org/resources/document/HIA-Report-Still-Lyell-Freeway-Channel-in-Excelsior-District.pdf.
    - See also *Key Findings*: http://www.sfphes.org/PODER/PODER_KeyFindings.pdf.

The San Francisco Department of Public Health conducted an HIA of the transportation system in a city neighborhood that included a freeway and heavy traffic corridors. Measured impacts included the effects of air pollution, noise exposures and pedestrian hazards. Analysis methods included surveys, traffic counts, community photography, oral histories, outdoor air quality and noise modeling and exposure assessment, pedestrian environmental quality evaluation, historical document review and publicly available data from numerous sources including hospitalization data, U.S. Census data and traffic-related injury data.

Related resources:

"Health, Traffic, and Environmental Justice: Collaborative Research and Community Action in San Francisco, California," Megan Wier, Charlie Sciammas, Edmund Seto, Rajiv Bhatia, Tom Rivard, *American Journal of Public Health*, Vol. 99, No. S3, November 2009.
See Appendix D.
This article includes a concise discussion of results for the HIA, including the fact that exposure to traffic had a number of impacts on community residents.

- **"Traffic Causes Death and Disease in San Francisco Neighborhood,"** Charlie Sciammas, Tom Rivard, Megan Wier, Edmund Seto, Rajiv Bhatia, *Race, Poverty & the Environment*, Vol. 15, No. 1, Fall 2008.
  http://urbanhabitat.org/node/2814

State Route 520 Bridge, Public Health — Seattle and King County, Puget Sound Clean Air Agency, Seattle and King County, WA.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/state-route-520-bridge.
- HIA web site: http://www.kingcounty.gov/healthservices/health/ehs/hia.aspx.
- HIA report: http://www.wsdot.wa.gov/NR/rdonlyres/EFDE4CC6-406F-48E4-BEFD-EF50B2842625/0/SR520HealthImpactAssessment.pdf.
- See also SR 520 — Bridge and HOV Project, Westside Project Impact Plan, December 2008. http://www.wsdot.wa.gov/NR/rdonlyres/FD796AFD-25DC-4D76-807E-F74D7F818F1E/0/FINALSR520PIP122908.pdf

Background

This HIA was conducted by the Seattle & King County Public Health Department and the Puget Sound Clean Air Agency to evaluate the health impacts of the State Route 520 Replacement Bridge and HOV Project in Washington. It builds on the August 2006 SR 520 Bridge Replacement and HOV Project draft EIS in which WSDOT proposed infrastructure elements (such as landscaped lids, pedestrian and bicycling connections, visual design elements and transit facilities) that would reduce vehicle emissions, create opportunities for physical activity and reconnect communities.

Methodology

Report appendices include separate papers on demographics, air quality, water quality, noise, physical activity, safety, social connections, mental well-being, green space and emergency medical services. The report also includes an analysis of the possible effects on greenhouse gases of three design alternatives for the State Route 520 project, with results showing all three alternatives producing similar levels of emissions.

Findings

HIA recommendations included:

- During construction, reducing construction-related pollution, increasing traffic management and providing for construction noise control.
- Increasing and improving transit services and installing walking and bicycle facilities throughout the corridor.
- Using landscaping and preserving green space throughout the corridor, along adjacent trails and roadways, and at transit stops.
- Reducing noise throughout the corridor and using innovative stormwater management practices.

I-710 Expansion, Human Impact Partners, Los Angeles.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/i-710-expansion.
- HIA web site: http://www.humanimpact.org/projects.

From the Health Impact Project web site: The plan for the HIA is to address the expansion and improvements planned for the I-710 freeway in Los Angeles, a vital transportation artery that links the Ports of Long Beach and Los Angeles to the Southern California region and beyond. As Caltrans is drafting the environmental impact statement (EIS) for the project, the Metropolitan Transportation Authority and the Gateway Cities Council of Governments — at the request of stakeholders — is drafting the HIA. Some of the pathways and health issues that will be explored include jobs and economy, pedestrian and motor vehicle safety, air quality, noise and neighborhood resources.

From the HIA web site: Following [an] HIA training conducted by HIP, a broad coalition was formed including HIP, community groups, academic experts, city, county, regional and federal agencies, and advocacy groups. Stakeholders worked together to scope out the potential health impacts of the proposed expansion project that should be taken into account by the project's decision-makers. Through developing health pathways and research questions, HIP and our partners then communicated this scope of health issues to Caltrans and other decision-making agencies. As a result of these efforts, decision-makers voted to conduct an HIA. HIP is now working with LA Metro and their contractor, ICF International, to conduct this HIA. In addition to this vote, and as a result of our training, the LA County Department of Public Health has become a Cooperating Agency in the EIR/EIS process.

Highway 550, University of New Mexico Prevention Research Center, Cuba, NM.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/highway-550.
- HIA report: http://www.healthimpactproject.org/hia/us/hia-report/U-S-Highway-550-Design-and-Health_Health-Impact-Assessment_FINAL.pdf.
- See also http://www.cdc.gov/prc/center-descriptions/university-new-mexico.htm.

Background and Findings

From the Health Impact Project web site: This HIA looked at a Department of Transportation proposal to redesign a five-lane, federal highway that runs through the small town of Cuba, New Mexico. This rapid HIA, initiated by a community advocacy group, looked at the potential impacts of proposed highway improvements, such as better lighting and sidewalks, on community health, walkability, pedestrian safety, social cohesion/community connectedness and economic development for downtown business. Ultimately, the HIA predicted that proposed improvements might encourage more walking in the downtown area, decrease the frequency and severity of pedestrian injuries, improve the overall atmosphere of downtown and potentially bolster the local economy. The HIA recommended that traffic calming measures, such as speed feedback signs, median islands and signage to designate the entrance into town and deceased speed limits, be included in the improvement plans to maximize potential community health benefits.

Methodology

The HIA for this project draws on general research about the effects of transportation planning on pedestrian safety, physical activity, social connections and community economics to recommend measures to mitigate any negative effects from the Highway 550 project in Cuba, NM. But it does not make any specific predictions concerning the health consequences of this project for Cuba.

I-5 Columbia River Crossing, Multnomah County Health Department, Portland, OR.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/i-5-columbia-river-crossing.
- HIA web site: http://www.oregon.gov/DHS/ph/hia/completedhias.shtml.
- HIA report: http://www.healthimpactproject.org/hia/us/hia-report/HIA-Report-1-5-Columbia-River-Crossing.pdf.

From the Health Impact Project web site: This HIA, led by the Multnomah County Health Department in collaboration with several other organizations, examined the health impacts of proposed alternatives for a renovation and expansion of the Interstate 5 Columbia River crossing between Oregon and Washington. The HIA was completed to inform an environmental impact statement (EIS) for the project being undertaken by the Department of Transportation. The HIA and health-based recommendations were submitted as a detailed comment letter during the public comment period for the draft EIS. The health issues considered mode of transportation (e.g., car versus public transportation or cycling); opportunities for exercise, traffic safety, air quality, noise and illnesses, such as asthma and heart disease; and the potential for impacts on vulnerable people such as children, the elderly and low-income families. Recommendations include maximizing the use of light rail transportation and ensuring that any transit

lines serve vulnerable communities; prioritizing the development of safe, accessible bike and pedestrian facilities; employing strategies, such as the use of toll roads and peak travel time restrictions, to decrease the number of single occupancy motor vehicle trips made; and proposing air quality and noise pollution standards that achieve the maximum practicable protection for the public's health and particularly for vulnerable populations. The HIA also proposed indicators to allow ongoing monitoring and management of any changes in health or health risk factors that might occur when the project is built.

Public Transit

Atlanta BeltLine HIA, Center for Quality Growth and Regional Development, Georgia Institute of Technology, Atlanta.

- Health Impact Project page: http://www.healthimpactproject.org/resources/case-study-atlantas-beltline.
- HIA web site: http://www.cqgrd.gatech.edu/projects/beltline_hia/index.php.
- HIA report: http://www.cqgrd.gatech.edu/projects/beltline_hia/pdfs/beltline_hia_final_report.pdf.

This HIA evaluated a proposed 22-mile loop of rail transit along with an extensive park and trail system. Two transportation studies are currently under way: an EIS for development of transit and trails in conjunction with the Metropolitan Atlanta Rapid Transit Authority (MARTA); and design and construction of the second major trail segment, Atlanta Memorial Trail.

In 2007, the Center for Quality Growth and Regional Development (CQGRD) at the Georgia Institute of Technology completed an HIA of the Atlanta BeltLine to consider the social and environmental justice impacts. The HIA evaluated the degree to which "access to parks, trails, transit, and redevelopment meet the needs of the existing and future populations, and whether improved access, and the resulting health benefits, are equitably distributed geographically and demographically." A multidisciplinary project team was assembled representing the fields of city planning and public health. The six-person advisory committee implemented the following steps:

- Screening: Determined the project could affect community health.
- Scoping: Defined the study area, identified vulnerable populations and key health impacts, developed a framework for drawing connections between elements of the project and potential impacts, and engaged in extensive public involvement and education. At the end of the scoping phase, the project team identified five critical issues that would be assessed in the next phase: access and social equity; physical activity; safety; social capital; and environment (air quality, noise and water management).
- Evaluation: Used GIS, census data, population and travel demand projections, crime rates, survey responses and a literature review to predict the health impacts on affected communities.
- Results: Overall, benefits were found to be distributed along the entire BeltLine. The study did observe some disparities based on race or income, and suggested that refining the BeltLine plans to focus development in vulnerable areas could resolve those issues.
    - Access and social equity: New access to parks for 5 percent of the study population, access to the trail system for 41 percent, improved access to transit for 36 percent.
    - Physical activity: Increased opportunities in planning areas with the highest mortality rates.
    - Safety: Will not reduce crime, but increased bike and pedestrian activity may reduce risk of bike and pedestrian crashes.
    - Social Capital: Five percent of survey respondents felt the BeltLine would improve their sense of community. The BeltLine would potentially improve social capital by preserving existing neighborhoods, creating places for formal and informal social interactions, and embracing an inclusive public participation process.
    - Environment: Transportation improvements would only achieve a 4 percent reduction in traffic volume growth (as projected by the Atlanta Regional Commission). The BeltLine would have a minimal positive impact on air quality.

Baltimore Red Line, Baltimore City Department of Transportation, Baltimore.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/baltimore-red-line.
- HIA web site: http://www.gobaltimoreredline.com/health_impact.html.
- HIA report: http://www.gobaltimoreredline.com/pdf/Red_Line_HIA_final.pdf; executive summary: http://www.gobaltimoreredline.com/pdf/Red_Line_Health_Impact.pdf).

Background

From the Health Impact Project web site: This HIA examined the potential health impacts of a proposal to build a new 14-mile light-rail line in Baltimore. Some of the pathways explored included access to safe outdoor activities, construction issues and air quality. HIA practitioners examined asthma, chronic lower respiratory disease, social cohesion, obesity, physical activity, bicycle and pedestrian risks, mental health, and noise and air pollution impacts on the neighboring communities. Recommendations included measures such as: 1) using a light-rail option to build the Red Line; 2) increasing green space to promote physical activity and social cohesion; 3) widening sidewalks and other traffic-calming measures to promote bicycle and pedestrian safety; and 4) implementing standards to reduce health problems related to construction and air pollution.

Methodology

This HIA involved interviews with residents, expert input, modeling the health effects of transit, an extensive literature review, and analysis of census and local data on Baltimore health. Through this process, the HIA ended up focusing on three areas: improving access and opportunities for safe outdoor activity, mitigating construction issues and improving air quality.

Findings

Results showed the Red Line project would improve the built environment, making physical activity and services more accessible and so had the potential to improve health. Potential construction issues included air quality, noise and the presence of rodents. The long-term effect of the Red Line would be a significant increase in local air quality. Recommendations included:

- The use of light rail, which is cleaner and quieter than other forms of rail.
- Appointing a public health expert to serve on decision-making committees involved in designing and planning for stations, streetscaping and landscaping.
- Increasing green space to maximize health benefits.
- Other recommendations for improving access to and opportunities for safe outdoor activity.
- Other recommendations to mitigate construction issues.

Portland to Lake Oswego Transit Project, Oregon Public Health Institute, U.S. Centers for Disease Control and Prevention, National Network of Public Health Institutes, Portland, OR.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/portland-to-lake-oswego-transit-project.
- HIA web site: http://www.orphi.org/healthy-community-planning/health-impact-assessments.
- HIA report: http://www.healthimpactproject.org/resources/document/portland-to-lake-oswego-transit-project.pdf.

From the Health Impact Project web site: The HIA was done in conjunction with an environmental impact statement (EIS) examining transit alternatives (e.g., light rail, enhanced bus service or no transportation improvements) for a new proposed public transit corridor in Portland, Oregon. The HIA was carried out by the Oregon Public Health Institute, in collaboration with the local transportation planning agency that was conducting the EIS. The HIA focused on how the proposed project would affect physical-activity levels; air quality; access to services that support health, such as healthy foods, employment and social services; and traffic injuries. Recommendations, such as developing stricter [state]

requirements for construction equipment emissions, were made to mitigate any unintended negative consequences.

MacArthur BART, University of California Berkeley Health Impact Group, Oakland, CA.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/macarthur-bart-uc-berkeley.
- HIA web site: http://sites.google.com/site/ucbhia/projects-and-research#TOC-MacArthur-BART-Transit-Village-HIA.
- HIA report: http://www.healthimpactproject.org/resources/document/macarthur-bart-uc-berkeley.pdf.

From the Health Impact Project web site: MacArthur Transit Village project was presented in October 2006 at the MacArthur BART Citizen's Planning Committee meeting. This HIA was conducted by the UC Berkeley Health Impact Group to evaluate the health effects of the proposed project, with the goal that it would be submitted to the Citizen's Planning Committee and other public agencies. A parallel environmental impact report (EIR) was being conducted by the City of Oakland as mandated by the California Environmental Quality Act (CEQA) law. Plans for the transit village include: multi-family housing, retail and community space, community and retail parking, and renovations to public infrastructure.

Nashville Northwest Corridor Transit, Nashville Area Metropolitan Planning Organization, Nashville, TN.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/nashville-northwest-corridor-transit.
  HIA report: http://www.healthimpactproject.org/resources/document/nashville-northwest-corridor-transit.pdf.
- See also Nashville Area Metropolitan Planning Organization's Regional Bicycle and Pedestrian Study, http://www.nashvillempo.org/regional_plan/walk_bike/regional_study09.aspx.

From the Health Impact Project web site: The Nashville Area Metropolitan Planning Organization (MPO) is creating a 30-mile transportation system between downtown Nashville and Gallatin, Tennessee. To do so, it has initiated a Northeast Corridor Study to develop a strategy for implementation. The HIA focused on the planning and design of the transit-oriented development in Madison, Tennessee and how aspects of the proposal might influence health, particularly through changes in physical activity and diet. The first phase of the HIA resulted in design considerations that were included in the plans for one site, such as senior housing, community gardens, walking paths, a community gathering space and public art. The MPO plans to use the pilot experience to conduct a more comprehensive HIA as part of the second phase of the planning process.

Mass Transit — CA, University of California, Los Angeles School of Public Health, Los Angeles.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/mass-transit-ca.
  HIA web site: http://www.hiaguide.org/hia/mass-transit-health-impact-assessment-potential-health-impacts-governors-proposed-redirection-ca.
- HIA report: http://www.ph.ucla.edu/hs/health-impact/docs/MassTransitHIA_June2008.pdf.

Background and Findings

From the Health Impact Project web site: The Governor of California proposed a budget (fiscal year 2007/2008) that included provisions to reallocate $1.3 billion that had been targeted for transit operations, maintenance and capital projects to other statewide programs. The HIA reviewed scientific evidence linking public transportation to health benefits from reduced air and water pollution, increased physical activity, improved economic development in well-served neighborhoods, and improved community cohesion and mental health. The HIA noted that the proposed cuts would have unpredictable impacts on

California's complex public transit systems. The impacts could be particularly severe for smaller agencies that lack other resources to make up the funds and for transit-dependent populations, such as the children, seniors, and low-income and disabled persons.

Methodology
Project staff reviewed state budget documents, claims of transit advocacy groups and the literature on transportation health to identify the major pathways through which state transit funding might impact health, including air pollution, water pollution, noise pollution, physical activity, discretionary time, social capital, accidents and collisions, household economics, community economics and land use patterns.

Lake Merritt BART Station Specific Plan, Human Impact Partners, Oakland, CA.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/lake-merritt-bart-station-specific-plan.

From the Health Impact Project web site: The HIA will address the City of Oakland's station area planning process for land use improvements around the Lake Merritt BART station in downtown Oakland. The plan, as yet not released, will likely include housing; new space for office, retail, and light industry; higher residential density; parkland improvement; and increased connectivity between several different nodes of the city. The planning area, in part, includes Oakland's Chinatown and there is community concern about displacement and continuing the cultural environment that currently exists. Pathways and health issues to be explored include jobs, business, economic development, retail (specifically grocery stores), transportation, public safety, parks and housing. The HIA is not yet completed.

Metro Westside Subway Extension (Wilshire Corridor), University of California, Los Angeles School of Public Health, Los Angeles County Department of Public Health, Los Angeles.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/metro-westside-subway-extension-wilshire-corridor.

From the Health Impact Project web site: The University of California, Los Angeles School of Public Health and the Los Angeles County Department of Public Health will work collaborate to conduct an HIA that will assess the potential health effects of a proposed subway and other mass-transit alternatives through Los Angeles' high-density, highly congested Wilshire Corridor running from mid-town Los Angeles to the city of Santa Monica. The HIA will address a range of health risks and benefits, such as the potential impacts on a resident's ability to find a safe place to exercise; community cohesion and safety; traffic-related injuries; and problems related to air pollution such as asthma and cardiovascular disease.

St. Paul Light Rail, ISAIAH, PolicyLink, TakeAction Minnesota, St. Paul, MN.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/st-paul-light-rail.
- HIA web site: http://www.isaiah-mn.org/Issues/HealthyCorridorforAll.htm.

From the Health Impact Project web site: ISAIAH, TakeAction Minnesota and PolicyLink are working together in the Minneapolis-St. Paul area to conduct an HIA of proposed land use changes related to a new light rail transit line that will connect the Twin Cities. The Central Corridor Light Rail Transit line, which runs through low-income and immigrant communities in St. Paul, could have wide-reaching, positive impacts on health if it leads to a reduction in air pollution and increased access to grocery stores, parks and open space without displacing local residents and businesses.

Pittsburg Railroad Avenue Specific Plan Health Impact Assessment, Human Impact Partners, Pittsburg, CA.
HIA Report: http://www.humanimpact.org/doc-lib/finish/8/93
This HIA focused on plans for a new Bay Area Rapid Transit stop and the planned surrounding development in the neighborhood.

Ports

Port of Los Angeles and Long Beach, Human Impact Partners, Los Angeles and Long Beach, CA.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/port-of-los-angeles-and-long-beach.

From the Health Impact Project web site: The plan for the project is to develop an HIA scope that would be useful to address future expansion projects and plans at the Ports of Los Angeles and Long Beach. The U.S. Environmental Protection Agency Region 9 undertook this project as a way to inform stakeholders about HIA and its benefits and to develop a more concrete understanding of what an HIA on port projects and plans would entail. Some of the pathways and health issues that were included in the scope relate to air quality, noise, displacement of low-income residents, jobs, the economy and neighborhood resources. Stakeholders are now considering the scope and potential next steps.

- See also Scoping a Health Impact Assessment for the Ports of Los Angeles and Long Beach, http://www.epa.gov/region9/nepa/PortsHIA/.
  Scoping-related materials available at this link include:
  - Frequently Asked Questions about Integrating Health Impact Assessment into Environmental Impact Assessment, http://www.epa.gov/region9/nepa/PortsHIA/pdfs/FAQIntegratingHIA-EIA.pdf.
  - The Steps of HIA, http://www.epa.gov/region9/nepa/PortsHIA/pdfs/Steps2CreatingAnHIA.pdf.
  - Scoping Meeting presentation, http://www.epa.gov/region9/nepa/PortsHIA/pdfs/OverviewPresentation.pdf.
  - Los Angeles and Long Beach Maritime Port HIA Scope, working draft, http://www.epa.gov/region9/nepa/PortsHIA/pdfs/DraftHIAScope4PortsOfLALB.pdf.

Port Container Fee, Human Impact Partners, Ports of Los Angeles, Oakland and Long Beach, CA.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/port-container-fee.
- HIA web site: http://www.humanimpact.org/current-projects.

From the Health Impact Project web site: The HIA addressed a proposed California state bill that would assess a fee on each container moving through the Ports of Los Angeles, Long Beach and Oakland. The fee would fund air-quality and traffic-congestion mitigations. Various types of projects that could be funded by the revenues were assessed, including grade separation (creating tunnels or bridges so that cars do not have to wait for passing trains); freeway expansion; train improvements (e.g., electrification of trains, retrofitting old diesel train engines and alternative train technologies); and heavy-duty truck retrofitting/replacement. Some of the typical influences on health that were considered included the impact that these projects could have on air quality, noise, stress, time spent in traffic and motor-vehicle collisions. Ultimately, the bill died in committee and so the HIA did not influence the process; however, conducting the HIA raised awareness of the tool with advocates and legislators. Preliminary data from the grade-separation evaluation is now being used by the City of Riverside.

Transportation Planning

City of Decatur Community Transportation Plan, Georgia Tech Center for Quality Growth and Regional Development, Decatur, GA.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/city-of-decatur-community-transportation-plan.
- FHWA case study page: http://www.fhwa.dot.gov/hep/climate/sustainability/sustain05.cfm.
- HIA web site: http://www.cqgrd.gatech.edu/projects/decatur_transportation_plan/index.php.
- HIA report: http://www.cqgrd.gatech.edu/projects/decatur_transportation_plan/pdfs/decatur_rapid_hia_final_report.pdf.

Background and Findings

When the city began a comprehensive transportation planning effort in 2006, it asked CQGRD to conduct a rapid HIA to identify health impacts related to safety, social connections and physical activity as affected by transportation and land use decisions.

From the Health Impact Project web site: The HIA focused on potential health impacts related to safety, social connections and physical activity as they are affected by the transportation and patterns of land use. The HIA found that the Plan may ultimately lead to a slight reduction in car use and thus a reduction in health problems that have been related to car use by research, such as injuries and the risk of obesity. Additionally, there will be immediate benefits from the increase in biking and walking in the City leading to increased levels of physical activity and social capital. To best leverage potential health benefits, the HIA recommended: 1) developing of a community-wide campaign to promote physical activity; partnering with local schools to promote childhood physical activity; 3) developing intersections to be ADA-compliant and easily accessible; 4) emphasizing the mobility of Decatur's most vulnerable populations; and 5) prioritizing connectivity throughout the city. After completion of the Community Transportation Plan, the City of Decatur created an Active Living Division to provide support services that contribute to the quality of life of its citizens.

Methodology

The project team:

- Created a profile of Decatur demographic and health statistics.
- Performed a literature review to identify potential health impacts and mitigation strategies.
- Conducted a community workshop investigating the concerns of residents, businesses and institutions.
- Assessed the health impacts of Community Transportation Plan interventions on physical activity, safety and injury, social capital, equity and access, and mental health.

Commute Options Central Oregon, Central Oregon Intergovernmental Council, Warm Springs Tribe, OR.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/commute-options-of-central-oregon.

From the Health Impact Project web site: This project will determine how a coordinated regional transit system might impact health in Central Oregon. By addressing factors like access to jobs, health care and food, the HIA will coincide with an initiative by the Central Oregon Intergovernmental Council to assess feasibility of such a system. In collaboration with other nonprofit organizations, the Warm Springs tribe, and municipal governments, the project team hopes the HIA will present a new perspective regarding the potential benefits of mass transit.

City of Spokane Downtown Plan Update, Spokane, WA.

- HIA report: http://www.srhd.org/documents/PA_N/HIA2.pdf.

This HIA was undertaken by the local health department in collaboration with the planning department.

Clark County Bicycle and Pedestrian Master Plan, Clark County, WA.

- HIA Report: http://www.co.clark.wa.us/public-health/reports/documents/FINAL_RapidHIA.pdf.

This HIA was undertaken by the local health department in collaboration with the county administration.

Atlanta Regional Plan 2040, Center for Quality Growth and Regional Development, Georgia Institute of Technology College of Architecture, Atlanta.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/atlanta-plan-2040.
- HIA web site: http://www.cqgrd.gatech.edu/projects/plan_2040_hia/index.php.
- See also: http://www.aashtojournal.org/Pages/102210georgia.aspx.

From the Health Impact Project web site: The first-ever HIA on a major metropolitan transportation and comprehensive growth plan will be led by the Center for Quality Growth and Regional Development (CQGRD) at the Georgia Institute of Technology's College of Architecture. Plan 2040 — which is being conducted by the Atlanta Regional Commission, the local intergovernmental-coordination agency — integrates multiple aspects of regional planning, including transportation, land use, water and air quality, housing and greenspace through the year 2040. CQGRD will examine the plan's potential impact on a range of health issues, such as injury and asthma rates, and the risks of obesity and diabetes. A final HIA is expected in September 2011.

Corridor Redevelopment

Buford Highway and NE Plaza Redevelopment, University of California, Los Angeles, Centers for Disease Control and Prevention, Atlanta.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/buford-highway-and-ne-plaza-redevelopment.
- HIA Report: http://www.healthimpactproject.org/resources/document/buford-highway-and-ne-plaza-redevelopment.pdf.

From the Health Impact Project web site: An HIA that examined the expected health benefits of proposed highway design changes (e.g., reducing lanes, adding sidewalks, medians, bike lanes and on-street parking) to the Buford Highway Corridor. Special emphasis was placed on the potential impacts on physical activity and pedestrian injuries.

Clark County Highway 99 Sub-Area Plan, Clark County Public Health, Clark County, WA.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/clark-county-highway-99-sub-area-plan.
- HIA web site: http://www.clark.wa.gov/planning/hwy99/docs.html.
- HIA report: http://www.healthimpactproject.org/resources/document/clark-county-highway-99-sub-area-plan.pdf.

Background and Findings

From the Health Impact Project web site: The Clark County Community Planning Department developed a Sub-Area Plan to revitalize Highway 99 and surrounding neighborhoods. Clark County Public Health conducted a health impact assessment which was included in the plan. The HIA explored the plan's potential impact on a number of health issues, such as the community's access to healthy foods, opportunities for physical activity, reliance on motor vehicles and the five leading causes of death in

Washington: cancer, heart disease, stroke, respiratory disease and unintentional injury. The HIA recommendations included: 1) prioritizing affordable housing; 2) enacting a living wage ordinance; 3) developing centralized mix-use districts (residential areas mixed with commercial services and recreational opportunities, such as parks and trails); 4) implementing mitigation strategies to address pedestrian and bicycle safety, air pollution and noise; and 5) increasing healthy food outlets, access to parks and green space, traffic calming measures and strategies to decrease crime and improve community safety.

The plan was adopted in December 2008. Policy makers embraced some of the recommendations, such as promoting areas of development that would include services and stores within a walkable range of surrounding neighborhoods. As a result of the HIA, the Clark County Board of Commissioners and Board of Health have begun to embrace a planning model that incorporates broader health considerations; whenever there is a new planning project, the health department is invited to the table.

Transportation-Related Policy

Oregon Vehicle Miles Traveled Legislation, Upstream Public Health, Northwest Health Foundation, Portland, OR.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/oregon-vehicle-miles-traveled-legislation.
- HIA web site: http://www.humanimpact.org/past-projects.
- HIA report: http://www.healthimpactproject.org/resources/document/oregon-vehicle-miles-traveled-legislation-portland.pdf.

Background and Findings

From the Health Impact Project web site: This HIA targeted proposed state legislation that was designed to reduce car use and ultimately meet greenhouse gas emission targets to help curb global warming. Specifically, it looked at 11 proposed strategies for reducing the number of vehicle miles traveled in the state and assessed them as they relate to physical activity patterns, air pollution and vehicle collision rates. The HIA recommended strategies that appear to carry the greatest potential health benefits, such as improving access to public transit, increasing the cost of driving as a deterrent to using the car and creating walkable neighborhoods with nearby access to goods and services.

From HIA web site: In 2009, the state of Oregon considered a bill to set targets for reducing vehicle miles traveled in the state. A coalition of groups, led by Upstream Public Health in Portland, supported the bill and received funding to conduct a HIA. Human Impact Partners' role was to guide the work of researchers at Upstream and Oregon Health and Science University in conducting the HIA. The HIA considered ways VMT could be reduced, including increasing the cost of driving, improving public transit, and changing the built environment, and analyzed the health impacts of each.

Methodology

From the HIA report: An advisory committee was formed with representatives from the public health and preventive medicine department at Oregon Health & Sciences University, the state public health division, metropolitan planning organizations, land use and planning community organizations, public health non-profits, and bicycle and pedestrian coalitions. The advisory committee identified the scope of the HIA including 11 specific policies to reduce VMT that were classified into three general categories: (1) changes to land use and the built environment, (2) increases to the cost of driving individual vehicles, and (3) investments in public transit. The report focused on the impact of each policy on three areas of health: physical activity, air pollution, and car collisions.

The project team/advisory committee:

- Met with community organizations to incorporate the needs and views of the community.
- Conducted a workgroup for more than a year to build skills in HIAs.
- Scoped the HIA to cover physical activity, air pollution and car collisions (with other cars, pedestrians or bicyclists) for counties in Oregon's six metropolitan areas.
- Collected county data on existing conditions for physical activity, air pollution and collisions. Sources included:
    - Physical activity: a Behavioral Risk Factor Surveillance System (BRFSS) compiled by the Oregon Department of Human Services in 2007.
    - Air pollution: 2000 U.S. Census data on average commute time; Oregon DOT data on vehicle miles traveled on state highways from 2002 to 2007; BRFSS data on the percentage of adults with asthma.
    - Collisions: Oregon DOT data on injuries and fatalities from 2003 to 2007.
- Conducted a literature review on:
    - Built environment and physical activity.
    - Built environment and driving/air pollution.
    - Built environment and car collisions.
    - Public transit and physical activity.
    - Increased costs and driving.

San Francisco Road Pricing, San Francisco Department of Public Health, San Francisco.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/san-francisco-road-pricing.
  HIA web site: http://www.sfphes.org/HIA_Road_Pricing.htm.
- Diagram of health impact pathways for road pricing: http://www.sfphes.org/HIA_Tools/RoadPricing_Health_Pathways.pdf.

Background

The San Francisco Department of Public Health is evaluating a policy that would charge drivers for use of congested areas for environmental and health impacts, with measures including the effects of air quality and increased physical activity. This HIA will be complete by mid-August. (See Integrating Health Considerations into Transportation Plans, Projects and Environmental Review in **Related Research**.)

Methodology

From the HIA web site: This HIA will … analyze and document baseline health factors and conditions in the targeted area, make evidence-based judgments of potential health impacts, recommend policy modifications or mitigations to address potential adverse impacts, and report findings and recommendations through various media. We will use forecasting methods to study impacts on future pedestrian conditions, active transportation, vehicle collisions, air pollutant exposures and premature mortality, greenhouse gas emissions, and traffic-related noise, annoyance and hypertension. We will assess economic impacts of morbidity and mortality related to air pollution, traffic collisions, and other impacts as feasible, and conduct analyses by age, ethnicity, income, and place to understand disparities in existing conditions or policy impacts.

Data sources will include:

- ArcGIS mapping and other statistical and mapping software.
- SFCTA's activity-based travel demand model (SF-CHAMP), the U.S. Census and other government agencies.
- Pedestrian and bicyclist counts, classifying pedestrians and bicyclists by age.

Transportation Policy Recommendations in the Eugene Climate and Energy Action Plan, Upstream Public Health, City of Eugene, Lane County Health Department, Oregon Public Health Institute, Eugene, OR.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/transportation-policy-recommendations-in-the-eugene-climate-and-energy-action-plan.
- HIA web site: http://www.upstreampublichealth.org/newsroom?type=news.
- HIA report: http://www.healthimpactproject.org/resources/document/transportation-policy-recommendations-in-the-eugene-climate-and-energy-action-plan.pdf.

From the Health Impact Project web site: This HIA explores seven transportation recommendations made in the Eugene Climate and Energy Action Plan (CEAP) and looks at the health impacts of each policy as it relates to physical activity, air pollution and collisions. Recommendations encouraged the full adoption of the transportation policies found in the CEAP — as they were found to have the potential to improve the public's health — especially those policies that facilitate "active transportation" (transportation options such as bike lanes and public transit, which have been shown to increase daily exercise). Strategies to promote urban density and investments in pedestrian and bicycle infrastructure were also recommended. Special consideration to ensure that the benefits of transportation investments reach vulnerable populations was recommended. Finally, the HIA provided recommendations for ongoing monitoring of health outcomes and risk factors such as collision rates.

Redirection of California State Transportation Spillover Funds, University of California, Los Angeles.

- HIA report: http://www.healthimpactproject.org/resources/document/mass-transit-ca.pdf.

This HIA by researchers at the University of California, Los Angeles addressed the governor's decision to allocate $1.3 billion in revenues from the state gasoline sales tax from public transit to the state general fund.

Sacramento Safe Routes to School Program, University of California, Los Angeles School of Public Health and the Centers for Disease Control and Prevention, Sacramento, CA.

- HIA report: http://www.hiaguide.org/hia/sacramento-safe-routes-school-program-natomas-unified-school-district.

This HIA addressed the proposed expansion of the Safe Routes to School Program in Natomas Unified School District (Sacramento, CA) from three elementary schools to two additional elementary schools and one junior high school.

Trails and Greenways

Treasure Island Transportation Plan, San Francisco Department of Public Health, San Francisco, CA.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/treasure-island-transportation-plan.
- HIA web site: http://www.sfphes.org/comm_ti_bicycle_ped.htm.
- HIA report: http://www.healthimpactproject.org/resources/document/Treasure-Island-Transportation-Plan.pdf.

Background

From the Health Impact Project web site: This HIA, funded by the California Department of Transportation and written by the San Francisco Department of Public Health and the San Francisco Bicycle Coalition, was done as part of a transportation plan for Treasure Island. The HIA focused on ways that the transportation system could be designed and implemented to maximize opportunities for active modes of transportation — such as walking and cycling — and minimize the risk of injuries.

Methodology and Findings

Steps for creating this HIA included:

1. Creating a Community Transportation Plan and conducting community outreach.
2. Reporting on existing health conditions.
3. Reporting on expected health impacts.
4. Recommending mitigation measures and solutions.

Community Transportation Plan and Outreach

The project team conducted outreach to community members, city agencies and community organizations. Strategies included:

- Convening a Technical Advisory Committee.
- Presenting to community organizations and city agencies.
- Participating in Treasure Island community events.
- Participating in interdepartmental streets working group.
- Conducting regular meetings with Treasure Island Development Authority, Treasure Island Community Development and the redevelopment project design team.
- Conducting community workshops, key stakeholder interviews and surveys.
- Hosting bike tours and a bike rack design contest.

Existing Conditions

This section of the HIA describes Treasure Island's existing demographics, land use, transportation facilities, and walking and bike paths. The Pedestrian Environmental Quality Index (PEQI) and Bicycle Environmental Quality Index (BEQI) were used to assess the bicycle and pedestrian environment. The PEQI is used to evaluate existing barriers to walking and assess the quality of the physical pedestrian environment (see http://www.sfphes.org/HIA_Tools_PEQI.htm); the BEQI is used to assess the bicycle environment on roadways and evaluate what streetscape improvements can be made in land use and planning processes to promote bicycling (see http://www.sfphes.org/HIA_Tools_BEQI.htm). The indices are designed to address what environmental factors support or prevent a walkable or bikeable environment.

Health Impact Assessment

The HIA was conducted using the Healthy Development Measurement Tool (TheHDMT.org), which "uses a set of community-level health indicators along with criteria for healthy development to connect physical and environmental planning to a wider set of social interests and to assess the extent to which urban development projects, plans and policies affect conditions and resources required for optimal health" (page 29). The tool uses a checklist to evaluate existing conditions and development targets (see pages 30-39) for decreasing private motor vehicle trips and miles traveled (with increased residential density, less parking, transportation demand management and traffic calming); providing affordable and accessible transportation options; and creating safe, quality environments for walking and biking.

Solutions

The document includes a transportation matrix of potential problems and solutions based on feedback from the community outreach phase of the assessment, and ranked them based on community support, health outcomes and other factors. It then assesses the health impacts and implementation of each solution, including designing streets for bicycling and walking using traffic calming devices; branding the island as pedestrian- and bicycle-focused; linking existing pathways; constructing bicycle and pedestrian pathways on the West Span of the Bay Bridge; using trees, plantings, sidewalk widths and other design features to create a pedestrian-friendly environment; establishing pedestrian-only routes; creating extensive facilities for parking bicycles; setting up a comprehensive bicycle network of on- and off-street facilities; instituting a bike sharing program; increasing bike capacity on transit; decreasing parking; and improving transit.

Xcel Energy Corridor, City of Bloomington, Bloomington, MN.

- Health Impact Project page: http://www.healthimpactproject.org/hia/us/xcel-energy-corridor.
- HIA web site: http://www.ci.bloomington.mn.us/cityhall/dept/commdev/planning/longrang/compplan/2008update/2008update.htm.
- HIA report: http://www.healthimpactproject.org/resources/document/Xcel-Energy-Corridor.pdf.

From the Health Impact Project web site: The HIA assessed the health benefits and obstacles to the Xcel Energy Corridor Trail. Some of the pathways and health issues explored included safety, accessibility, social capital, social interaction, mental health, physical activity, water and air quality, land use and traffic. The HIA recommended: 1) safety measures, such as lighting, police presence and traffic-calming measures; 2) amenities, such as benches, bathrooms and quiet spaces; 3) landscape design, such as community gardens; and 4) community-involvement initiatives.

East Bay Greenway, Human Impact Partners, Urban Ecology, The California Endowment, Oakland and Hayward, CA.

- Health Impact Project page: http://www.healthimpactproject.org/resources/case-study-east-bay-greenway.
- HIA report: http://www.healthimpactproject.org/resources/document/East-Bay-Greenway.pdf.

This HIA was conducted to inform planning for a pedestrian corridor and greenway along a 12-mile section of the Bay Area Rapid Transit corridor.

Related Research

Integrating Health Considerations into Transportation Plans, Projects and Environmental Review, Megan Wier, San Francisco Department of Public Health, TRB 2011 Annual Meeting, January 2011.
http://www.sfphes.org/Env_Health_Impact_Assessment.htm
See Appendix A.
This presentation gives an overview of incorporating HIAs into transportation project planning and includes two case studies.

In the first case study, the San Francisco Department of Public Health conducted an assessment for a proposed rezoning by using:

- Air quality modeling, calculating the health effects of increased particulate matter exposure from expected increases in traffic volume, vehicle emissions rates and other factors.
- Traffic-related noise modeling, calculating traffic-related noise levels from expected traffic volumes and speeds, road surface types and other factors.
- Pedestrian injury forecast modeling, calculating the expected number of vehicle-pedestrian collisions from traffic volume, zoning, number of residents and other factors.

This assessment led to recommendations for mitigation measures, including sensitive land uses, traffic volume reductions, sound walls, intersection improvements and speed reductions in residential areas.

The second case study describes the department's ongoing assessment of the city's road pricing policy for environmental and health impacts, with measures including the effects of air quality and increased physical activity. This HIA will be complete by mid-August. (See San Francisco Road Pricing in **Transportation-Related HIA Case Studies**.)

The presentation ends by advocating the integration of HIAs into environmental impact assessments.

Health Impact Assessment (HIA) for Planners: What Tools Are Useful?, Ann Forsyth, Carissa Schively Slotterback, Kevin Krizek, *Journal of Planning Literature*, Vol. 3, No. 24, 2010.
http://carbon.ucdenver.edu/~kkrizek/pdfs/hiajpl.pdf
This article describes the history of HIAs and their relationship to other analogous tools, reviews current theory and practice of HIAs, and discusses the role of HIAs in current planning initiatives. The authors suggest it is important to modify existing HIA tools so that they are perceived by planners as a useful supplement to current planning processes rather than a burdensome additional requirement. The authors close by discussing how HIAs present distinct advantages, providing a more specific focus on the important topic of human health and a further opportunity to more closely partner with potential allies from public health and related fields. The article includes a table (page 3 of the PDF) comparing and contrasting the HIA to three other tools: the environmental impact analysis, social impact analysis and sustainability indicators. Another table (pages 8-9) compares and contrasts three HIA tools: the Healthy Development Measurement Tool, Leadership in Energy and Environmental Design–Neighborhood Development (LEED–ND), and Design for Health suite. Finally, it summarizes arguments for and against the use of HIAs in planning (page 11) and concludes that with "the right tool used in the right setting, these HIA tools represent a valuable approach to move the field of urban planning front and center in assessing plans, policies, and projects relative to health."

Wisconsin Health Impact Assessment Initiative, Jennifer Boyce, Bureau of Environmental and Occupational Health, Division of Public Health, Department of Health Services, Madison, WI, August 2010.
http://www.dhs.wisconsin.gov/hia/Docs/ASTHO%20HIA%20Grant%20Final%20Report_Web.pdf
In 2009, Wisconsin's Bureau of Environmental and Occupational Health (BEOH) was awarded funding by the Association of State and Territorial Health Officials to build capacity among state and local partners to implement HIAs by primarily providing training, resources and technical assistance. This report documents the planning, activities and outcomes related to this capacity building initiative. The overarching goal of this project was to build the capacity of local health departments and their partner organizations to participate in decision-making processes using HIAs. Once funding was awarded, BEOH embarked on a nine-month plan to:

- Train state and local partners on the HIA framework by:
  - Working with Human Impact Partners to develop a training curriculum.
  - Collaborating with Human Impact Partners to provide two, two-day trainings on the HIA framework in January and Marc, 2010. (Training slides, http://www.dhs.wisconsin.gov/hia/Docs/HIATrainingSlides_March2010_Milwaukee.pdf; and webinars, http://www.dhs.wisconsin.gov/hia/webcast.htm)
- Provide technical assistance to trained local partners. BEOH provided staff time, data and analytical resources; supported and facilitated community outreach and engagement; and consulted on health-based message development to influence decision making. Pilot projects included:
  - Milwaukee River Estuary Area of Concern (AOC).
  - Marquette County Ice Age Trail Corridor Planning.
- Develop a Wisconsin-specific HIA toolkit: http://dhs.wisconsin.gov/hia.
  This toolkit includes links to practical guides, case studies, survey tools and indicators, data resources and professional/community organizations, and invites users to join and connect through the HIA Network.
- Develop a working model for HIA in Wisconsin. BEOH convened focus groups composed of eight to 10 local health department staff to assess the strengths, weaknesses, opportunities and barriers of employing HIA at the county and local level, and facilitated discussions on the topic at both HIA trainings. Local health departments saw significant value in the HIA framework and despite noted barriers to implementation, optimistically proposed approaches, partners and resources to overcome limitations.

- Create a Wisconsin HIA network. To date, the HIA network includes more than 120 contacts from 55 organizations and agencies. The network has been activated for the purposes of sharing information about available training or funding resources, HIA-related documentation, making connections with appropriate partners, or requesting feedback on or participation in project activities. The network is anticipated to grow and continues to be advertised via the HIA online toolkit.

A Climate/Environmental/Health Impact Assessment IT-Tool for Freight Transportation, Magnus Swahn, Martin Hagstrom, Sebastian Backstrom, Christina Wolf, 16th ITS World Congress and Exhibition on Intelligent Transport Systems and Services, Stockholm, Sweden, 2009.
http://trid.trb.org/view.aspx?id=906859
From the abstract: This paper presents a novel web-service tool, which offers different levels of calculating the climate, environmental and health impacts of freight transports, that are presently being developed within the framework of NTM - The Network for Transport and Environment. The primary components of the tool include 1) consistent, transparent and internationally recognized methodologies to calculate emissions of greenhouse gases and air pollutants and fuel/energy use associated with freight transports, 2) a common database containing the data needed to perform these calculations, linking to 3) a web-service carrying out the calculations, either via a web user interface or via a client-server solution.

"Quantitative Health Impact Assessment of Transport Policies: Two Simulations Related to Speed Limit Reduction and Traffic Re-allocation in the Netherlands," Dieneke Schram-Bijkerk, Elise van Kempen, Anne Knol, Hanneke Kruize, Brigit Staatsen, Irene van Kamp, *Occupational and Environmental Medicine*, Vol. 66, Issue 10, 2009: 685-690.
http://trid.trb.org/view.aspx?id=908843
From the abstract: This article reports on a study undertaken to evaluate the usability of existing health impact assessment (HIA) methodology to quantify health effects of transport policies at the local level. The authors quantified the health impact of two simulated but realistic transport interventions: speed limit reduction and traffic re-allocation. These were quantified by selecting traffic-related exposures and health endpoints, modeling of population exposure, selecting exposure-effect relations and estimating the number of local traffic-related cases and disease burden, expressed in disability-adjusted life years (DALYs), before and after the intervention. The authors note that exposure information was difficult to retrieve because of the local scale of the interventions and exposure-effect relations for subgroups and combined effects were missing. Given uncertainty in the outcomes originating from this kind of missing information, simulated changes in population health by two local traffic interventions were estimated to be small (<5%), except for the estimated reduction in DALYs by fewer traffic accidents (60%) due to speed limit reduction. The authors conclude that the interpretation of the HIA information should be done in the context of the quality of input data and assumptions and uncertainties of the analysis. However, the data may still be useful for policymakers because, despite uncertainties, they show the order of magnitude and range of health effects that may be expected after the interventions.

"An Area-Level Model of Vehicle-Pedestrian Injury Collisions with Implications for Land Use and Transportation Planning," Megan Wier, June Weintraub, Elizabeth Humphreys, Edmund Seto, Rajiv Bhatia, *Accident Analysis and Prevention*, Vol. 41, 2009: 137-145.
See Appendix B.
From the abstract: There is growing awareness among urban planning, public health, and transportation professionals that design decisions and investments that promote walking can be beneficial for human and ecological health. Planners need practical tools to consider the impact of development on pedestrian safety, a key requirement for the promotion of walking. Simple bivariate models have been used to predict changes in vehicle-pedestrian injury collisions based on changes in traffic volume. We describe the development of a multivariate, area-level regression model of vehicle-pedestrian injury collisions based on environmental and population data in 176 San Francisco, California census tracts. Predictor variables examined included street, land use, and population characteristics, including commute

behaviors. The final model explained approximately 72% of the systematic variation in census-tract vehicle-pedestrian injury collisions and included measures of traffic volume, arterial streets without transit, land area, proportion of land area zoned for neighborhood commercial and residential-neighborhood commercial uses, employee and resident populations, proportion of people living in poverty and proportion aged 65 and older. We have begun to apply this model to predict area-level change in vehicle-pedestrian injury collisions associated with land use development and transportation planning decisions.

"Spatial Distribution of Traffic Induced Noise Exposures in a US City: An Analytic Tool for Assessing the Health Impacts of Urban Planning Decisions," Edmund Yet Wah Seto, Ashley Holt, Tom Rivard, Rajiv Bhatia, *International Journal of Health Geographics*, Vol. 6, No. 24, June 2007. See Appendix C.
From the abstract: Authors investigated the spatial distribution of community noise exposures and annoyance. Traffic data from the City of San Francisco were used to model noise exposure by neighborhood and road type. Remote sensing data were used in the model to estimate neighborhood-specific percentages of cars, trucks, and buses on arterial versus non-arterial streets. The model was validated on 235 streets. Finally, an exposure-response relationship was used to predict the prevalence of high annoyance for different neighborhoods. Results showed that urban noise increased by 6.7 dB ($p < 0.001$) with 10-fold increased street traffic, with important contributors to noise being bus and heavy truck traffic.

Appendix A

Integrating Health Considerations into Transportation Plans, Projects and Environmental Review

Megan Wier, MPH
San Francisco Department of Public Health
Program on Health, Equity and Sustainability

TRB 2011 Annual Meeting
Reinventing the Environmental Process to Reflect Livable and Sustainable Outcomes in Transportation Planning and Project Development
Washington DC - January 23, 2011

Livable, Sustainable Environments Advance Health

Livable 1***:*** suitable for **living** in, on, or with

<a *livable* house> <*livable* wages>

Worldwide, thirteen million deaths annually are due to preventable environmental causes. *World Health Organization, 2008*

Health:

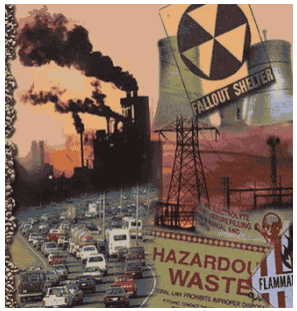
"a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity"

World Health Organization, 1948

Links between Environmental & Health Impacts for Transportation Infrastructure

EIA Category	Environmental Impacts of Transportation Facilities	Health Effects
Transportation Systems	Increase in Vehicle Trips; Increase in Traffic Density	Traffic injuries; access food resources, jobs; reduced physical activity
Air and Water Quality	Air pollution emissions; Water contamination	Pollutant exposure; child develop development; infectious and chronic diseases
Noise	Environmental Noise	Sleep disturbance; psychosocial stress; hypertension; heart disease
Social Environment	Displacement of residences; Displacement of businesses; Concentrated poverty; Division of a community; Loss of cultural or historical resources	Crowding, homelessness; hunger; social support; social support; livelihood; traditional cultural practices and diets; community violence
Natural Habitats	Loss of open space; division of natural habitats	Physical activity; brain development; mental health

Health Should Be Considered



Health Impact Assessment (HIA): a systematic process to make evidence-based judgments on the health impacts of public decisions

Screening	Determine need for and value of a HIA
Scoping	Determine which health impacts to evaluate, methods for analysis, and workplan to complete the assessment
Assessment	Judge magnitude and likelihood of potential health impacts and identify responsive design strategies and recommendations
Reporting	Communicate results to stakeholders and decision-makers
Monitoring/ Evaluation	Track effects of HIA and decision on health and evaluate HIA from start to finish

SF Case Study: Eastern Neighborhoods Rezoning

Integrating Health into the CEQA Process, 2007

- City proposed rezoning of historically industrial lands
- Potential environmental impacts on residents from noise, air pollutants, traffic hazards, and limited infrastructure
- SFDPH contributed analysis and mitigations to EIR as “cooperating agency”
- EIA required new mitigations to protect respiratory health, reduce noise exposure and added “improvement measures” to reduce pedestrian injuries

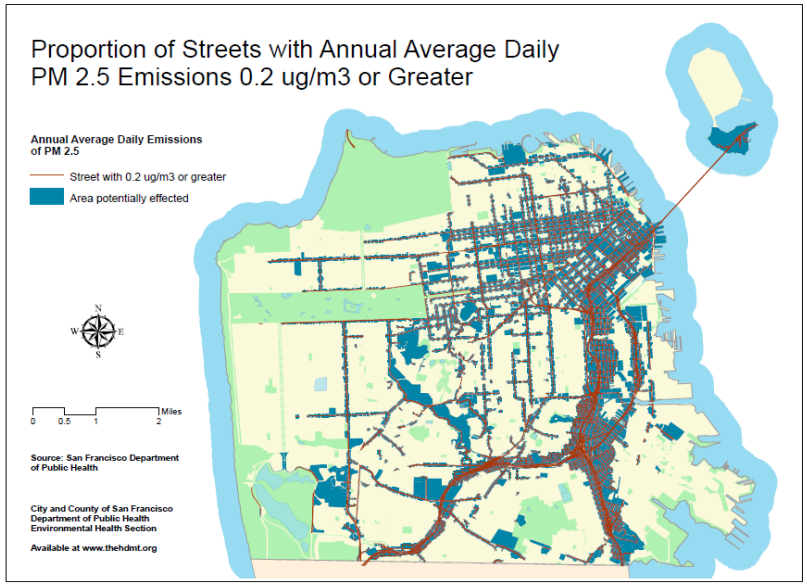
SFDPH HIA Tools

- **Air Quality Modeling**
- **Traffic-related Noise Modeling**
- **Pedestrian Injury Forecasting Modeling**

Cross-cutting characteristics:

- Quantitative approach
- Transportation analysis outputs as HIA inputs
- Traffic volume a key predictor
- ArcGIS mapping and spatial analysis
- Interpreted relative to health-based thresholds, targets or goals

SFDPH Air Quality Modeling



- Responds to growing need to identify air quality hot spots within cities
- Supports guidance and regulations to prevent health impacts associated with air pollution hot spots including concentrations of PM2.5

Inputs: Traffic volumes and speeds; Vehicle emissions rates; Temperature and humidity; Surface meteorology; Receptors and exposure height

Outputs: Traffic-related fine particulate matter (PM 2.5) exposure levels – used to assess population exposure relative to health protective thresholds

Estimating Health Effects: Excess Mortality, Traffic Attributable PM 2.5 = (Concentration Traffic Attributable PM 2.5 in ug/m3) x (Crude Incidence Non-Injury Mortality) x (Relative Risk PM2.5, Non-Injury Mortality)*

* The relative risk (effect measure) in this formula, 0.014, is derived from the study by Jerrett et al. (2005) showed that every 1.0 ug /m3 increase in PM 2.5 results in a 1.4% increase in annual mortality incidence from all non-injury causes.

Air Quality Assessment and Mitigation: Institutionalization in San Francisco

Eastern Neighborhoods EIR (2007)

Article 38 of the SF Health Code (2008): Air Quality Assessment and Ventilation Requirement for Urban Infill Residential Developments

Uses SFDPH HIA Work to:

- Identify areas with potential traffic pollution hot spots
- Establishes PM 2.5-based action levels for mitigation

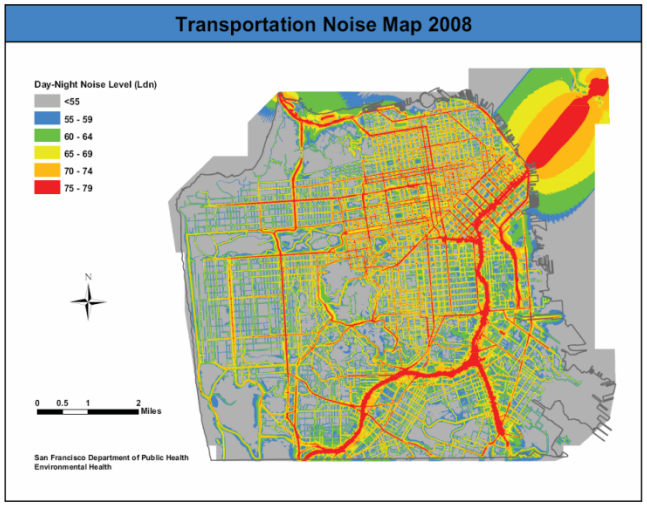
Requires sponsors of new development to:

- Assess air pollution from traffic at project sites using modeling tools
- Design buildings or ventilation systems to preserve good indoor air quality

Analysis and review by SFDPH occurs routinely and in parallel with the CEQA process.

Provides a uniform, predictable analysis and mitigation procedure which can help developers avoid producing a time-consuming, expensive or potentially contested Environmental Impact Report.

SFDPH Traffic Noise Modeling



Inputs: Traffic volumes and speeds; Vehicle type; Road surface type; Topology; Building Dimensions

Outputs: Traffic-related noise levels (decibels)

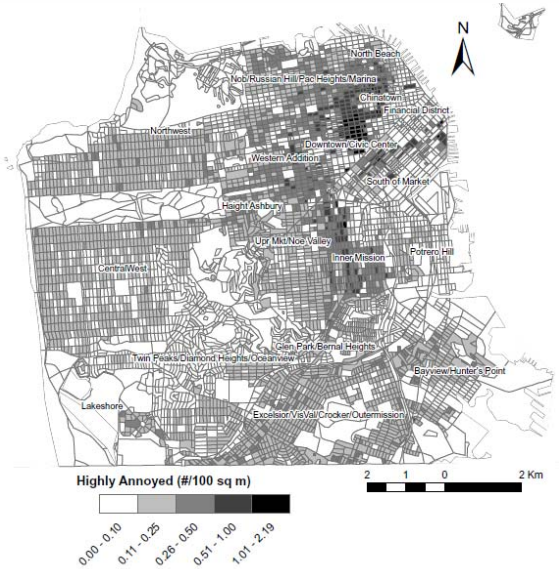
Simple first order model is the FHWA-Traffic Noise Model Lookup Table (www.fhwa.dot.gov/ENVIRonment/noise/tnm/lookup/25lookup.pdf)

San Francisco Noise Model elaborates with **SoundPLAN software** - allows inclusion of topology and 3-dimensional buildings, provides ***residential exposure levels at the parcel level***.

Estimating Health Effects - Exposure-response equation for Ldn and percentage "highly annoyed" :

$$\%HA = 9.994\times10^{-4}\left(L_{dn}-42\right)^3 - 1.523\times10^{-2}\left(L_{dn}-42\right)^2 + 0.538\left(L_{dn}-42\right)$$

(Miedema et al. 2001)



Noise Assessment and Mitigation: Institutionalization in San Francisco

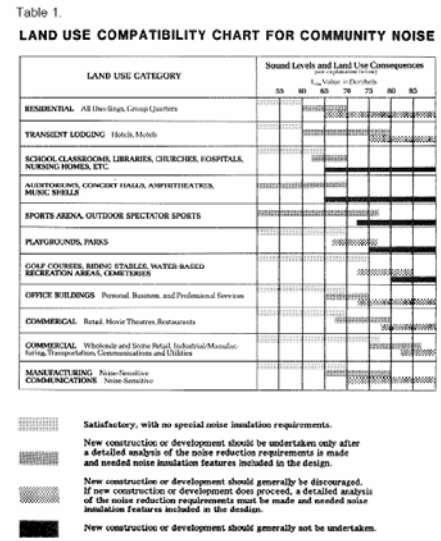


Table 1.

LAND USE COMPATIBILITY CHART FOR COMMUNITY NOISE

LAND USE CATEGORY	Sound Levels and Land Use Consequences (see explanation below) L_{dn} Value in Decibels 55	60	65	70	75	80	85
RESIDENTIAL All Dwellings, Group Quarters							
TRANSIENT LODGING Hotels, Motels							
SCHOOL CLASSROOMS, LIBRARIES, CHURCHES, HOSPITALS, NURSING HOMES, ETC.							
AUDITORIUMS, CONCERT HALLS, AMPHITHEATRES, MUSIC SHELLS							
SPORTS ARENA, OUTDOOR SPECTATOR SPORTS							
PLAYGROUNDS, PARKS							
GOLF COURSES, RIDING STABLES, WATER-BASED RECREATION AREAS, CEMETERIES							
OFFICE BUILDINGS Personal, Business, and Professional Services							
COMMERCIAL Retail, Movie Theatres, Restaurants							
COMMERCIAL Wholesale and Some Retail, Industrial/Manufacturing, Transportation, Communications and Utilities							
MANUFACTURING COMMUNICATIONS Noise-Sensitive							

Satisfactory, with no special noise insulation requirements.

New construction or development should be undertaken only after a detailed analysis of the noise reduction requirements is made and needed noise insulation features included in the design.

New construction or development should generally be discouraged. If new construction or development does proceed, a detailed analysis of the noise reduction requirements must be made and needed noise insulation features included in the desdign.

New construction or development should generally not be undertaken.

Integral part of the citywide Noise Enforcement program

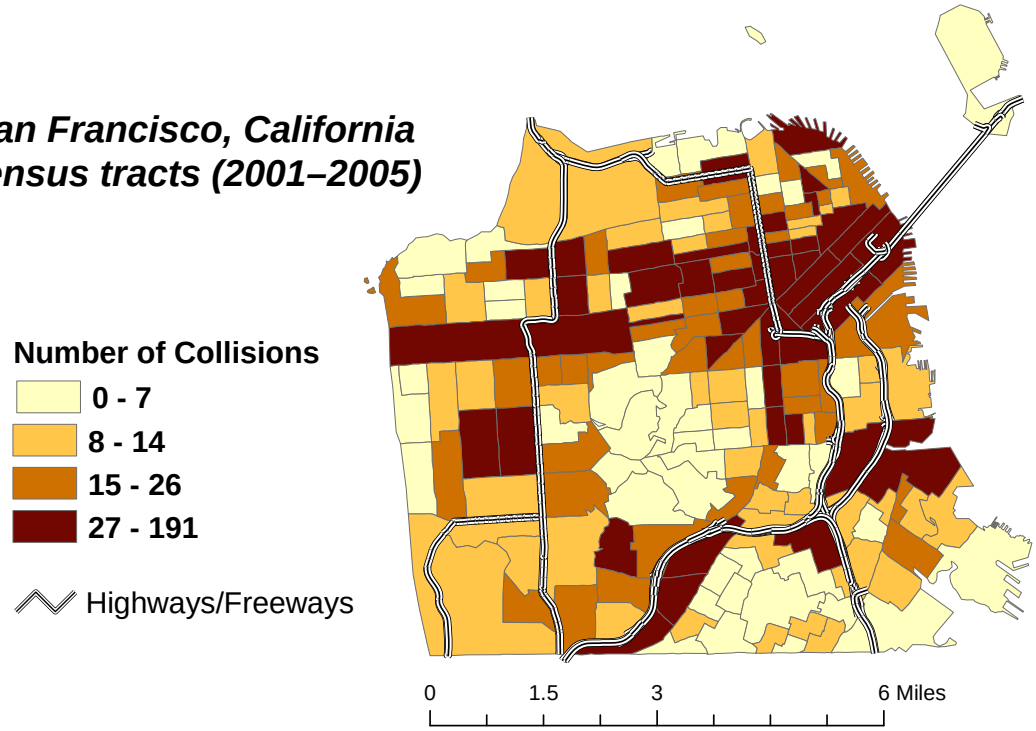
- SF General Plan citywide noise map updated - compatible land use planning
- Future noise levels for streets, land use parcels, neighborhoods, communities, or the entire city
- Used in the implementation of acoustical building code standards
- SFDPH routinely responds to noise complaints

SFDPH, Noise, and Environmental Review:

- Analyses and mitigations in Eastern Neighborhoods EIR
- Routinely review EIR Noise sections for large-scale residential development
- Goal: uniform approach to analysis and mitigation (similar to AQ)
- "At least every two years the Department of Public Health shall make recommendations to the Planning Commission for noise assessment and prevention in land use planning or environmental review." *(Article 29, SF Police Code - Regulation of Noise, 2008 Update)*

SFDPH Pedestrian Injury Collision Forecasting Model

San Francisco, California census tracts (2001–2005)



Source: California Highway Patrol, Statewide Integrated Traffic Records System

Significant predictors of area-level collisions:

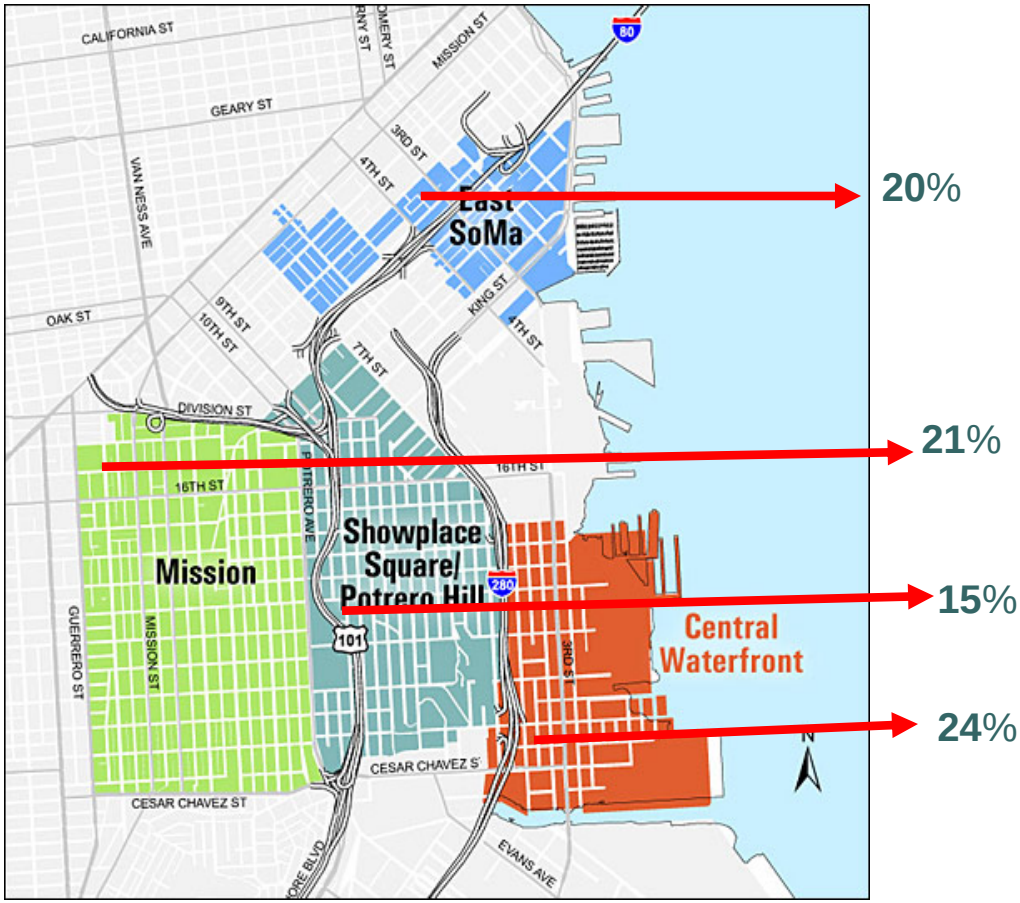
- Traffic volume (+)
- Arterial streets (+) w/o surface transit
- Neighborhood commercial zoning (+)
- Employees (+)
- Residents (+)
- Land area (-)
- Below poverty level (+)
- Age 65 and over (-)

A multivariate, linear regression model: $\ln(PedInjCollisions) = b0 + \sum biXi$

Predicts the ***natural log of vehicle-pedestrian injury collisions.***

Wier M, Weintraub J, Humphreys EH, Seto E, Bhatia R. An area-level model of vehicle-pedestrian injury collisions with implications for land use and transportation planning. *Accident Analysis & Prevention*. 2009 Jan;41(1):137-45.

Vehicle-Pedestrian Injury Collisions: Eastern Neighborhoods Area Plans



Overall **17% increase in pedestrian injury collisions in the neighborhoods** based on estimated **changes** in **residents (16%)** and **traffic (15%)**.

32 more people injured/year.

Recommended Improvements – but No Required Mitigations:

"Because the City of San Francisco has not established criterion of significance and has not thoroughly evaluated various analysis tools for pedestrian injury collisions, it cannot be concluded that the proposed project would result in a significant effect with regard to pedestrian conditions."

Application report available online at: http://www.sfphes.org/HIA_Tools_Ped_Injury_Model.htm

Pedestrian Injury Assessment and Mitigation: Institutionalization

Advocating for the City to adopt quantifiable performance targets and metrics for pedestrian safety that can inform thresholds

Healthy People 2020 Target for Fatalities + Injuries : 21.6 /100,000 pop

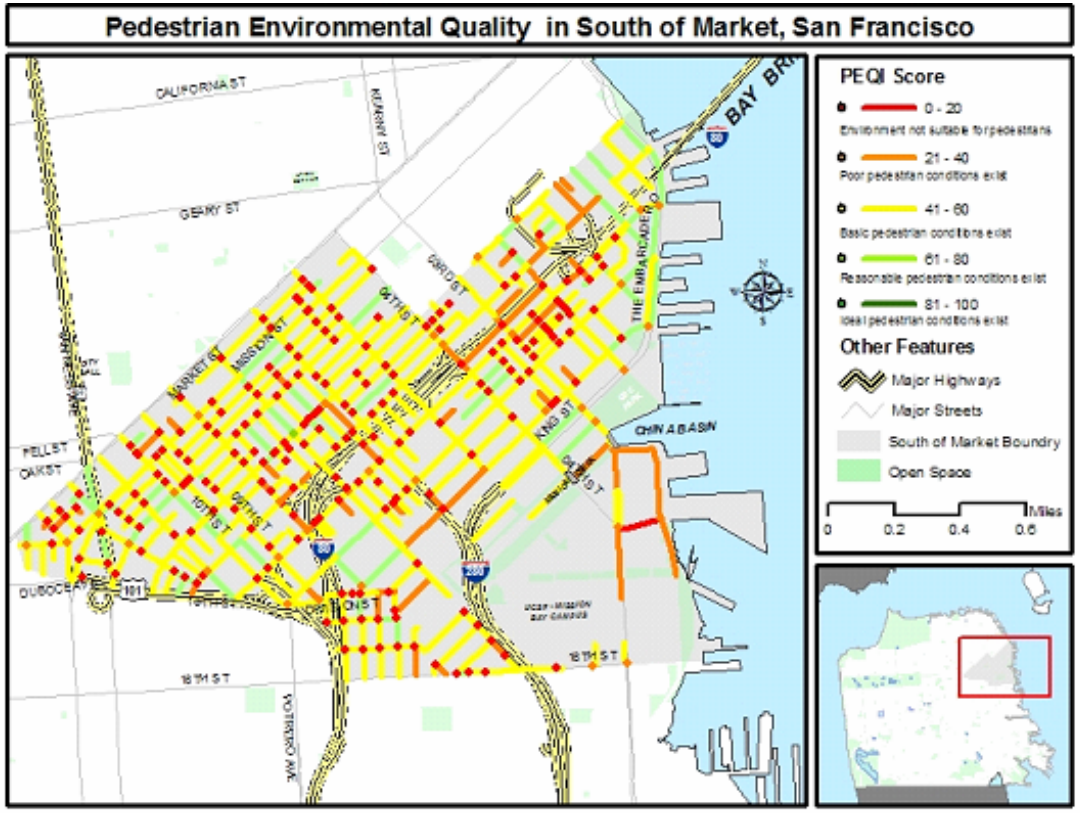
- SF current: approx. 100/100,000 pop.

Mayoral Executive Directive (December 2010)

- decrease severe and fatal pedestrian injuries by 25% in 5 years, 50% in 10 years
- through measures including speed limit reductions, traffic calming, and targeted enforcement
- to be coordinated by SFDPH and SFMTA

Developing a smaller area (e.g., intersections) model consistent with NCHRP Pedestrian Safety Prediction Methodology

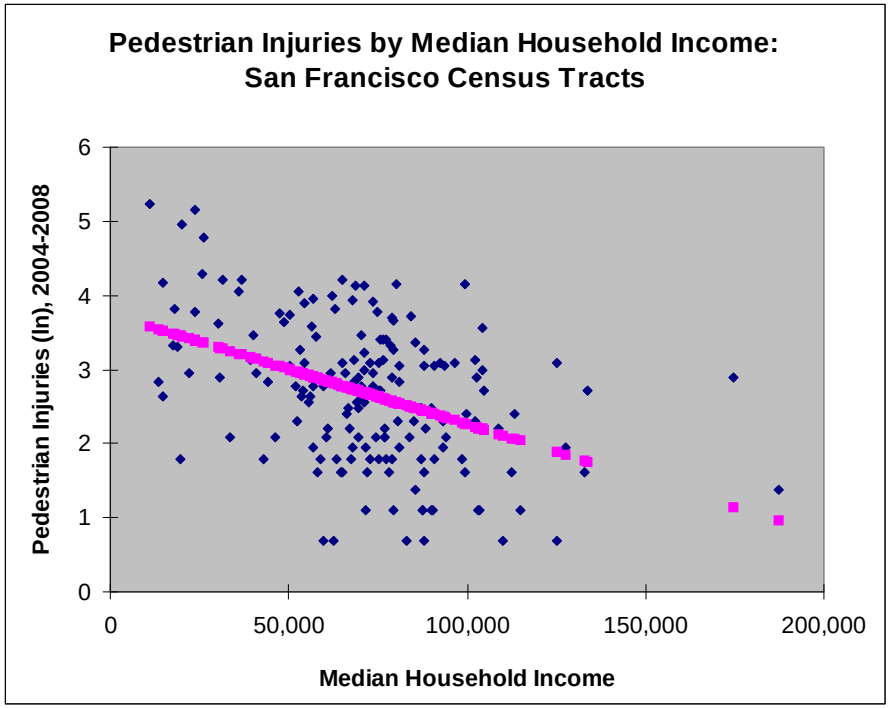
Pedestrian Environmental Quality Index (PEQI)



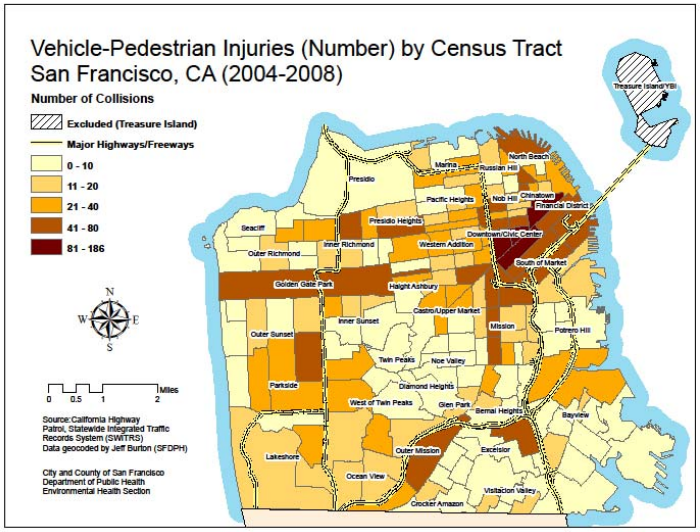
- Quantitative, observational survey
- Street and Intersection weighted scores
- 30 street segment and intersection level indicators in 5 domains:
  1. Intersection Safety
  2. Traffic
  3. Street Design
  4. Perceived Safety
  5. Land Use
- Compare presence of street factors that support pedestrian safety and environmental quality in existing and future conditions

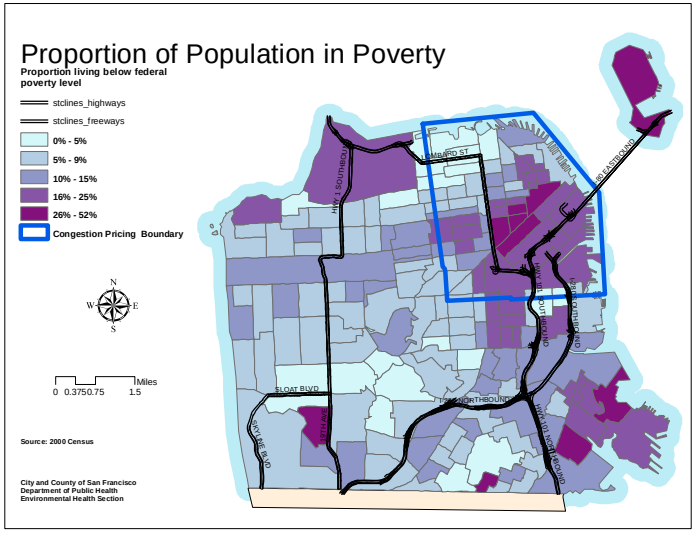
More information available at: www.sfphes.org/HIA_Tools_PEQI.htm

Equity



Regression Statistics	
Multiple R	0.428829
R Square	0.183895
Adjusted R Square	0.179008
Standard Error	0.872975
Observations	169





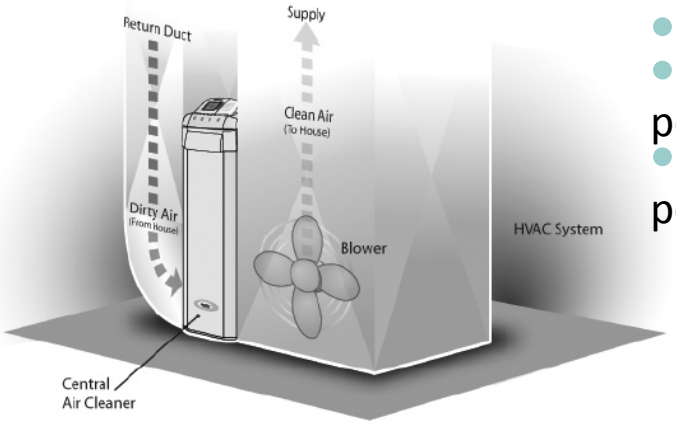
Recommendations and Mitigations

Sensitive Land Uses *(residences, schools, health care facilities, child care, etc.)*:

- Indoor Ventilation and Filtration Systems (HVAC)
- Using lower floors for commercial use and upper for residential
- Setback of buildings from roadway air pollution source
- Double-paned Windows
- *Potential co-benefits of energy efficient windows, insulation, etc.*

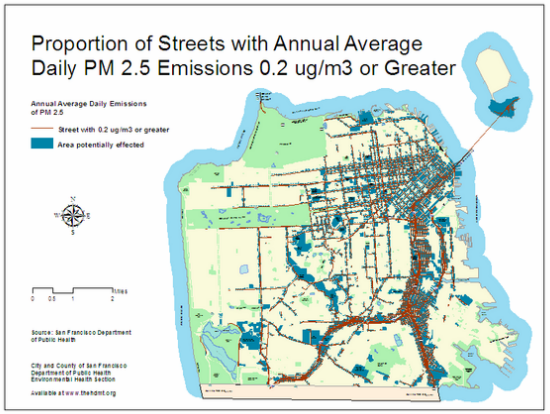
Transportation Systems:

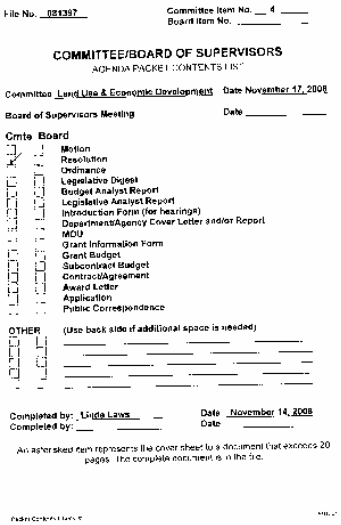
- Traffic Volume Reductions (e.g., Road and Parking Pricing Policy, Transit Investments, Transportation Demand Management, Truck Routing, etc.)
- Soundwalls
- Street and intersection improvements
- Reducing traffic hazards, risk of severe injury
- Speed reductions in residential areas, near vulnerable population attractors
- Attention to high injury areas, routes traveled by vulnerable populations (i.e., children, elderly, disabled, transit dependent)



SFDPH HIA Applications in San Francisco, California

- Review and analysis for environmental impact reports (air quality, noise, and transportation sections), working with Planning Dept., developers, consultants, etc.
- Review of new residential development projects and plans, working with Planning Dept., developers, consultants, etc.
- Community-Based Participatory Research: Collaborating with community organizations and other local stakeholders to assess existing or future housing and transportation conditions and make policy recommendations.
- Assessing the impacts of proposed transportation planning efforts on local residents (e.g., Road Pricing), working with Transportation Agencies





File No. 081397 Committee Item No. 4
Board Item No.

COMMITTEE/BOARD OF SUPERVISORS
AGENDA PACKET CONTENTS LIST

Committee Land Use & Economic Development Date November 17, 2008

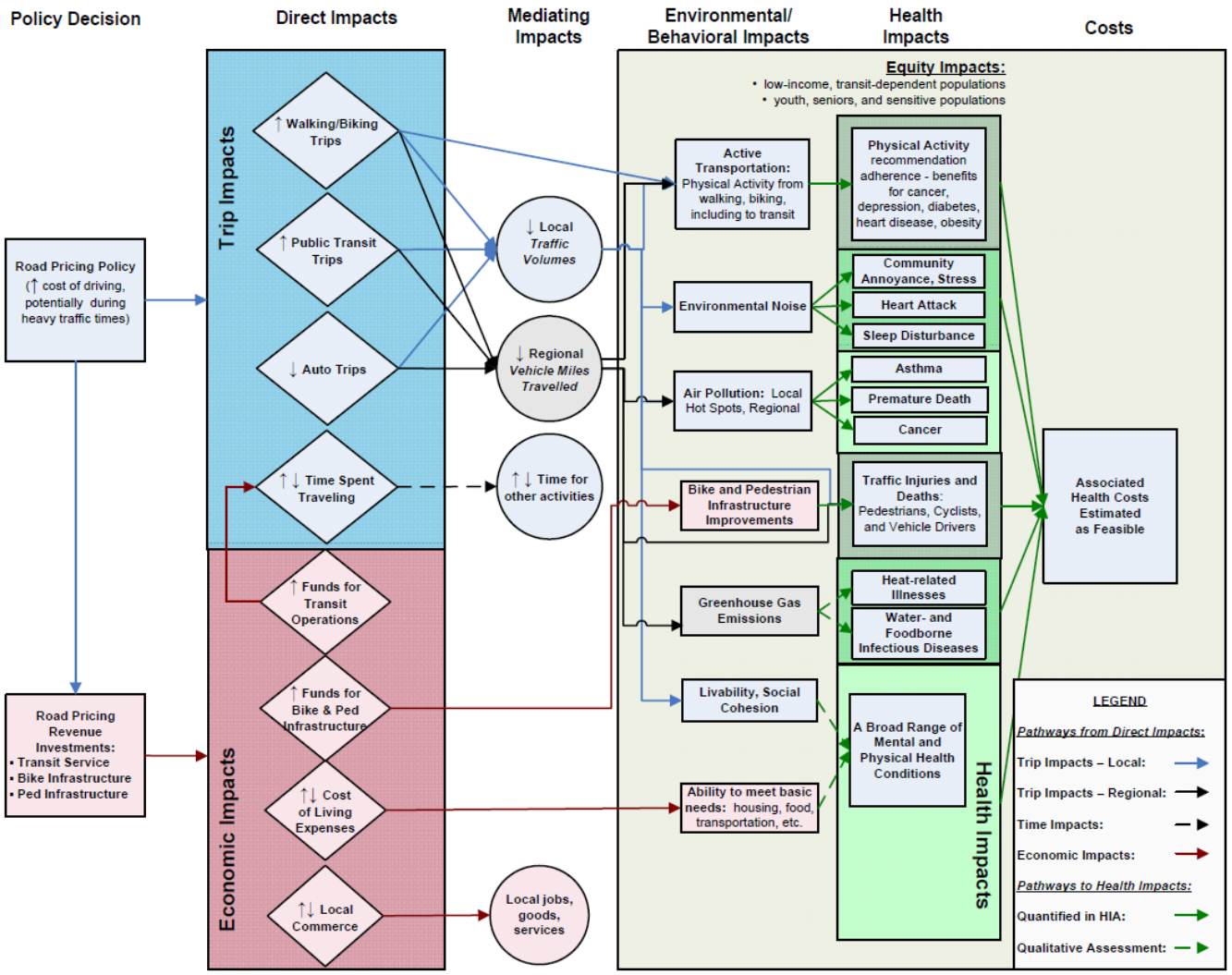
Board of Supervisors Meeting Date

Cmte	Board	
		Motion
		Resolution
		Ordinance
		Legislative Digest
		Budget Analyst Report
		Legislative Analyst Report
		Introduction Form (for hearings)
		Department/Agency Cover Letter and/or Report
		MOU
		Grant Information Form
		Grant Budget
		Subcontract Budget
		Contract/Agreement
		Award Letter
		Application
		Public Correspondence
OTHER		(Use back side if additional space is needed)

Completed by: Linda Laws Date November 14, 2008
Completed by: Date

An asterisked item represents the cover sheet to a document that exceeds 20 pages. The complete document is in the file.

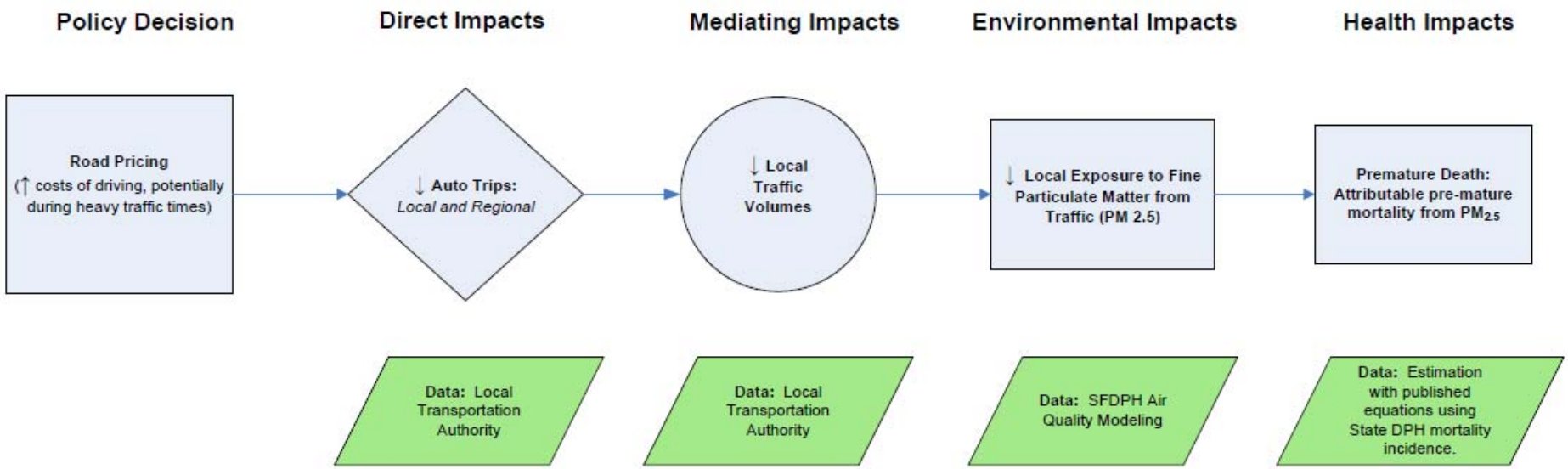
A Health Impact Assessment of Road Pricing Policy in San Francisco, California



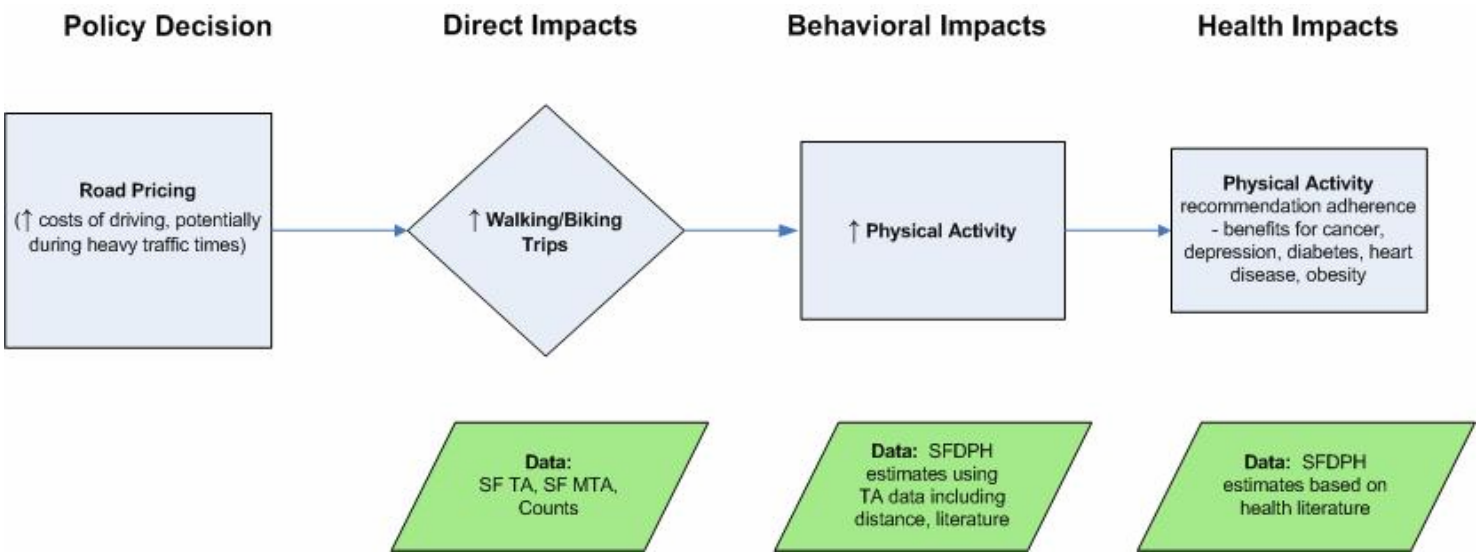
Funding from the Robert Wood Johnson Foundation's Active Living Research Program

San Francisco Department of Public Health

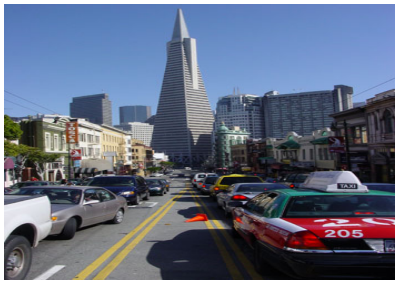
Assessment: *Air Pollution Health Impacts*



Active Transportation Modeling: *Pathway Example*



Assessment: Baseline & Future Conditions



Includes:

- Active transportation, physical activity, adherence with health guidelines
- Pedestrian and bicycle collisions - pedestrian injury forecasting modeling approach
- Air pollution and asthma, premature mortality
- Noise levels and community annoyance, sleep disturbance, and myocardial infarction
- Economic impacts of air quality and collisions
- Equity impacts - disparities based on population subgroup and place
- Resident & stakeholder perceptions of existing conditions and potential impacts

Complete findings in Spring/Summer 2011 – updates available at:
www.sfphes.org/HIA_Road_Pricing.htm

Integrated HIA/EIA: *Benefits*

- Avoids duplication, builds on existing data and analysis already contained in EIA
- HIA can address local community concerns, engage community stakeholders.
  - Requires a focus on project impacts on people - communities, sensitive populations, as well as potential disparate population impacts.
- HIA can contribute to transportation planning and policy debates typically focused on impacts on motor vehicle drivers or longer-term environmental Impacts.
- Health analyses have unique implications for mitigations or alternatives that can protect and promote health.
  - Cumulative impacts of transportation systems on local air quality, noise, safety require comprehensive, context sensitive mitigations.
- Health analyses can also quantify health benefits.
  - For example, to local air quality and noise from traffic reductions or to physical activity from increased pedestrian and bicycle infrastructure.

Thank you!

San Francisco Department of Public Health
Program on Health, Equity and Sustainability
www.sfphes.org

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Appendix B

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An area-level model of vehicle-pedestrian injury collisions with implications for land use and transportation planning

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ABSTRACT

There is growing awareness among urban planning, public health, and transportation professionals that design decisions and investments that promote walking can be beneficial for human and ecological health. Planners need practical tools to consider the impact of development on pedestrian safety, a key requirement for the promotion of walking. Simple bivariate models have been used to predict changes in vehicle-pedestrian injury collisions based on changes in traffic volume. We describe the development of a multivariate, area-level regression model of vehicle-pedestrian injury collisions based on environmental and population data in 176 San Francisco, California census tracts. Predictor variables examined included street, land use, and population characteristics, including commute behaviors. The final model explained approximately 72% of the systematic variation in census-tract vehicle-pedestrian injury collisions and included measures of traffic volume, arterial streets without transit, land area, proportion of land area zoned for neighborhood commercial and residential-neighborhood commercial uses, employee and resident populations, proportion of people living in poverty and proportion aged 65 and older. We have begun to apply this model to predict area-level change in vehicle-pedestrian injury collisions associated with land use development and transportation planning decisions.

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1. Introduction

1.1. Pedestrian safety and planning

In the 20th century, pedestrian needs were rare priorities in urban and transportation planning (Frumkin et al., 2004). Yet, environments that support walking can benefit human health by reducing motor vehicle collisions, motor vehicle-related noise and air pollution, and increasing physical activity and social cohesion (Cavill, 2001; Ewing, 2006; Leyden, 2003; Lavizzo-Mourney and McGinnis, 2003). To achieve walkable communities, planning professionals need practical tools to assess and mitigate the impact of development on pedestrian safety, including vehicle-pedestrian collisions.

Traffic collisions are a major cause of mortality in the United States (Mokdad et al., 2004), and the leading cause of death for persons aged 4–34 (Subramanian, 2006). Nationwide, pedestrians account for 11% of motor vehicle collision fatalities, with approximately 4700 pedestrian deaths in 2006 (NHTSA, 2006a). 15% of those people killed while walking died in California (NHTSA, 2006b).

Among California cities, San Francisco has historically had the highest per capita vehicle-pedestrian injury collision rate (STPP and California Walks, 2002). In stark contrast with the national figure of 11%, pedestrians account for half of San Francisco traffic deaths, with 13 fatalities and 726 non-fatal vehicle-pedestrian collisions in 2006. Pedestrian injuries and fatalities in San Francisco have declined over the last decade, attributed to intersection and mid-block pedestrian safety countermeasures, traffic calming, law enforcement, and improved planning efforts. Still, San Francisco's injury rate remains approximately 100/year/100,000 population (CCSF MTA, 2007; U.S. Census Bureau, 2000) or over five times the Healthy People 2010 national target of no greater than 19 pedestrian injuries/year/100,000 people; San Francisco's fatal injury rate of 2/year/100,000 is twice the national target (US DHHS, 2000).

Motor vehicles and pedestrians are two necessary component causes of vehicle-pedestrian injury collisions. San Francisco is a

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relatively dense, urban city, with approximately 776,000 residents and over 250,000 additional non-resident employees. By 2025, residential and job growth are expected to increase trips to, from, and within San Francisco by 12% (SFCTA, 2004). Of the projected 5 million trips in 2025, 3.3 million will be within San Francisco and over 50% of those are estimated to be auto trips. Both the relatively high frequency of pedestrian injuries and fatalities and the projected growth in San Francisco's traffic and population underscore the need to prioritize pedestrian safety needs in land use and transportation planning processes.

Currently, limited planning tools are available to evaluate the impacts of land use planning on pedestrian safety conditions. The Pedestrian and Bicycle Crash Analysis Tool software identifies pre-crash actions that lead to collisions, and links them to potential mitigation strategies (PBCAT, 2007). Crossroads software (Crossroads, 2007) and zonal analysis (USDOT, 1998) identify collision patterns and areas with high densities of pedestrian injuries.

Tools for prospectively forecasting the impacts of transportation and land use development on future vehicle-pedestrian collisions would complement the above methods for assessing existing collision patterns. To be useful in a planning context, a vehicle-pedestrian injury collision forecasting model needs to be based on available or routinely produced data, provide meaningful, easily interpreted, robust estimates, and be applicable in diverse areas to routine land use and transportation planning decisions. We are not aware of any vehicle-pedestrian injury collision forecasting tools in general use by planners for environmental or health impact assessments.

Empirically, increases in road facility vehicle volume increase the probability of vehicle-pedestrian conflicts on that facility (Lee and Abdel-Aty, 2005). A simple way to forecast change in vehicle-pedestrian collisions associated with change in vehicle volume is by applying a *road safety function*—which describes the relationship between traffic volume and collisions. The following power function (1.1) is an empirically supported parametric form of a road safety function, where AADT = Average Annual Daily Traffic:

$$\Delta\ (\%),\ \text{vehicle-pedestrian collisions} = \left[\left(\frac{\text{Future AADT}}{\text{Baseline AADT}}\right)^{\beta} - 1\right] \times 100 \qquad (1.1)$$

Typically $\beta < 1$, and empirical evidence suggests that 0.5 is a reasonable parameter (Lee and Abdel-Aty, 2005). At $\beta = 0.5$, vehicle-pedestrian collisions are forecasted to increase proportional to the square root of AADT, with a 50% increase in AADT predicting a 22% increase in collisions. Fig. 1 graphically illustrates the relationship

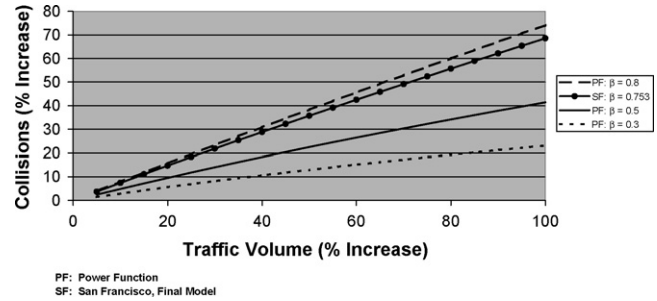

Fig. 1. Vehicle-pedestrian injury collision increases associated with traffic volume increases: power function and San Francisco final model predictions.

between change in vehicle volume and change in the number of collisions as β varies. Applying this power function (1.1) to estimate collision increases associated with traffic volume changes due to area-level development is more challenging and requires simplifying assumptions, including: (1) development does not affect pedestrian flow and behavior; (2) development does not implement pedestrian safety countermeasures; and (3) AADT changes at intersections or street segments selected for evaluation are reasonable surrogates for changes at adjacent area roadways. (We included an example application in the Appendix A.)

As vehicle volume is not the only variable mediating the impacts of development on vehicle-pedestrian injury collisions, a multivariate area-level model might more robustly predict related change in collisions. In this paper, we describe our development of a context-specific regression model for forecasting vehicle-pedestrian injury collisions that includes local traffic volume and environmental and area-level population determinants associated with vehicle-pedestrian injury collisions.

1.2. Area-level predictors of vehicle-pedestrian collisions

Fig. 2 describes the conceptual framework that informed our model development. Specifically, we sought to understand how an area's built environmental context – street and land use characteristics – as well as compositional factors, including resident and employee population size, population characteristics and travel behaviors, predict the area-level distribution of vehicle-pedestrian injury collisions. Vehicle-pedestrian injury collisions are also associated with a number of individual-level factors including age, alcohol consumption, and other driver or pedestrian behaviors (Laflamme and Diderichsen, 2000; Ryb et al., 2007; Wazana et

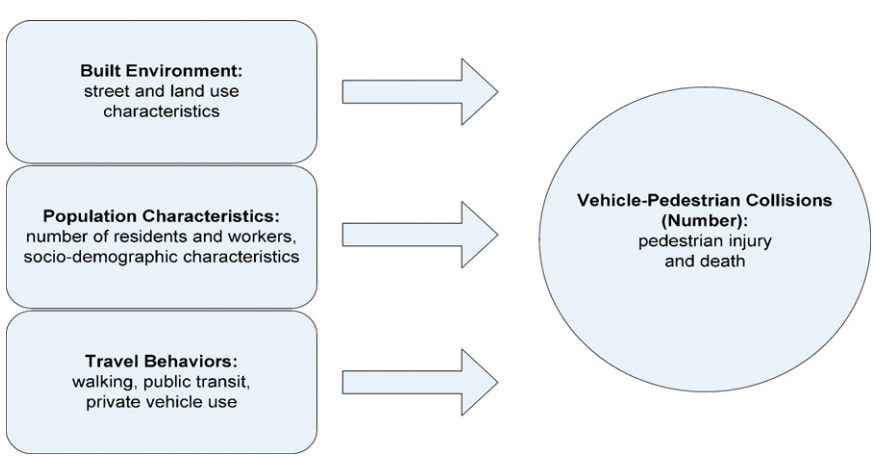

Fig. 2. Conceptual framework: an area-level model of vehicle-pedestrian injury collisions.

al., 1997). In the typical study of individual-level determinants, the environmental context of the injury is viewed as a "given" (Christoffel and Gallagher, 1999); however, individual behaviors occur in and are influenced by the environment, which is the focus of our research.

Previous research on environmental correlates of vehicle-pedestrian collisions shows that traffic volume is a significant predictor (Brugge et al., 2002; LaScala et al., 2000; Lee and Abdel-Aty, 2005; Loukaitou-Sideris et al., 2007; Roberts et al., 1995), while injury severity is largely determined by vehicle speed (Ewing, 2006; NHTSA, 1999). Other roadway characteristics associated with pedestrian injuries include street type (e.g., residential, freeway, arterial) and intersection and street design features (e.g., traffic and pedestrians signals, signage, lighting) (Ewing, 2006; Retting et al., 2003). Similarly, the land use type in an area has been associated with vehicle-pedestrian collisions (overall and fatal)—with increases predicted by increasing proportions of land used for commercial, mixed use, park, retail, or community uses (Geyer et al., 2005; Kim et al., 2006; Loukaitou-Sideris et al., 2007; Wedagama et al., 2006).

Pedestrian volumes, at the intersection-level as well as larger geographic regions, are also associated with increased pedestrian injury risk, though individual risk may be attenuated as pedestrian volumes increase (Geyer et al., 2005; Jacobsen, 2003). Actual pedestrian count data is not routinely collected in the United States; however, U.S. Census data on population or commute travel mode data can serve as a surrogate for pedestrian volume (Jacobsen, 2003).

Aside from pedestrian volumes, specific population characteristics can affect vehicle-pedestrian collision risk. Vehicle-pedestrian collisions are a leading cause of injury and death for youth (Walton-Haynes, 2002). Nationally, youth aged 10–20 have the highest population rates of pedestrian (non-fatal) injury at 35 injuries/100,000, well above the overall population rate of 20/100,000 (NHTSA, 2006b). Seniors aged 65 and over actually have non-fatal injury rates slightly lower than the overall population rate (some have speculated due to less pedestrian activity); however, seniors are more likely to die when hit by a vehicle based on national and local data (NHTSA, 2006b; Sciortino and Chiapello, 2005a). The elderly and children take longer to cross a street, increasing their exposure for injury (Demetriades et al., 2004), and children also have less developed cognitive, perceptual, motor and traffic safety skills (Johnson et al., 2004). Lower income children have a higher rate of pedestrian injury than higher income children, though the mechanisms contributing to this disparity – including the physical and social environment – are not well understood (Laflamme and Diderichsen, 2000; Johnson et al., 2004; LaScala et al., 2004).

Findings from many of the above studies may be specific to local contexts, and the resulting findings and risk estimates therefore may not be generalizable. In addition, some of the above studies did not adjust for confounding by important covariates, while others standardized outcome variables by factors we would like to understand as predictors—such as street length or land area.

1.3. Macro-level collision models

Vehicle-pedestrian collisions tend to be dispersed throughout urban areas, and these dispersion patterns are missed by intersection or other micro-level analyses that focus on "black spots" with pre-existing high crash rates (Campbell et al., 2004; Morency and Cloutier, 2006). For example, from 2001 to 2005, eliminating all vehicle-pedestrian injury collisions at the five San Francisco intersections with 10 or more collisions during that period would leave over 98% of the city's vehicle-pedestrian injury collisions unaddressed (CCSF MTA, 2006). However, based on our data review, almost 10% of San Francisco's vehicle-pedestrian injury collisions were concentrated in two of 176 census tracts. A macro-level approach focused on census tracts could inform area-wide community transportation safety planning, and complement micro-level traffic safety mitigation measures such as intersection signalization (Lovegrove and Sayed, 2006).

Transportation researchers have modeled motor vehicle collisions at an area-level using multivariate regression methods, aggregate variables and linked datasets (Hadayeghi et al., 2003; Ladron de Guevara et al., 2004; Lovegrove and Sayed, 2006). Positive associations between collisions and traffic volume or vehicle miles travelled, population density, road network, and area-level socio-demographic characteristics are consistently significant in these macro-level models, which include pedestrian collisions with all motor vehicle collisions. Given potentially different determinants and risk estimates, separate macro-level vehicle-*pedestrian* collision models are warranted. For example, Loukaitou-Sideris et al. (2007) analyzed the spatial distribution of vehicle-pedestrian collisions in Los Angeles, and found pedestrian exposure, traffic, socioeconomic and land use variables were predictive of census-tract collision density.

To evaluate and model census-level predictors of vehicle-pedestrian injury collisions in San Francisco, we used cross-sectional, aggregated data, to (1) describe the distribution of vehicle-pedestrian injury collisions and select environmental and population characteristics in San Francisco census tracts; and (2) estimate the nature and strength of the independent effect of census-tract traffic volume on census-tract vehicle-pedestrian injury collisions, adjusting for covariates. We then discuss the strengths and limitations of this approach and its potential for practical application to predict change in vehicle-pedestrian injury collisions associated with land use development and transportation planning decisions.

2. Methods

This area-level model is based on cross-sectional data for San Francisco, California County, aggregated at the level of the census tract (outlined in Fig. 3). We selected our analytic variables based on the previous literature and our interest in environmental predictors of vehicle-pedestrian injury collisions as detailed in Fig. 2.

2.1. Outcome variable

We used data on vehicle-pedestrian injury collisions in San Francisco, 2001–2005, from the Statewide Integrated Traffic Records System (SWITRS) which contains data on reported vehicle collisions on public roadways (CHP, 2008). SWITRS vehicle-pedestrian injury collision data were imported into ArcGIS (version 9.2; ESRI Inc., Redlands, CA, USA) and geocoded to the intersection of the reported primary and secondary streets (exact street address is not collected). We used a spatial join to assign vehicle-pedestrian injury collisions to one of the 176 census tracts in San Francisco (Geolytics Inc., 2004). We excluded non-injury collisions which are reported as "Property Damage Only". We included collisions resulting in pedestrian injuries and/or fatalities, hereafter referred to as "vehicle-pedestrian injury collisions."

2.2. Independent variables

We obtained street segment traffic counts and street length and type data from researchers at the San Francisco Department of Public Health and the University of California - Berkeley. This dataset

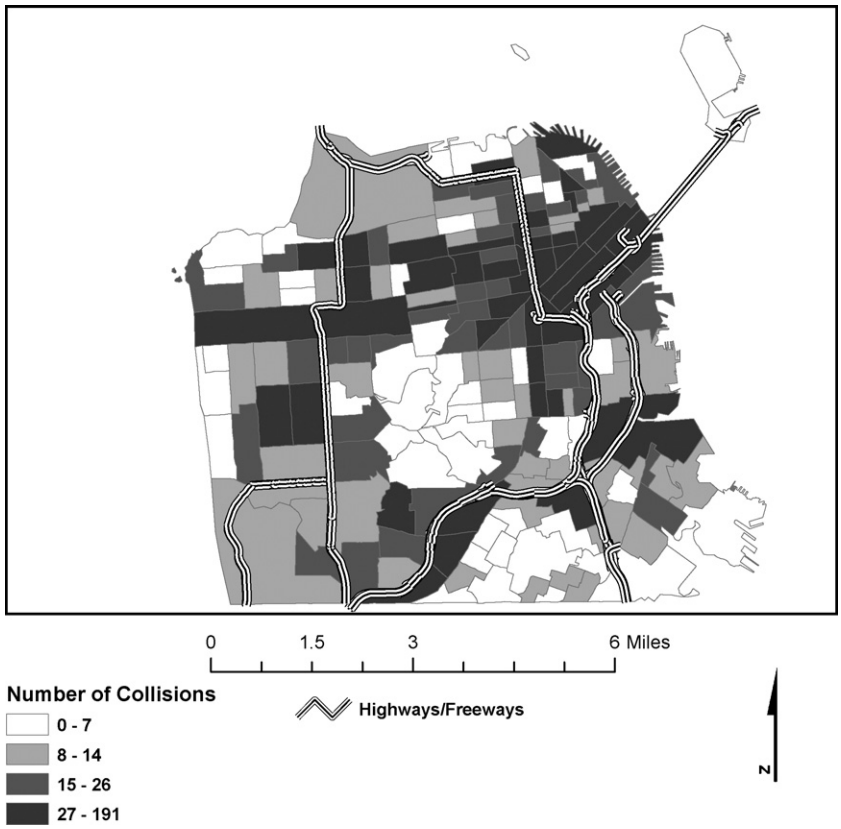

Fig. 3. Vehicle-pedestrian injury collisions: San Francisco, California census tracts (2001–2005). Source: California Highway Patrol, Statewide Integrated Traffic Records System (SWITRS).

Table 1
Descriptive statistics for San Francisco, California census tracts ($n = 176$).

Variable	Mean	Median	Minimum	Maximum	Standard deviation
Dependent variable					
Vehicle-pedestrian injury collisions,[a] 2001–2005 (*n*)	23	14	0	191	28
Street characteristics					
Traffic volume (*n, natural log, aggregated average daily traffic counts*)[b]	925,544	703,145	153,355	4,485,193	686,193
Intersections (*n*)	103	86	21	760	79
Residential streets (%, *street length*)	61.5	64.1	23.0	100.0	14.7
Arterial streets, without public transit (%, *street length*)	17.0	16.8	0.0	48.3	11.6
Arterial streets, with public transit (%, *street length*)	19.4	16.3	0.0	67.2	13.2
Freeways and highways[b] (%, *street length*)	2.1	0.0	0.0	23.3	5.3
Land use characteristics					
Commercial (%, *land area*)	3.4	0.0	0.0	62.0	10.4
Industrial (%, *land area*)	3.6	0.0	0.0	74.9	11.3
Neighborhood commercial (%, *land area*)	5.5	2.9	0.0	32.3	7.0
Residential (%, *land area*)	33.3	38.5	0.0	67.9	22.6
Higher density residential (%, *land area*)	8.9	3.4	0.0	65.0	12.9
Residential-neighborhood commercial (%, *land area*)	2.5	0.0	0.0	56.9	8.3
Land area (*square miles*)	0.27	0.19	0.02	2.40	0.29
Population characteristics					
Employee population (*n*)	3,337	1,063	70	94,770	9,343
Resident population (*n*)	4,413	4,383	137	9,221	1,916
Age 65 and older (%, *resident population*)	13.5	13.1	0.6	40.0	6.9
Age 17 and under (%, *resident population*)	14.2	13.9	1.5	43.9	7.5
Living below the poverty level last year (%, *resident population*)	11.6	9.1	0.0	51.8	7.7
Unemployed[c] (%, *resident population*)	2.7	2.3	0.0	13.3	1.8
Commute behaviors					
Workers[d] commuting to work by walking (%, *resident population*)	7.6	5.6	0.0	41.8	7.7
Workers[d] commuting to work by public transit (%, *resident population*)	16.2	16.1	3.0	34.0	6.1

[a] Includes collisions resulting in pedestrian injuries and/or fatalities.
[b] Excludes grade-separated street segments inaccessible to pedestrians.
[c] $\geq$16 years old, in the civilian labor force, unemployed.
[d] Workers 16 years and older.

was created from existing street segment daily traffic counts collected principally from 1997 to 2002 and maintained by the San Francisco Municipal Transportation Agency and the County Transportation Authority. Researchers consolidated the traffic counts, adjusted them by street direction (one-way, two way, and divided streets), and applied them to their respective street centerline network number for geocoding purposes. Traffic counts were imputed for street segments with unknown counts based on the average traffic count for the street segment type (highway/freeway, arterial with public transit (e.g., streetcars, light rail vehicles, buses, cable cars), arterial without public transit, residential) within each planning neighborhood as detailed in Seto et al. (2007). We excluded grade-separated street segment counts (i.e., streets without pedestrian access) and then aggregated the remaining street segment traffic counts by census tract to obtain the study traffic estimates—hereafter referred to as *traffic volume*. We obtained 2005 zoning district area data from the San Francisco Planning Department, and aggregated zoning use districts into census-tract level land use characteristic categories (Table 1).

We obtained the following census-tract level aggregate variables from the U.S. Census Bureau (2000), Summary Files 1 and 3: land area (square miles); population age 65 and older and under age 18; unemployed population; workers traveling to work by walking or by public transit; population living below the poverty level last year. We used the census-tract level variables as numerators and the total population from the corresponding Summary File as the denominator to create census-tract level proportions (Table 1). The number of workers-at-work in the census tract was obtained from the Census Transportation Planning Package (2000). We determined the number of intersections in each census tract using a spatial join with intersection, node, and street CNN data provided by the City and County of San Francisco (SFDTIS, 2006).

2.3. Data analysis

We first assessed the distribution of vehicle-pedestrian injury collisions, land use, street characteristics, pedestrian exposure proxies, and demographic characteristics in San Francisco census tracts. We then used ordinary least squares regression (OLS) to model the natural log of the number of vehicle-pedestrian injury collisions over a 5-year period. We added one collision to the three census tracts with zero collisions reported so they would not be dropped from the analysis. The model form used for our analyses is

$$\ln(\mathrm{PIC}) = \beta_0 + \sum \beta_i X_i \tag{1.2}$$

where ln(PIC) is the predicted natural log of vehicle-pedestrian injury collisions per census tract; β_0, the intercept; β_i, the model coefficient for 1-unit change in predictor variable i; and, X_i, the census-tract level data for predictor variable i. All variables are continuous and at the census-tract level. To better approximate the normality assumptions of the linear model, we applied a natural log transformation to both the traffic volume and employee variables, as in previous research (Hadayeghi et al., 2003; Jacobsen, 2003; Lovegrove and Sayed, 2006).

We used the conceptual framework for our model building approach (Fig. 2). We started with a base model including the street and land use characteristics in Table 1, then added population characteristics followed by commute behavior variables. In each step, variables were dropped from the model based on coefficient p-value. We assessed model fit based on the values, distribution, and tests of spatial autocorrelation (Moran's I) of the residuals. One census tract was an evident outlier based on our assessment of model fit based on residual plots. This census tract was one of three census tracts to which we had added one collision because it had zero collisions reported. We reviewed the census tract's predictor variable values and found no extreme or erroneous values. We then visually assessed the tract's geographic characteristics using ArcGIS and Google™ maps, which provided evidence that it is likely a true outlier. This tract's street network has numerous dead ends, lacks connectivity, and has large portions of area densely forested and without streets, in contrast with the grid street network and sparser street trees in most of the city. Additionally, the large medical center that employs most of the tract's >5000 employees is on the tract border, its campus split by the boundary and the area in the census-tract largely surrounded by forested land. Based on these anomalous environmental conditions, we dropped the tract from our analysis, which improved model fit. Our final model is therefore based on 175 census tracts. All analyses were conducted using STATA software (version 9; StataCorp, College Station, TX, USA).

3. Results

There were 4039 recorded vehicle-pedestrian injury collisions in San Francisco's 176 census tracts from 2001 to 2005, with a median 14 and mean 23, ranging from 0 to 191 vehicle-pedestrian injury collisions in a tract (Table 1). As illustrated in Fig. 3, vehicle-pedestrian injury collisions were dispersed throughout the city, with evident concentrations in areas near freeways and highways that carry high traffic volumes from bridges and highways, as noted in previous literature (UCSF SFDPH, 2004).

San Francisco census tracts exhibit a wide range in aggregate traffic volume estimates, with a median of 703,145 and a mean of 925,544 aggregated vehicles, largely influenced by the presence of arterial streets and freeway ramps (data not shown). A scatter plot of traffic volume by vehicle-pedestrian injury collisions shows a positive linear association (unadjusted Pearson R^2 = .359, natural logs, data not shown).

Table 1 shows the mean, median, standard deviation, and range of street and land use characteristics, population characteristics, and commuting behaviors in San Francisco, revealing the diversity in compositional and contextual characteristics of the city's census tracts. A median of 64% of census-tract street length was residential (range, 23–100%), while the median percentages of census-tract streets that were arterial with and without public transit were similar (16% and 17%, respectively), the range in values across census tracts was large (0–67% and 0–48%, respectively). The census-tract median population was close to 4000—consistent with the average tract size as defined by the U.S. Census Bureau (2001). The median number of workers in a census tract was 1063, with a higher mean of 3337 reflecting the skewed range of less than 100 to almost 95,000 workers. Median proportions of youth and seniors were similar—approximately 13–14%, though both subgroups had wide ranges across census tracts of approximately 1 to >40%. The median proportion of residents living in poverty was 9%, and ranged from 0 to >50% across the city. A median of 6% of residents walk to work (range, 0–42%) while an average of 16% take public transit (range, 5–49%).

With the exception of land area and proportion of residents who are seniors, all final model variables had a positive association with vehicle-pedestrian injury collisions (Table 2). Increases in traffic volume, proportion of arterial streets without transit, proportion of land area zoned for neighborhood commercial and mixed residential/neighborhood commercial use, employee and resident populations, and proportion of people living in poverty predicted increased vehicle-pedestrian injury collisions.

The final model explains approximately 72% of the systematic variation in census-tract vehicle-pedestrian injury collisions.

Table 2
Final ordinary least squares regression model of census-tract level vehicle-pedestrian injury collisions: San Francisco, California, 2001–2005 (n = 175).

Census-tract level variable	Coefficient	S.E.	p-Value	95% CI, lower limit	95% CI, upper limit	Partial correlation coefficient (r)
Traffic volume (*n, natural log, aggregated average daily traffic counts*)[a]	0.753	0.115	0.000	0.526	0.981	0.454
Arterial streets, without public transit (%, *street length*)	0.017	0.004	0.000	0.009	0.025	0.314
Neighborhood commercial (%, *land area*)	0.029	0.007	0.000	0.016	0.042	0.323
Residential-neighborhood commercial (%, *land area*)	0.021	0.006	0.000	0.009	0.032	0.267
Land area (*square miles*)	−0.704	0.195	0.000	−1.089	−0.319	−0.271
Employee population (*n, natural log*)	0.228	0.046	0.000	0.136	0.319	0.358
Resident population (*n*)	0.00010	0.00003	0.000	0.00005	0.00015	0.303
Living below the poverty level last year (%, *resident population*)	0.019	0.006	0.003	0.006	0.031	0.228
Age 65 and older (%, *resident population*)	−0.016	0.007	0.013	−0.029	−0.003	−0.192
Constant	−9.954	1.283	0.000	−12.488	−7.420	
Adjusted Pearson R^2	0.7154					

[a] Excludes grade-separated street segments inaccessible to pedestrians.

Traffic volume had the highest adjusted partial correlation with vehicle-pedestrian injury collisions (r = .454), followed by the number of employees (r = .358), proportion of land zoned neighborhood commercial (r = .323), proportion of arterial streets without transit (r = .314), and resident population (r = .303).

Since we used a natural log transformation for both the traffic volume and employee population variables, the interpretation of their coefficients is equivalent to the power function described in Formula (1.1) (assuming all other final model covariates are held constant). Fig. 1 illustrates the power function's (PF) predictions of percent change in vehicle-pedestrian injury collisions based on percent change in traffic volume at varying β. Adjusting for the other covariates, our final model (Fig. 1, FM) is equivalent to a power function with $\beta = 0.753$ (Table 2, coefficient on log traffic volume). Therefore, a 15% increase in census-tract traffic volume is associated with an approximate 11% increase in vehicle-pedestrian injury collisions ($(1.15)^{0.753} - 1 = 11.1\%$). Similarly, a 15% increase in area employees (e.g., from 10% to 11.5%) predicts an approximately 3% increase in vehicle-pedestrian injury collisions ($(1.15)^{0.228} - 1 = 3.2\%$).

Model coefficients for independent variables that were not log transformed estimate the change in the log count of vehicle-pedestrian injury collisions per unit increase in the predictor. For example, a 5-unit increase in the proportion of census-tract street length that is arterial (without transit) is associated with an approximately 8% change in vehicle-pedestrian injury collisions ($\exp(5*0.017) = 1.08$). Similarly, an increase in resident population of 500 people would predict an approximately 5% ($\exp(500*0.0001) = 1.05$) increase in vehicle-pedestrian injury collisions.

4. Discussion

In San Francisco, California, in a multivariate regression model at the census-tract level, statistically significant predictors of vehicle-pedestrian injury collisions include traffic volume, arterial streets without public transit, proportions of land area zoned for neighborhood commercial use and residential-neighborhood commercial use, land area, employee population, resident population, proportion of people living in poverty, and proportion of people aged 65 and over. All model variables had a positive association with vehicle-pedestrian injury collisions, with the exception of land area (its increase potentially capturing decreasing population density) and proportion of the population that are seniors.

Comparing predicted percent change in vehicle-pedestrian injury collisions based on our final model with those based on the simpler power function illustrates that variables in addition to traffic volume – including built environment characteristics that are potential pedestrian attractors (neighborhood commercial districts) and area-level population characteristics that are potential proxies for pedestrian activity (resident and employee populations) – contribute significant explanatory power to the model. While our results are specific to San Francisco, California, our conceptual model (Fig. 2) and the findings of this novel approach to estimating the impact of area-level changes on vehicle-pedestrians collisions may inform models in other urban areas. We next discuss potential strengths and limitations of this approach.

We used census tracts as our unit of analysis, ideal for small area-level analysis as they are created to be relatively homogeneous with respect to demographic characteristics (U.S. Census Bureau, 2001) and census data is publicly available. Additionally, U.S. Census data for number of employees, resident socioeconomic data, and commute behaviors is available at the census-tract level, but not at a smaller area level. Other potential data sources include the American Community Survey. Area-specific data on number of residents, employees, traffic, streets, land use and other environmental factors are routinely collected, analyzed and reported in local planning processes—which would enable the model to be applied to predict the impacts of large development projects on vehicle-pedestrian injury collisions.

Our final model of vehicle-pedestrian injury collisions is an ecological analysis (i.e., all units of analysis are at the census-tract level) using both aggregate (summaries of observations derived from individuals) and environmental (physical characteristics) variables. An *ecological fallacy* occurs when one makes (incorrect) causal inferences about associations between individual-level variables based on observed associations in ecological analyses. In applying and interpreting our area-level pedestrian injury collision model, we intend to make inferences to areas; no causal inferences are made at the level of the individual.

Underreporting of collisions could affect model results. Based on a comparison of SWITRS and hospital records in 2000–2001, Sciortino et al. (2005b) found that SWITRS under-reported San Francisco pedestrian injuries by 21% (using San Francisco General Hospital medical records as a gold standard), with African Americans and males less likely to have a SWITRS-reported injury. This ascertainment bias could have caused our model to underestimate area-level pedestrian injuries, particularly in predominantly African American neighborhoods. Because area-level racial/ethnic composition is highly correlated with poverty, this bias may have resulted in an underestimate of the effect of poverty, which may partially capture disparities in built environmental conditions or increased pedestrian activity among less auto-dependent populations.

We aggregated vehicle-pedestrian injury collision data by census tract, after geocoding collisions to the nearest intersection. This

could result in erroneous census-tract assignment for some collisions that fall on census-tract boundaries. However, we do not have reason to believe that there would be systematic bias in this error.

Actual pedestrian volume data was not available. Significant predictors in our final model were number of residents, employees, and proportion of land zoned neighborhood commercial/residential-neighborhood commercial—potential partial proxies for pedestrian activity and pedestrian attractors. As previously mentioned, researchers have found that pedestrian volumes or proxy variables are associated with increased pedestrian injury risk that is attenuated as pedestrian volumes increase (Geyer et al., 2005; Jacobsen, 2003). While the commuting via walking variable was not a significant predictor in our final model, the log-transformed employee population variable was a significant strong predictor. An attenuated relationship was not found for resident population, potentially because census-tract boundaries are informed by resident population size and therefore have less variation across the city. A spatial analysis of pedestrian collisions in Hawaii also found both resident population and commercial areas were positively associated with pedestrian collisions; however, total jobs was not a statistically significant predictor for this analysis which focused on land use, population, employment and economic variables—potentially due to regional differences (Kim et al., 2006).

We were not able to include a reliable vehicle speed assessment variable. Vehicle speed strongly predicts injury severity—the chance of a fatal vehicle-pedestrian collision increasing from 5% at 20 mph to 85% at 40 mph (UK Department of Transportation, 1987). Our model did not distinguish collisions by severity, a question for which vehicle speed data would be more salient. The street type variables we did include were associated with both vehicle-pedestrian injury collisions and traffic volume, and were potentially proxies for vehicle speeds or other street characteristics for which we did not have citywide data (e.g., number of lanes, street width).

We repeated these analyses using a negative binomial regression model and obtained very similar coefficients and standard errors. We used the OLS model for our final analysis based on our stated interest in developing a model for practical application that can be readily applied and interpreted, its transparency preferable for establishing and understanding the causal relationship between traffic volume and vehicle-pedestrian injury collisions. An assumption when using a simple OLS approach is that the dependent variable values are linearly distributed, with a 1-unit change in an independent variable x predicting the same corresponding change in the dependent variable across all values of x. We adjusted for the non-linear relationship between collisions and the independent variables traffic volume and employee population using a natural log transformation of those variables. Once a causal relationship between traffic volume and collisions is established, it is likely that advanced statistical techniques incorporating both linear and non-linear approaches, such as neural networks, may improve model prediction (Tu, 1996).

Our results are partly consistent with those reported in a previous study of 1990 vehicle-pedestrian injury collisions in San Francisco census tracts. LaScala et al. (2000) reported a significant, positive association with traffic flow, resident population, and proportion unemployed, and a significant, negative association with proportion with a high school diploma or higher—similar to our findings regarding increased risk with a higher proportion of poverty, higher traffic volumes and more residents. Proportion of the resident population that was male also had a significant positive association in their model and proportion aged 0–15 was inversely associated with vehicle-pedestrian injury collisions; we did not include proportion male population as a potential predictor, and proportion of the population aged 0–15 was not a significant predictor in our final model. This difference could be explained by the correlation of land use and street characteristics (only included in our model) with population characteristics (such as age distribution) in San Francisco census tracts. Similar to our results, proportion of seniors age 55 and older was inversely associated with pedestrian injury collisions. This 1990 study did not explore employee population, street type or land use variables (other than bars, restaurants, alcohol outlets per kilometer roadway, which were not significantly associated with overall vehicle-pedestrian injury collisions). La Scala et al. standardized their log-transformed pedestrian injury outcome by roadway length, which limits comparisons.

Similar to our findings, a recent Los Angeles study found population and employment density, traffic density, and land use variables – as well as proportion of population that was Hispanic (described as a socioeconomic variable) – predicted pedestrian collision density (Loukaitou-Sideris et al., 2007). However, the researchers did not explore street type variables—and proportion of population over age 65 was not significant in their final model. Their findings also differed from ours in that – based on ranking of independent variable beta weights – population density was the most predictive variable, followed by traffic density and employee density—whereas traffic volume was the most predictive variable in our model, followed by employee population and neighborhood commercial land use proportion (data not shown). Notably, traffic volume and employee populations were strong predictors in both models.

The coefficient for (log)traffic volume in our model, 0.753, was notably higher than the 0.5 reported for the simpler road safety function (Lee and Abdel-Aty, 2005) as well as the 0.221 from the Los Angeles study (Loukaitou-Sideris et al., 2007). A primary reason for these differing estimates may be regional and/or geographic differences in land use, transportation, population or other characteristics (e.g., weather) that result in differences in the predictive value of traffic volume. Understanding these differences is another research question, requiring multi-level models and regional data.

5. Conclusion

Consistent with previous national and international findings (Roberts et al., 1995; Lee and Abdel-Aty, 2005; Brugge et al., 2002; LaScala et al., 2000), our study provides additional evidence that traffic volume is a primary environmental cause of vehicle-pedestrian injury collisions at the area level. In addition to traffic volume, employee and resident populations, arterial streets without public transit, proportions of land area zoned for neighborhood commercial use and residential-neighborhood commercial use, land area, proportion of people living in poverty, and proportion of people aged 65 and over are statistically significant predictors of vehicle-pedestrian injury collisions in a multivariate model at the census-tract level in San Francisco, California.

We developed this model to predict vehicle-pedestrian injury collisions resulting from land use and transportation planning decisions—specifically, in the context of environmental impact assessment and as required by the National Environmental Policy Act and related state laws (Bhatia and Wernham, 2008). A bivariate power function may be used as a simple predictive tool to forecast the impact of increased traffic on vehicle-pedestrian injury collisions; however, a multivariate approach may provide more defensible estimates in planning or development scenarios which have broad impacts on an area's land use, transportation and population characteristics. We have used this multivariate model to analyze the impacts of San Francisco neighborhood rezoning plans on vehicle-pedestrian injury collisions, and our findings

were incorporated in the plans' environmental impact assessment (SFPD, 2007). San Francisco also intends to use this model to predict collision impacts associated with area-level congestion pricing proposals. Subsequent reports and publications will describe these practical applications.

Micro-level (e.g., intersection) approaches that identify specific locations with existing high numbers of vehicle-pedestrian injury collisions support targeted pedestrian safety countermeasures. This area-level model can similarly support pedestrian injury prevention by justifying area-level interventions in development and planning processes. Examples of these interventions include: transit-oriented development that coordinates high-density land use with public transit locations and includes street amenities and design features that slow traffic and support safe walking; employer-based transportation demand management programs to incentivize commuting to work via walking, biking and public transit and decrease driving; and street design that slows traffic and improves the quality and safety of the pedestrian environment near land uses including residences, schools, or senior centers (VTPI, 2008).

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Appendix A. Application of the bivariate power function to a local development project

The following application was conducted by one of the authors (R. Bhatia) in the context of a health impact assessment of the Oak to Ninth Development Project proposed in Oakland, California (UCBHIG, 2006).

Traffic analysis in the proposed project's environmental impact report provided data on changes in traffic volume on area roadways. Estimates projected that the development, which includes 3100 residential units and 3500 parking spaces, would result in an additional 27,110 daily vehicle trips external to the project. An intersection-level traffic analysis for 51 intersections demonstrated that those trips would increase traffic volume on surrounding local streets, with 5% or greater cumulative increases at several intersections. Overall, the increase in intersection vehicle volumes varied considerably, ranging from 2% to 127%. The average weighted project-related increase in vehicle volume at studied intersections was approximately 11% after project completion; the average cumulative increase in vehicle volume by 2025 was 45%, including other proposed area development projects at these intersections.

The Statewide Integrated Traffic Records System (SWITRS) provided data on reported pedestrian injuries occurring in Oakland from 2000 to 2005. Pedestrian injuries were mapped to intersections using ArcGIS (>90% successfully geocoded). 545 pedestrian-vehicle collisions occurred at the 51 study intersections during 2000–2005. Since approximately 10% of collisions could not be geocoded, the current annual average number of pedestrian injuries in areas affected by project-traffic was assumed, approximately 100 per year. Because some pedestrian injuries may not be reported, this may underestimate the actual number of pedestrian injuries.

Based on a power function of vehicle volume described in Formula (1.1), an 11% increase in vehicle volume on all roadways in an area with a baseline of 100 pedestrian injuries per year predicts an increase in 5.4 injuries per year, or 268 injuries between 2025 and 2075. Based on a cumulative increase in average daily trips of 45% in 2025, the impact is 20 injuries per year or 1000 injuries between 2025 and 2075.

References

Bhatia, R., Wernham, A., 2008. Integrating human health into environmental impact assessment: an unrealized opportunity for environmental health and justice. Environmental Health Perspectives 116, 991–1000.

Brugge, D., Lai, Z., Hill, C., Rand, W., 2002. Traffic injury data, policy, and public health: lessons from Boston Chinatown. Journal of Urban Health 79 (1), 87–103.

Campbell, B.J., Zegeer, C.V., Huang, H.F., Cynecki, M.J., McLean, V.A., 2004. A Review of Pedestrian Safety Research in the United States and Abroad. Federal Highway Administration, Publication No. FHWA RD-03-042. http://www.walkinginfo.org/pdf/PedSynth/Ped_Synthesis_Report.pdf, accessed on 15 February 2007.

Cavill, N., 2001. Walking and health: making the links. World Transport Policy and Practice 7 (4), 33–38.

CCSF MTA (City and County of San Francisco Municipal Transportation Agency Traffic Engineering Division), 2007. San Francisco 2006 Collision Report. San Francisco, CA. http://www.sfmta.com/cms/rtraffic/documents/Collision_report_2006.pdf, accessed on 8 April 2008.

CCSF MTA (City and County of San Francisco Municipal Transportation Agency Traffic Engineering Division), 2006. San Francisco 2005 Collision Report. San Francisco, CA.

Census Transportation Planning Package, 2000. http://www.mtc.ca.gov/maps_and_data/datamart/census/ctpp2000, accessed on 13 November 2006.

CHP (California Highway Patrol), 2008. Accident Investigation Unit. Statewide Integrated Traffic Records System. http://www.chp.ca.gov/switrs/index.html, accessed on 7 April 2008.

Christoffel, T., Gallagher, S.S., 1999. Injury Prevention and Public Health: Practical Knowledge, Skills, and Strategies. Aspen Publishers Inc., Gaithersburg, MD.

Crossroads Software Inc., 2007. http://www.crossroadssoftware.com/. Accessed on 1 March 2007.

Demetriades, D., Murray, J., Martin, M., Velmahos, G., Salim, A., Alo, K., Rhee, P., 2004. Pedestrians injured by automobiles: relationship of age to injury type and severity. Journal of the American College of Surgeons 199 (3), 382–387.

Ewing, R., 2006. Fatal and Non-fatal Injuries. Understanding the Relationship Between Public Health and the Built Environment: A Report Prepared for the LEED-ND Core Committee. http://www.activeliving.org/files/LEED_ND_report.pdf, accessed on 7 April 2008.

Frumkin, H., Frank, L., Jackson, R., 2004. Urban Sprawl and Public Health: Designing, Planning, and Building for Healthy Communities. Island Press, Washington, DC.

Geolytics Inc., 2004. Neighborhood Change Database (NCDB) 1970–2000.

Geyer, J., Raford, N., Ragland, D., Pham, T., 2005. The Continuing Debate about Safety in Numbers—Data from Oakland, CA. TRB Annual Meeting CD-ROM, TRB Paper #06-2616. http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1029&context=its/tsc.

Hadayeghi, A., Shalaby, A.S., Persaud, B.N., 2003. Macrolevel accident prediction models for evaluating safety of urban transportation systems. Transportation Research Record 1840, 87–95.

Jacobsen, P.L., 2003. Safety in numbers: more walkers and bicyclists, safer walking and bicycling. Injury Prevention 9 (3), 205–209.

Johnson, E., Geyer, J., Rai, N., Ragland, D.R., 2004. Low Income Childhood Pedestrian Injury: Understanding the Disparate Risk. U.C. Berkeley Traffic Safety Center, Paper UCB-TSC-RR-2004-20. http://repositories.cdlib.org/its/tsc/UCB-TSC-RR-2004-20.

Kim, K., Brunner, I.M., Yamashita, E.Y., 2006. Influence of land use, population, employment, and economic activity on accidents. Transportation Research Record 1953, 56–64.

Ladron de Guevara, F., Washington, S.P., Oh, J., 2004. Forecasting crashes at the planning level: simultaneous negative binomial crash model applied in Tucson, Arizona. Transportation Research Record 1897, 191–199.

Laflamme, L., Diderichsen, F., 2000. Social differences in traffic injury risks in childhood and youth—a literature review and a research agenda. Injury Prevention 6 (4), 293–298.

LaScala, E.A., Gruenewald, P.J., Johnson, F.W., 2004. An ecological study of the locations of schools and child pedestrian injury collisions. Accident Analysis and Prevention 36 (4), 569–576.

LaScala, E., Gerber, D., Gruenwald, P.J., 2000. Demographic and environmental correlates of pedestrian injury collisions: a spatial analysis. Accident Analysis and Prevention 32 (5), 651–658.

Lavizzo-Mourney, R., McGinnis, J.M., 2003. Making the case for active living communities. American Journal of Public Health 93 (9), 1386–1388.

Lee, C., Abdel-Aty, M., 2005. Comprehensive analysis of vehicle-pedestrian crashes at intersections in Florida. Accident Analysis and Prevention 37, 775–786.

Leyden, K.M., 2003. Social capital and the built environment: the importance of walkable neighborhoods. American Journal of Public Health 93 (9), 1546–1551.

Loukaitou-Sideris, A., Ligget, R., Sung, H.G., 2007. Death on the crosswalk: a study of pedestrian-automobile collisions in Los Angeles. Journal of Planning Education and Research 26, 338–351.

Lovegrove, G.R., Sayed, T., 2006. Macrolevel collision prediction models for evaluating neighborhood traffic safety. Canadian Journal of Civil Engineering 33 (5), 609–621.
Mokdad, A.H., Marks, J.S., Stroup, D.F., Gerberding, J.L., 2004. Actual causes of death in the United States, 2000. Journal of the American Medical Association 291 (10), 1238–1245.
Morency, P., Cloutier, M.S., 2006. From targeted "black spots" to area-wide pedestrian safety. Injury Prevention 12, 360–364.
NHTSA (National Highway Traffic Safety Administration), 1999. Literature Review on Vehicle Travel Speeds and Pedestrian Injuries. USDOT, Washington, DC.
NHTSA (National Highway Traffic Safety Administration), 2006a. Fatality Analysis Reporting System, National Statistics. http://www-fars.nhtsa.dot.gov/, accessed on 12 February 2008.
NHTSA (National Highway Traffic Safety Administration), 2006b. Traffic Safety Facts. http://www.nhtsa.dot.gov/portal/site/nhtsa/menuitem.dfedd570f698cabbbf-30811060008a0c/, accessed on 12 February 2008.
PBCAT (Pedestrian and Bicycle Crash Analysis Tool), 2007. Pedestrian and Bicycle Information Center. http://www.walkinginfo.org/pc/pbcat.cfm, accessed on 14 March 2007.
Retting, R.A., Ferguson, S.A., McCartt, A.T., 2003. A review of evidence-based traffic engineering measures designed to reduce pedestrian-motor vehicle crashes. American Journal of Public Health 93 (9), 1456–1463.
Roberts, I., Norton, R., Jackson, R., Dunn, R., Hassall, I., 1995. Effect of environmental factors on risk of injury of child pedestrians by motor vehicles: a case-control study. British Medical Journal 310 (6972), 91–94.
Ryb, G.E., Dischinger, P.C., Kufera, J.A., Soderstrom, C.A., 2007. Social, behavioral and driving characteristics of injured pedestrians: a comparison with other unintentional trauma patients. Accident Analysis and Prevention 39 (2), 313–318.
Sciortino, S., Chiapello, E., 2005a. Environmental, Behavioral, and Demographic Factors that Affect the Severity of Pedestrian Injuries. http://www.sfdph.org/dph/files/trafficsafety/EnviroFactorsSeverity4.pdf, accessed on 19 September 2006.
Sciortino, S., Vassar, M., Radetsky, M., Knudson, M.M., 2005b. San Francisco pedestrian injury surveillance: mapping, under-reporting, and injury severity in police and hospital records. Accident Analysis and Prevention 37, 1102–1113.
Seto, E.Y., Holt, A., Rivard, T., Bhatia, R., 2007. Spatial distribution of traffic induced noise exposures in a US city: an analytic tool for assessing the health impacts of urban planning decisions. International Journal of Health Geography 6, 24.
SFCTA (San Francisco County Transportation Authority), 2004. Countywide Transportation Plan. San Francisco, CA. http://www.sfcta.org/content/view/13/30/, accessed on 18 January 2008.
SFDTIS (San Francisco Department of Telecommunications Information Services GIS Server), 2006. San Francisco Department of Parking and Traffic, San Francisco Street Basemap San Francisco, CA. SFDTIS.
SFPD (San Francisco Planning Department), 2007. Eastern Neighborhoods Rezoning and Area Plans, Draft Environmental Impact Report: Transportation, Circulation, and Parking. http://www.sfgov.org/site/uploadedfiles/planning/EN_DEIR_Part-7_Trans-Noise-AQ.pdf, accessed on 5 September 2008.
STPP (Surface Transportation Policy Project) and California Walks, 2002. Pedestrian Safety in California: Five Years of Progress & Pitfalls. STPP, California. http://www.transact.org/Ca/ped_safety_2002_finalreport.htm, accessed on 18 April 2008.
Subramanian, R., 2006. Motor Vehicle Traffic Crashes as a Leading Cause of Death in the United States, 2003. NHTSA Traffic Safety Facts Research Note. http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/RNotes/2006/810568.pdf, accessed on 9 March 2007.
Tu, J., 1996. Advantages and disadvantages of using artificial neural networks versus logistic regression for predicting medical outcomes. Journal of Clinical Epidemiology 49, 1225–1231.
UCBHIG (University of California-Berkeley Health Impact Group), 2006. Oak to Ninth Avenue Health Impact Assessment. http://ehs.sph.berkeley.edu/hia/projects/projects.htm, accessed on 18 January 2008.
UCSF SFDPH (University of California-Injury Center and the San Francisco Department of Public Health), 2004. Profile of Injury in San Francisco. http://www.surgery.ucsf.edu/sfic/profile05.pdf, accessed on 16 January 2007.
UK Department of Transportation, 1987. Killing Speeds and Saving Lives. UK Dept of Transportation, London, England.
U.S. Census Bureau, 2001. Introduction to Census 2000 Data Products. U.S. Department of Commerce. http://www.census.gov/prod/2001pubs/mso-01icdp.pdf, accessed on 15 September 2006.
U.S. Census Bureau, 2000. American Factfinder, Census 2000. http://factfinder.census.gov/, accessed on 22 September 2006.
USDHHS (U.S. Department of Health Human Services), 2000. Healthy People 2010: Understanding and Improving Health, 2nd ed. U.S. Government Printing Office, Washington, DC.
USDOT (U.S. Department of Transportation), 1998. Zone Guide for Pedestrian Safety. DOT HS 808 742.
VTPI (Victoria Transport Policy Institute), 2008. Transportation Demand Management Encyclopedia. Victoria Transport Institute, Victoria, BC. http://www.vtpi.org/nmtguide.doc, accessed on 29 August 2008.
Walton-Haynes, L., 2002. Pedestrian injuries to young children. EPICGram, No. 5. California Department of Health Services, Epidemiology and Prevention for Injury Control (EPIC) Branch. http://www.dhs.ca.gov/epic/publications/EPICgrams/EPICgram5_Pedestrian.pdf, accessed on 12 Feb 2008.
Wazana, A., Krueger, P., Raina, P., Chambers, L., 1997. A review of risk factors for child pedestrian injuries: are they modifiable? Injury Prevention 3 (4), 295–304.
Wedagama, D.M.P., Bird, R., Metcalfe, A.V., 2006. The influence of urban land-use on non-motorised transport casualties. Accident Analysis and Prevention 38, 1049–1057.

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Spatial distribution of traffic induced noise exposures in a US city: an analytic tool for assessing the health impacts of urban planning decisions

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Abstract

Background: Vehicle traffic is the major source of noise in urban environments, which in turn has multiple impacts on health. In this paper we investigate the spatial distribution of community noise exposures and annoyance. Traffic data from the City of San Francisco were used to model noise exposure by neighborhood and road type. Remote sensing data were used in the model to estimate neighborhood-specific percentages of cars, trucks, and buses on arterial versus non-arterial streets. The model was validated on 235 streets. Finally, an exposure-response relationship was used to predict the prevalence of high annoyance for different neighborhoods.

Results: Urban noise was found to increase 6.7 dB ($p < 0.001$) with 10-fold increased street traffic, with important contributors to noise being bus and heavy truck traffic. Living along arterial streets also increased risk of annoyance by 40%. The relative risk of annoyance in one of the City's fastest growing neighborhoods, the South of Market Area, was found to be 2.1 times that of lowest noise neighborhood. However, higher densities of exposed individuals were found in Chinatown and Downtown/Civic Center. Overall, we estimated that 17% of the city's population was at risk of high annoyance from traffic noise.

Conclusion: The risk of annoyance from urban noise is large, and varies considerably between neighborhoods. Such risk should be considered in urban areas undergoing rapid growth. We present a relatively simple GIS-based noise model that may be used for routinely evaluating the health impacts of environmental noise.

Background

Landuse and transportation development policies have significant effects on health and the environment [1]. While development is often associated with increased use of automobiles, which can adversely affect physical activity [2], injuries [3,4], and air pollution-related health [5-9], good landuse and transportation policies can potentially reduce these adverse effects, and promote wellness through increased access, mobility, and walking.

Automobile traffic is one of the primary sources of community noise. Recent reviews by Stansfeld and Matheson

[10], Shield and Dockrell [11], and Passchier-Vermeer [12] document the relationships between noise exposure and annoyance [13-19], sleep disturbance [20-23], hypertension and cardiovascular disease [24-28], mental disorder [29-31], and children's cognition, including speech intelligibility, reading comprehension, memory, motivation, attention, problem-solving, and performance on standardized tests [15]. These effects may relate not only to the intensity of noise, but also its temporal variation, frequency range, perceived threat or lack of control associated with the noise, whether or not adaptation to the noise occurs, and the degree of interaction with other stressors [10,16,32,33]. Moreover, studies suggest that noise is just one of many physical and psychosocial stressors that work together to affect the socioemotional development of children living in poverty [34], as well as the functional health and well-being of older adults [35]. Of all health effects associated with noise, the dose-response relationship between community noise and annoyance is the most developed. High annoyance to noise is typically determined via questionnaires. Despite it being a relatively subjective measure, its association with community noise has been found to be fairly consistent across multinational studies [12].

Generally it has been recognized that environmental hazards in urban areas disproportionately affect low-income people [36]. However, few studies have documented the inequalities in noise exposures that exist as a result of land use and transportation development policies. European studies have found that higher noise exposures are associated with low income [37], and that traffic noise adversely impacts rates of physical activity [38]. Yet those that are more affluent may be more likely to complain about environmental noise [39]. While the aforementioned studies provide some evidence for the inequities in noise exposures in Europe, we are aware of no assessments of urban noise done in recent years for any US city. This is partly due to different attitudes towards environmental noise and the lack of federal-funded noise research and regulation [40]. Hence, exposures to environmental noise are poorly understood in the US. As a first step to understanding noise inequities it is necessary to understand the spatial variation in noise exposures that exist in US urban areas.

In recent years, the City of San Francisco has received increasing numbers of noise complaints due to the juxtaposition of new residential development with existing commercial and industrial land use. This has motivated the need for noise and annoyance maps to better inform future redevelopment. Such a map would also inform potential inequalities in noise exposures that may occur between the city's diverse communities that include high-rise financial districts, multi-million dollar residential, multiple ethnic, public housing areas, and redeveloping industrial neighborhoods. Due to the demand for further housing, city planners may use such maps to better balance pressure to build more high-density housing, while at the same time trying to consider issues of community preservation and the larger socio-environmental implications of their decisions.

This paper describes a quantitative assessment of the spatial distribution of transportation-related noise exposures, and their impact on population annoyance for neighborhoods in San Francisco. We present a geographic information system (GIS) -based noise and annoyance model that relies on the city's extensive traffic count database, as well as an analysis of aerial photography to determine the proportion of different types of vehicles in different neighborhoods. We explore and discuss the implications of spatial variation in neighborhoods at risk for environmental noise exposure.

Results

A diagram of the steps in the GIS model from traffic data to noise to estimates of high annoyance is presented in figure 1. Along the pathway, maps were created to better understand the role that environmental conditions play in community health for each neighborhood.

Characteristics of the measured traffic

The first step in the model consisted of an assessment of community traffic. Most neighborhoods followed a consistent daily temporal pattern with rush hour peaks between 06:00 – 10:00 and 15:00 – 19:00 hr (figure 2). On average, the rush hour periods accounted for 50% of the daily traffic volume. Based on the city-wide average

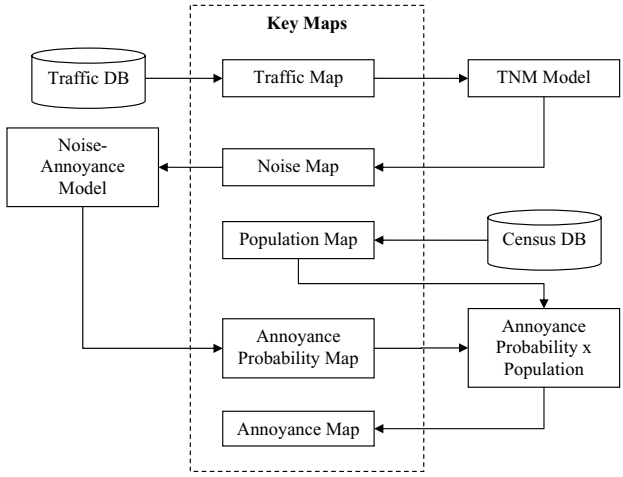

Figure 1
Flow diagram of GIS Traffic Noise Annoyance Model.

time series, 73% of 24-hour traffic occurred during the daytime hours (07:00 – 19:00), 16% occurred during the evening hours (19:00 – 23:00), and 11% occurred during the nighttime hours (23:00 – 07:00). Traffic data from counted streets are summarized by neighborhood and by arterial versus non-arterial streets in Table 1. The table also presents the differences in neighborhood with respect to the percentage of vehicle traffic that were medium trucks, heavy trucks, or buses.

Analysis of extrapolated traffic by neighborhood

Using the neighborhood-specific arterial and non-arterial traffic averages in Table 1 we extrapolated traffic counts to the remaining uncounted streets. The number of arterial and non-arterial street segments, and cumulative traffic across all streets by neighborhood are presented in Table 2. The highest noise levels were found in the South of Market (SoMa) neighborhood.

Estimated noise levels

Traffic-induced noise levels estimated from the Federal Highway Administration's (FHWA) Traffic Noise Model (TNM) 2.5 model [41] are shown in figure 3, and summarized by neighborhood in Table 3. Because the probability of high annoyance is exponentially related to noise (Figure 4), it mimics the general spatial pattern of community noise levels (Figure 3). Hence, the noise levels were greatest in SoMa and so too were the risks of annoyance.

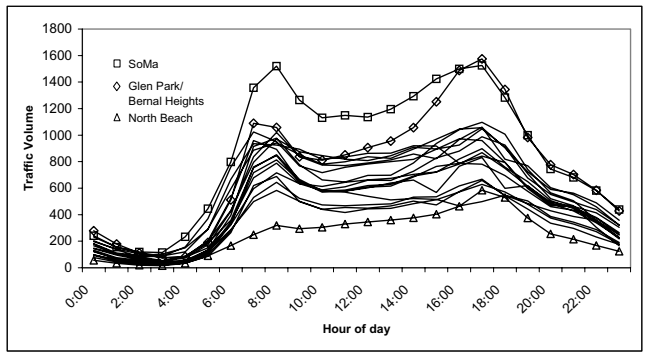

Figure 2
Average hourly traffic for different San Francisco neighborhoods (three neighborhoods with different temporal characteristics from the others are labeled).

Distribution of the general population and those highly annoyed by noise

Figure 5 shows the distribution of the population by census block in the city. The greatest population densities are

Table 1: Measured traffic counts from pneumatic tube counters and vehicle type percentages determined from remote sensing for arterial and non-arterial streets by neighborhood.

		24-hr Traffic (1,000s)				Vehicle type (%)					
		Non-arterial		Arterial		Non-arterial			Arterial		
Neighborhood	No. street segments	Mean	25–75%ile	Mean	25–75%ile	Medium Truck	Heavy Truck	Bus	Medium Truck	Heavy Truck	Bus
Bayview/Hunter's Point	86	6	2–7	16	12–22	6	4	2	6	3	3
Central West	161	5	3–7	19	11–26	2	1	2	2	1	0
Chinatown	15	11	11–11	17	10–23	2	1	4	1	2	4
Downtown/Civic Center	53	14	9–17	25	20–28	4	4	1	2	2	4
Excelsior/Visitation Valley/Crocker/ Outer Mission	188	4	1–5	12	7–15	0	6	1	0	1	4
Financial District	114	15	8–19	31	12–45	3	1	5	3	2	8
Glen Park/Bernal Heights	80	2	1–3	20	9–25	7	2	1	3	1	5
Haight Ashbury	60	6	3–7	29	13–37	5	6	0	3	0	0
Inner Mission	119	9	1–13	23	14–31	4	4	2	10	1	7
Lakeshore	96	7	1–11	21	12–31	2	2	4	2	0	0
Nob Hill/Russian Hill/Pacific Heights/ Marina	133	7	2–8	22	14–30	9	5	0	2	1	5
North Beach	43	6	3–8	19	15–18	6	4	3	1	5	4
Northwest	181	4	2–6	25	13–28	5	0	3	3	0	2
Potrero Hill	73	5	2–7	19	12–23	9	2	6	5	5	3
South of Market	106	17	10–24	24	17–30	3	6	2	1	2	9
Twin Peaks/Diamond Heights/ Oceanview	199	5	1–4	13	9–15	5	0	2	4	1	2
Upper Market/Noe Valley	126	4	1–5	14	11–19	8	3	0	6	2	5
Western Addition	166	10	4–10	30	20–44	7	4	2	2	3	0
All	1,999	7	2–9	20	11–25	5	3	2	3	2	4

Table 2: Extrapolated traffic and noise outcomes in dB for the entire city by neighborhood.

	No. street segments		Total 24-hr traffic (1,000s)		Noise level (dB Ldn)		
Neighborhood	Non-arterial	Arterial	Non-arterial	Arterial	Non-arterial	Arterial	Mean (SD)
Bayview/Hunter's Point	1,226	170	7,571	2,683	66	70	66 (1.6)
Central West	1,400	286	7,209	5,512	62	67	63 (2.3)
Chinatown	155	34	1,637	578	66	69	67 (1.6)
Downtown/Civic Center	291	63	4,161	1,550	69	71	69 (1.0)
Excelsior/Visitation Valley/Crocker/Outer Mission	1,567	366	6,925	4,328	64	66	64 (1.5)
Financial District	343	93	5,077	2,841	67	72	68 (2.6)
Glen Park/Bernal Heights	747	77	1,662	1,553	60	69	61 (2.8)
Haight Ashbury	222	61	1,317	1,785	65	69	66 (2.2)
Inner Mission	577	130	5,344	2,995	67	71	68 (2.8)
Lakeshore	407	134	2,903	2,787	63	66	64 (2.5)
Nob Hill/Russian Hill/Pacific Heights/Marina	959	135	6,672	2,958	66	69	67 (1.5)
North Beach	486	43	2,849	805	65	70	65 (1.6)
Northwest	1,379	294	6,012	7,267	61	68	63 (3.0)
Potrero Hill	439	44	2,339	815	65	71	65 (2.1)
South of Market	569	126	9,829	2,994	70	70	70 (1.5)
Twin Peaks/Diamond Heights/Oceanview	1,379	243	6,370	3,060	61	66	62 (2.6)
Upper Market/Noe Valley	709	213	2,703	3,043	63	68	64 (2.6)
Western Addition	601	122	5,750	3,670	67	71	68 (2.6)
All	13,456	2,634	86,330	51,224	64	68	65 (3.3)

Table 3: Population characteristics for each neighborhood, predicted noise, numbers of highly annoyed.

Neighborhood	Population (1,000s)	Population per 100 m^2	Noise level (dB Ldn)	Highly annoyed (1,000s)	Prevalence of highly annoyed	Highly annoyed per 100 m^2
Bayview/Hunter's Point	33	0.27	66	6	18%	0.05
Central West	100	0.56	63	13	13%	0.07
Chinatown	10	2.88	67	2	20%	0.54
Downtown/Civic Center	40	2.37	69	9	23%	0.55
Excelsior/Visitation Valley/Crocker/Outer Mission	98	0.78	64	15	15%	0.12
Financial District	4	0.21	68	1	25%	0.04
Glen Park/Bernal Heights	31	0.84	61	4	13%	0.10
Haight Ashbury	23	1.08	66	4	17%	0.19
Inner Mission	48	1.24	68	10	21%	0.25
Lakeshore	18	0.19	64	3	17%	0.03
Nob Hill/Russian Hill/Pacific Heights/Marina	82	1.23	67	16	20%	0.24
North Beach	12	0.68	65	2	17%	0.11
Northwest	85	0.53	63	12	14%	0.07
Potrero Hill	11	0.27	65	2	18%	0.04
South of Market	22	0.38	70	6	27%	0.10
Twin Peaks/Diamond Heights/Oceanview	58	0.51	62	7	12%	0.06
Upper Market/Noe Valley	51	0.98	64	8	16%	0.15
Western Addition	51	1.30	68	10	20%	0.26
All	775	0.64	65	128	17%	0.11

Figure 3
Predicted noise levels along city streets.

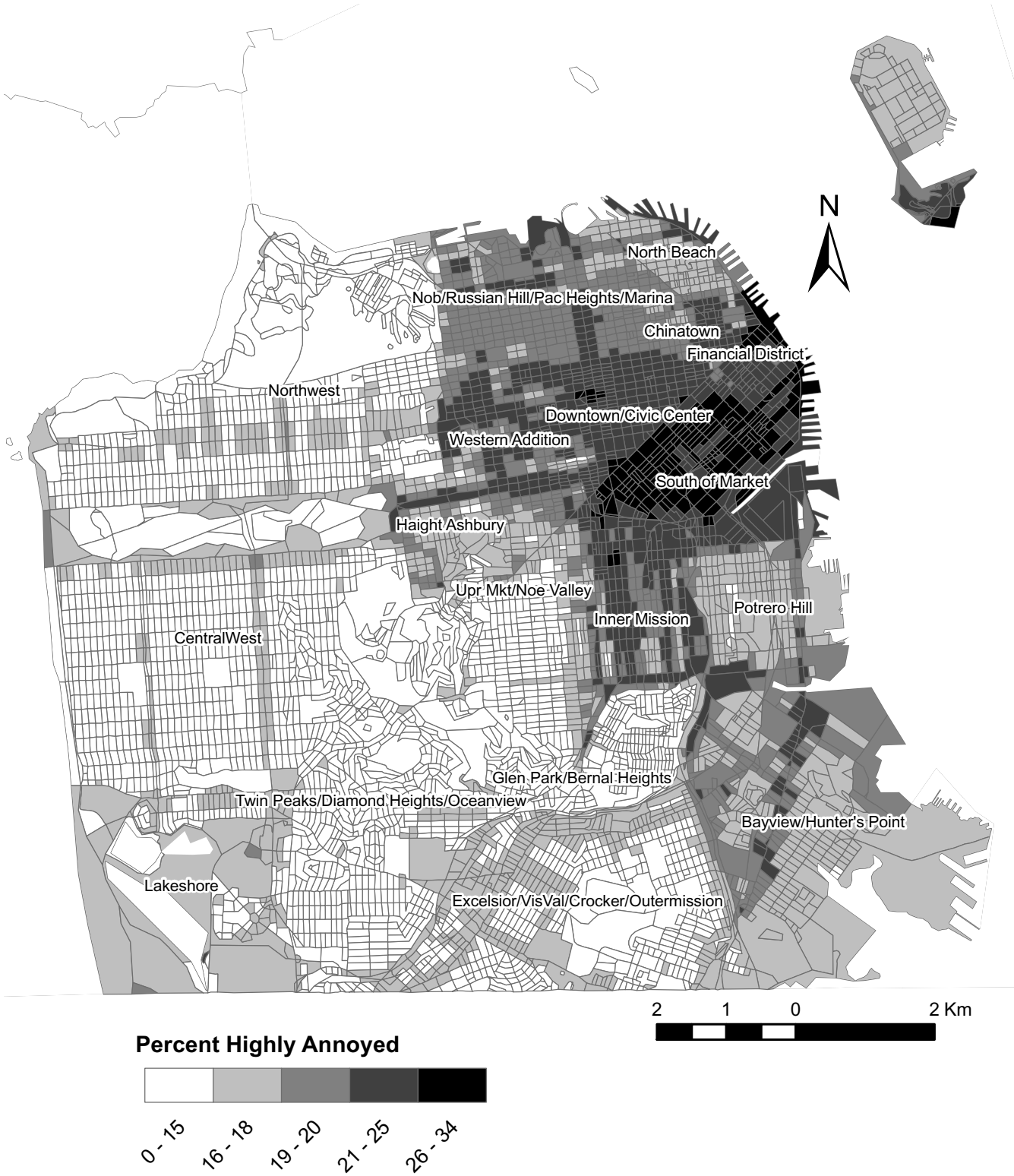

Figure 4
Spatial distribution of the risk of high annoyance to traffic noise.

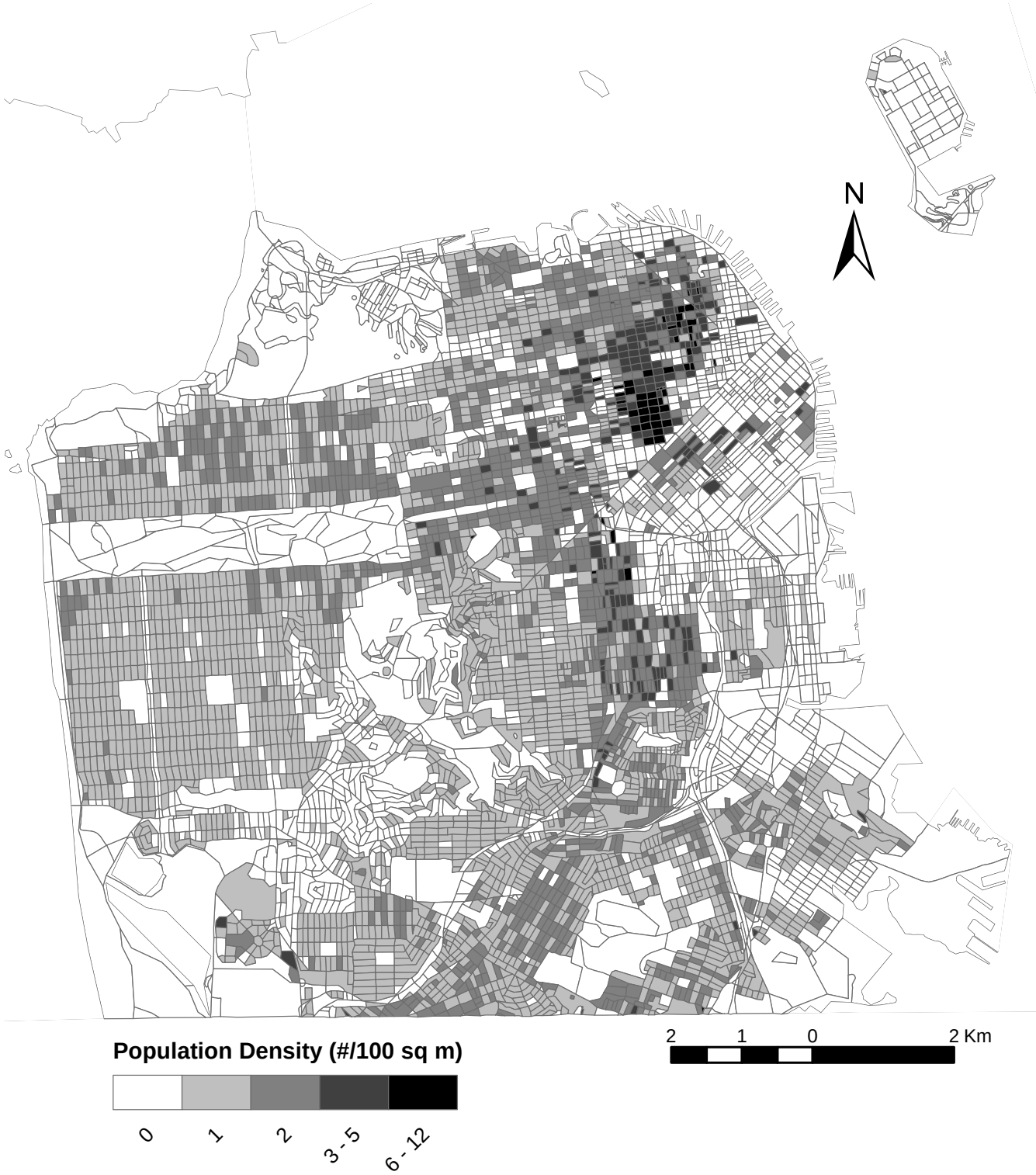

Figure 5
Population density in 2000 by census block.

located in Chinatown and Downtown/Civic Center. Multiplying the population in each census block by the probability of being highly annoyed by traffic noise (Figure 4) results in the estimate of highly annoyed (Figure 6 and Table 3). The spatial distribution of risk (probability) of high annoyance differs dramatically from the resulting population density of highly annoyed. Although the risk was greatest in SoMa, few people lived there in the year 2000, and hence, only small pockets of highly annoyed existed within that neighborhood. In contrast the highest densities of highly annoyed were in Downtown/Civic Center. Of the approximately 775,000 people living in the city, we estimated that 17% had the potential to be highly annoyed by noise.

Field validation of the traffic noise model

Noise measurements were obtained at 235 field sites where traffic count data existed. The relationship between traffic counts (log scale) and measured noise L_{Aeq} is shown in figure 7. Linear regression models were used to assess the relationship between measured noise to log transformed traffic counts, and the effect neighborhood-level adjustments for time of day and truck and bus percentages. A simple model of noise using only log hourly traffic based on a weighting factor (w(k, t)), which accounts for neighborhood-specific hourly differences resulted in estimated noise increases of 6.7 dB for a 10-fold increase in traffic (95 % CI: 5.4–7.9, and $R^2 = 0.33$). A second model that adjusted for neighborhood differences in vehicle makeup resulted in an improved fit ($R^2 = 0.37$) with important contributors being increases of 0.3 dB ($p < 0.001$) and 0.2 dB ($p < 0.07$) when the neighborhood traffic makeup is increased by 1-percent for buses or heavy trucks, respectively. This supports the need for accounting for noise contributions from different sources of traffic.

Figure 7 also shows the relationship between traffic counts and noise predicted by the TNM model. The relationship between TNM modeled noise versus measured noise was fit to a linear regression with an intercept of 21.7 (95 % CI: 13.4–30.1) and slope of 0.70 (95 % CI: 0.57–0.82) ($R^2 = 0.34$), with errors that were normally distributed. This suggests that the TNM model underestimates noise in environments < 73 dB, and overestimates otherwise. An analysis of potential spatial-temporal factors related to the errors suggests that the error is only weakly related to the time of day field sampling occurred. In addition, we mapped the error by geographic location, and found a mix of both positive and negative errors in each neighborhood, which indicate that errors are not spatially autocorrelated. Hence, the TNM model does not tend to under or over predict noise in any particular neighborhood. These findings suggest that both the time of day weighting factors and neighborhood-specific inputs in the TNM model are important and appropriate.

Discussion

The objective of this paper was to describe spatial variation in environmental noise exposures and estimate high annoyance to traffic noise for neighborhoods in San Francisco. In the analyses it was important to account for differences between neighborhoods and street types. First, we found that traffic varied considerably across the city both between and within neighborhoods (Table 1). Since the neighborhoods varied in size, so too did the number of street segments within them. However, the number of streets within a neighborhood was not correlated with traffic (arterial or non-arterial). This reflected the commercial land-use and public services of the city which creates transportation demand, for instance high non-arterial traffic in Chinatown, Civic Center, the Financial District, and SoMa. The traffic data also clearly demonstrated the importance of arterials as major transit pathways within and between neighborhoods in the city. On average, counts on arterials were 2.7 times those of non-arterials, and were consistently higher than non-arterials in all neighborhoods.

The temporal pattern of traffic volumes were also neighborhood-dependent (Figure 2). Based on the measured counts, traffic was on average 72% greater in SoMa than the city average, despite the population of SoMa ranking only thirteenth highest amongst the 18 neighborhoods in the city. SoMa serves as a major thoroughfare that serves the downtown Financial District and Civic Center (themselves high traffic areas), the baseball park, and the Moscone Convention Center with on and off-ramps for the three major freeways. SoMa experienced the greatest fluctuations during rush hours because most commuters enter and leave the city via this neighborhood. The other noticeable peak was in Glen Park/Bernal Heights, which like SoMa was influenced by nearby freeways. In contrast, North Beach is a relatively isolated community in the northeast corner of the city, far from the freeways, and thus had the lowest rush hour peaks.

We explored the relationship between traffic and noise using two methods. The first relied on our own field collected noise measurements. Again, neighborhood-level differences were important. The fit of regression models relating noise measurements to traffic measurements using city-wide averages to adjust for time of day improved more than two-fold with the addition of neighborhood-level adjustments for time of day. The relationship was further improved by neighborhood-specific adjustments for vehicle makeup. We found differences in buses percentages to be particularly important, which varied from 0 to 6.5% between neighborhoods. The importance of vehicle makeup is related to empirical data in TNM, which indicate that a bus is equivalent in noise to 12 automobiles, a medium truck is equivalent to nine

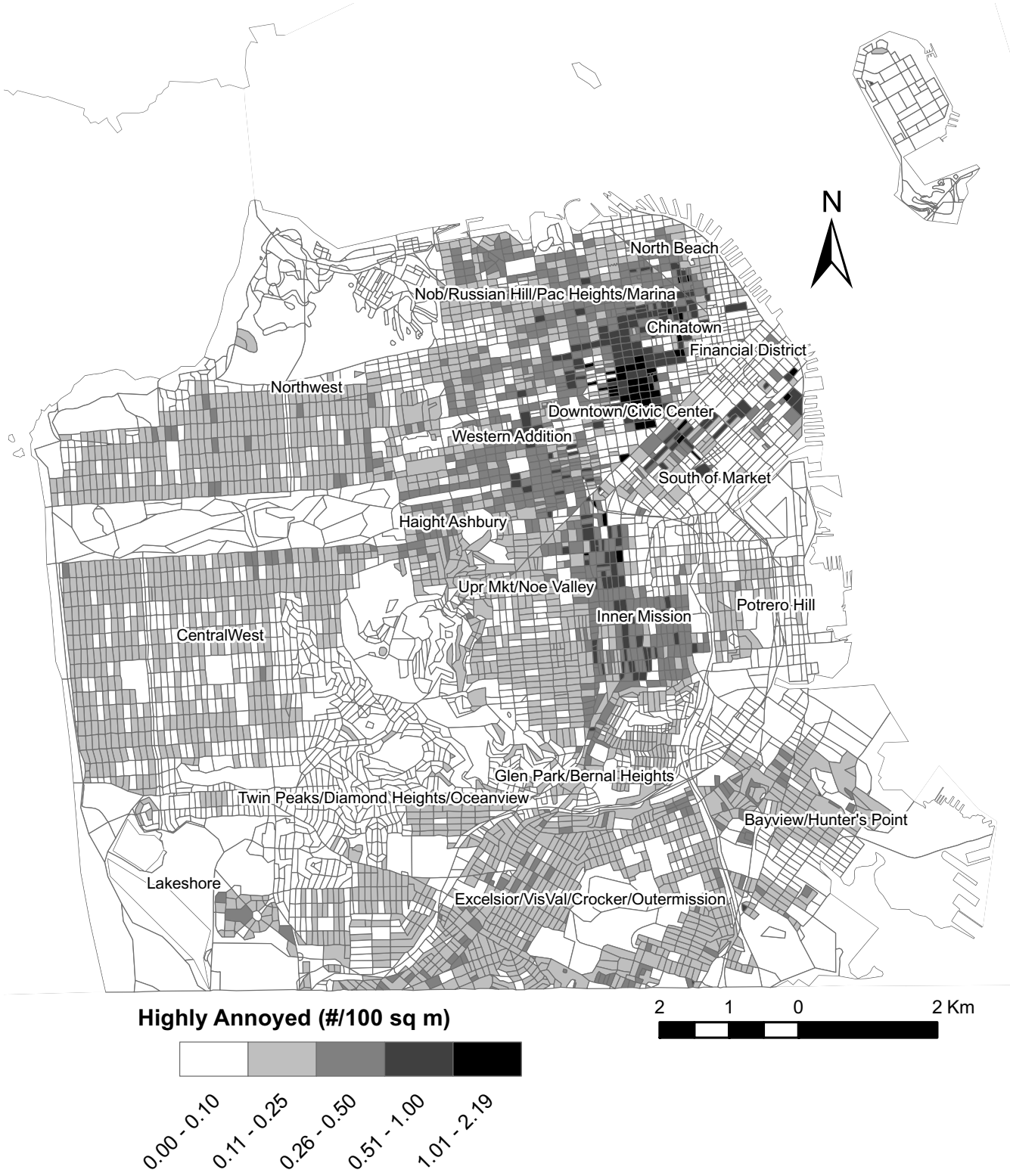

Figure 6
Spatial distribution of the density of high annoyance.

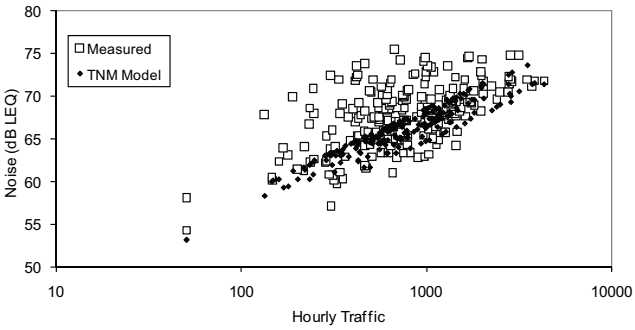

Figure 7
Relationship between time-of-day adjusted hourly traffic counts (log scale) and field measured noise (squares), and predicted noise from the TNM model (diamonds).

automobiles, and a heavy truck is equivalent to over 22 automobiles. While buses may be noisier than cars, they may offer substantial benefits to neighborhoods that have bus service. Moreover, the city is currently in the process of replacing its bus fleet with cleaner and quieter buses, which may negate some of the adverse noise effects.

Maps of bus and truck percentages (Figures 8 and 9), may help transportation planners understand how these major contributors to noise vary by neighborhood. They indicate how the density of bus routes and the presence of the bus terminal resulted in buses being a major contributor to noise in the Financial District and SoMa neighborhoods. In contrast, the presence of the main postal distribution annex, recycling center drop-off, and numerous light manufacturing made trucks more prevalent in areas like Bayview/Hunter's Point and Potrero Hill, in contrast to streets in the Inner Mission and Upper Market/Noe Valley that were more populated by medium trucks. SoMa also had a high percentage of heavy trucks, again reflecting its major role as a way in and out of the city. Surprisingly, the relatively isolated North Beach area also had high percentages of heavy trucks. However, overall it had much less traffic than SoMa.

Based on the traffic extrapolations to the entire city (Table 2), we find that larger communities had more streets, and hence larger total amounts of community traffic. However, of primary importance is the average traffic per street (Table 1), particularly the street in front of the residence, since the noise-annoyance relationships are based on residential exposures and in open air, traffic noise decreases rather rapidly (6 dB per doubling of distance) [42]. Hence, a large community like the Northwest district had the highest cumulative amount of traffic, but the average noise levels on its arterial and non-arterial streets were relatively low at 68 and 61 dB, respectively.

Although the standard deviations for arterial and non-arterial traffic within each neighborhood were large, arterial streets generally experienced the highest traffic (Table 1), producing noise averaging 68 dB (Table 2). On average, we estimated that 21% of noise exposures along arterials resulted in high annoyance (HA), a relative risk for high annoyance of 1.4 (95 % CI: 1.3–1.5) compared to non-arterials (62 dB, 15% HA). The noisiest community as a whole was SoMa (Table 3, 70 dB, 27% HA). The relative risk of high annoyance in SoMa was 2.1 times higher than the lowest risk neighborhood (Glen Park/Bernal Heights, 61 dB, 13% HA, 95 % CI RR: 2.0–2.2). SoMa was the noisiest neighborhood largely due to high traffic along both arterial and non-arterial streets. In contrast, arterial streets in the Financial District were the noisiest in the city. Although the noise levels may be higher in the Financial District, its taller building heights may reduce exposure and annoyance levels. Moreover, on average the Financial District did not have as high noise as SoMa because the non-arterial streets in the Financial District were relatively quiet.

There were several limitations encountered in our study. One was the difficulty in extrapolating traffic from measured streets to unmeasured ones. Although there were clear differences between arterial and non-arterials, there remained considerable residual variability between streets of the same type and neighborhood. Future improvements to the model might include better categorization of roads, and using more sophisticated traffic flow modeling and/or geostatistical interpolation models. The other limitation concerns the validity of the exposure-annoyance relationship for this present setting. Although the relationship has been shown to be robust across several countries, no US-based studies have contributed to the most recent model [17]. This again highlights the lack of community noise studies in recent US history. Yet an older US-based model exists [13] and shows consistency with the recent models. Still, these models may not adequately account for building age and quality and noise insulating factors that are specific to San Francisco that may modify exposures to environmental noise. In urban environments the degree to which building heights affect exposures may also need to be better considered. It is hoped that this analysis will motivate renewed interest in conducting epidemiological studies on the effects of community noise within the US to develop more specific exposure-outcome models and improved estimates of noise burdens.

It was important to validate the noise predictions from TNM in an urban setting. A regression analysis suggests

Figure 8
Bus routes and percentage of neighborhood traffic that are buses.

that the model may have underestimated noise for most noise levels found in community settings. One possible explanation for this may be greater acoustical reflections in an urban landscape, which might not be representative of the freeway settings in which the TNM model was originally developed. Accounting for variations in traffic speed, starting and stopping of traffic, and elevation changes within the city may also explain the underestimate of noise. Correspondingly, the 17% rate of high annoyance for the city may be a conservative estimate.

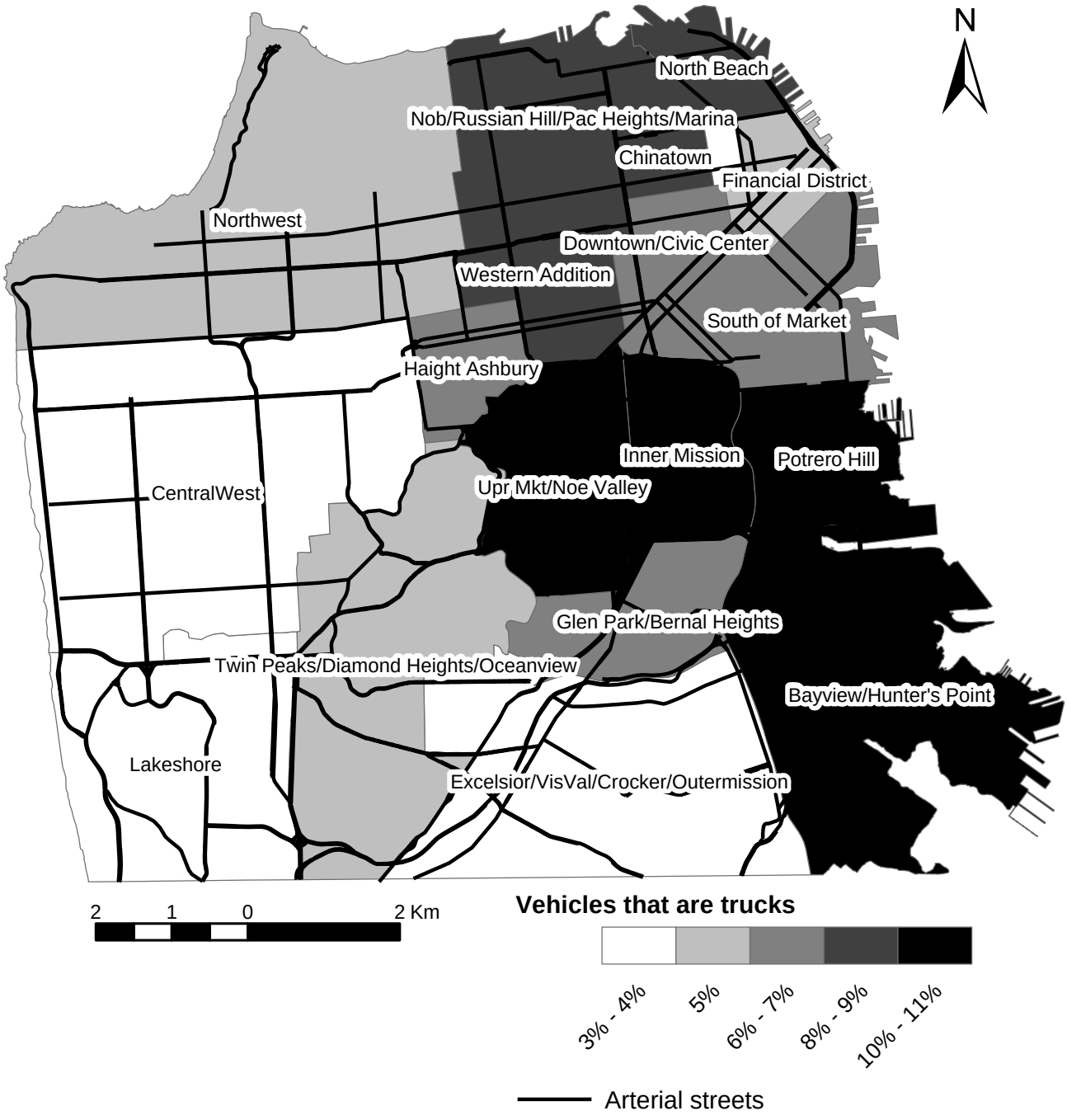

Figure 9
Arterial streets and percentage of neighborhood traffic that are trucks.

Furthermore, traffic noise is only one component of community noise. A more comprehensive noise assessment in the future might also consider the added noise of living near airports, fire stations, hospitals with emergency vehicles and helicopters, entertainment districts, and various types of rail lines that serve the city. Conversely, various factors can serve to reduce noise which might be considered, including noise attenuation via green spaces, sound barriers, and living in taller buildings that distance certain populations away from street-level noise. Previously, we

mentioned how new buses in the city are quieter. We may also find that newer vehicles, such as hybrid/electric vehicles that may be quieter in urban settings may also lower traffic noise.

Despite these limitations, several policy implications emerge from these analyses. The first relates to building design and construction in new urban neighborhoods. Future development of residences in areas of existing high traffic areas should not only be evaluated in terms of the added traffic burden, but on the placement in persons where they will certainly have the potential adverse health impacts. SoMa is a perfect example of such an area, where noise mitigation measures should be employed to protect new residents and thoroughly evaluated. This is also an important consideration for new transit-oriented high-density developments. For instance, new smart growth policies that include a greater reliance on mass transportation, less segregation of land uses, higher residential and commercial density, and complete, mixed-income neighborhoods may have regional benefits that include reducing sprawl and automobile-reliance. However, the benefits of such development need to be balanced against environmental health concerns of having more people live in urban areas of high traffic, noise, and air pollution.

The second implication of this work relates to mitigating traffic demand from new development. In San Francisco over 90% of the city's traffic is due to automobiles, and not trucks or buses. Even though buses and trucks are much noisier than automobiles, with the vehicle type percentages present in San Francisco, automobiles are still the major source of urban noise (e.g., given 1,000 vehicles, automobiles would contribute 64 dB, medium trucks 60 dB, heavy trucks 61 dB, and buses 59 dB, respectively based on hourly LEQs using the TNM assumptions described in Methods). Hence the promotion of walking, bicycling, public transportation, carpooling, work-at-home and telecommuting all equate to less urban noise, and reduced health impacts. If there are good transit options that reduce vehicular traffic, transit-oriented high-density development may reduce noise annoyance. Changes in parking supply and congestion pricing may also be effective measures for reducing traffic demand.

The third implication of this study relates to environmental justice. While some individuals who are highly sensitive to noise may have the means to avoid living in noisy areas, not everyone can afford to live in relatively quieter neighborhoods. Moreover, some highly sensitive individuals may also bear a greater burden of risk, such as elderly persons and children who may be more exposed to daytime noise. Not only should new residents be protected from poorly planned new development, consideration should also be made towards populations currently experiencing the greatest burden of risk. Although the greatest risk currently exists in SoMa, its population is still relatively small compared to those living in other neighborhoods. Our predictions suggest that most of the city's highly annoyed do not live in SoMa. In fact, the highest population densities of highly annoyed exist in Chinatown and Civic Center (average noise levels of 67 and 69 dB, respectively). Hence, if the city were to mitigate noise, for instance by renovation of old construction, it may be most prudent to focus on these neighborhoods, where the most people per area would benefit.

Continued analyses of noise exposure may better elucidate the relationship between the spatial patterns observed and their impacts on low income, different ethnic populations, and children, particularly for these high density areas. In the US, noise issues are typically evaluated at the project level as part of the Environmental Impact Assessment process. However, in other countries noise impacts are increasingly evaluated within a Health Impact Assessment (HIA) process that considers more broadly the overall health of communities. The goal of HIA is to analyze and consider the direct and indirect health effects of public policy ranging from urban planning and transportation to agriculture, energy and natural resources management. The GIS-model presented here for San Francisco can serve as an example of one quantitative tool within the HIA toolbox for the US. Considerable work remains to develop quantitative tools for HIA that can account for the numerous transportation-related health effects. Such tools can serve as a way to track the health of a community over time as it develops. Here, we have established a baseline for noise, which is essential for evaluating current and future changes in annoyance. Our estimate of 17% of the population at risk of being highly annoyed by noise is of considerable concern. Such high rates of annoyance highlight the seriousness of the noise problem for US cities.

Conclusion

In this paper we present a GIS-based model for evaluating the spatial distribution of traffic-induced noise in an urban environment. Applying the model to the City of San Francisco, we find that the potential risk of annoyance is large, and varies considerably between neighborhoods. This work has implications for building design and construction in new urban neighborhoods, particularly urban infill that may increase density in environments with pre-existing noise problems. It also highlights the need for transportation alternatives, as automobiles are the major source of community noise. Finally, the work has implications for environmental justice, as we show that areas of high population density suffer disproportionately from the impacts of urban noise. The relatively simple model presented here may be used to evaluate changes in noise

exposures and annoyance as one tool in a larger toolbox for Health Impact Assessments of transportation and land use planning.

Methods

Spatial database and traffic analyses

The GIS implemented in ArcGIS [43], includes neighborhood, block and parcel boundaries with land use zoning and building heights attributes, as well as 16,090 street segments for the City of San Francisco. Each street segment corresponds to a city block, and is identified by a unique centerline network number (CNN). Of the total CNNs, 2,634 are classified as arterial street segments, roads defined as major thoroughfares for the neighborhood. The SF Department of Transportation has 6,444 traffic counts for 1,999 CNN segments using pneumatic tube counters from 1992 – 2000. These data were only available due to an effort in 2000 to digitize paper traffic records, which has not occurred more recently. The traffic counts were averaged for segments with multiple measurements. Separate counts were measured for each direction of travel. For two-way streets we summed the measurements taken in opposite directions. We assumed a doubling of traffic if measurements were only taken in one direction of a two-way street. Traffic volumes along uncounted streets were extrapolated from measured neighborhood arterial/non-arterial-specific averages.

Hourly traffic volumes were available for 709 measurements, while 24-hour total counts were available for the remaining counted streets. Based on the hourly traffic data, we computed temporal weighting factors, w(k, t) for each neighborhood k as the 24-hour count divided by the hourly count for hour, t. These weighting factors were then used to convert the streets with only 24-hour total count data to hourly counts. Thus, with hourly traffic estimates for all streets, we were able to compute hourly noise levels as described below.

Traffic noise is largely a function of the vehicular makeup of the traffic. However, data on truck and bus percentages for individual roads were not available for the city. Instead, we derived these percentages using remote sensing techniques. We used an August 2001 georeferenced mosaic of 254 quarter-foot resolution aerial orthophotography, with a positional accuracy of 2.5 feet. From these we performed manual counts of 100 vehicles along arterial and 100 vehicles along non-arterial streets separately for each of the eighteen neighborhoods. Parked vehicles were not counted. Each counted vehicle was classified as an automobile, medium truck, heavy truck, or bus, and used to compute the vehicle makeup by neighborhood and by arterial/non-arterial street status. We further restricted bus fractions to bus routes since this information was available from the GIS. An automated object-oriented classification of vehicle quantity and type from orthophotos is in development [44].

Noise exposure assessment

The relationship between traffic and noise was assessed via both modeling and field measurement. Various country-specific models are available that model the noise induced by vehicle traffic [45]. In the USA the Federal Highway Administration's (FHWA) Traffic Noise Model (TNM) 2.5 model [41] is generally accepted for estimating traffic-induced noise. Using TNM, we assumed vehicle speeds of 50 km/hr over hard surfaces with receivers located 10 m from the center of the roadway. For simplicity, we did not consider motorcycles, barriers, or reflections other than the hard road surface in the model. Using the hourly traffic estimates and the vehicle makeup percentages, we used the model to estimate hour-specific noise associated with each street segment as follows:

$$L_{Aeq} = 10 \times Log_{10} \left\{ \left[\frac{T_A}{1000} \times 10^{LA/10} \right] + \left[\frac{T_{MT}}{1000} \times 10^{LMT/10} \right] + \left[\frac{T_{HT}}{1000} \times 10^{LHT/10} \right] + \left[\frac{T_B}{1000} \times 10^{LB/10} \right] \right\} \quad (1)$$

where the 1-hour A-weighted sound level (L_{Aeq}) is described by LA, LMT, LHT, and LB noise contributions from automobile, medium truck, heavy truck, and bus traffic (T_A, T_{MT}, T_{HT}, T_B in thousands), respectively. Under the assumptions above, LA, LMT, LHT, and LB are 64.0, 73.5, 77.5, and 74.7 dB, respectively.

To validate the model, we choose 235 segments (stratified by neighborhood and traffic level) for field measurement. Freeway on/off-ramps were excluded for safety reasons. Sites were visited between 09:00 – 18:00 hr on weekdays during the summer of 2005. Fifteen-minute L_{Aeq} measurements were obtained at each site using Quest Model 1800 Sound Level Meters, and were compared to the results of the TNM model.

In order to create city-wide maps of noise for exposure assessment, we extrapolated the existing traffic count data to the uncounted streets as described above, and then applied the TNM model to compute the hourly noise for each CNN. In accordance with standard community noise assessments, we summarized the hourly measurements into a 24-hour noise indicator, the L_{dn}, which applies a 10 dB penalty to noise during the night hours of 22:00–07:00.

Noise-annoyance assessment

We applied the Miedema and Oudshoorn exposure-response equation for L_{dn} and percentage "highly annoyed" (HA)[18]:

$$\%HA = 9.994 \times 10^{-4} (L_{dn} - 42)^3 - 1.523 \times 10^{-2} (L_{dn} - 42)^2 + 0.538(L_{dn} - 42) \quad (2)$$

Block-level population data from the 2000 US Census were overlaid upon the modeled traffic noise and used to estimate populations at risk of high annoyance to traffic noise. This was done by buffering each census block 50 m, and taking the mean probability of high annoyance for all streets that are intersected by the buffer. The mean probability was then multiplied by the population living in the census block to estimate the number of highly annoyed.

Statistical analysis

Linear regression models were used to estimate the relationship between sampled noise levels at a given hour from log-transformed hourly-adjusted traffic counts based on the w(k, t) factor described above, adjusting for neighborhood differences in vehicle makeup. An additional linear model was used to compare TNM predicted noise levels to the field noise measurements. Model error was explored for spatial autocorrelation, and for correlation with time of day. Stata 8.0 was used for statistical analyses [46].

Competing interests

The author(s) declare that they have no competing interests.

Authors' contributions

ES and TR designed the study. ES was involved in data collection, GIS and statistical analysis and modeling, and writing of the manuscript. AH worked on the traffic database and analysis of orthophotos. TR and RB contributed to the writing of the manuscript, and were instrumental in interpreting the results in the context of Health Impact Assessment and development trends within City of San Francisco. All authors read and approved the final manuscript.

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References

1. Dannenberg AL, Jackson RJ, Frumkin H, Schieber RA, Pratt M, Kochtitzky C, Tilson HH: **The impact of community design and land-use choices on public health: a scientific research agenda.** *Am J Public Health* 2003, **93(9):**1500-1508.
2. Kahn EB, Ramsey LT, Brownson RC, Heath GW, Howze EH, Powell KE, Stone EJ, Rajab MW, Corso P, Briss PA, Serv TFCP: **The effectiveness of interventions to increase physical activity - A systematic review.** *Am J Prev Med* 2002, **22(4):**73-108.
3. Mueller BA, Rivara FP, Lii SM, Weiss NS: **Environmental factors and the risk for childhood pedestrian-motor vehicle collision occurrence.** *Am J Epidemiol* 1990, **132(3):**550-560.
4. Roberts I, Norton R, Jackson R, Dunn R, Hassall I: **Effect of environmental factors on risk of injury of child pedestrians by motor vehicles: a case-control study.** *Bmj* 1995, **310(6972):**91-94.
5. Nyberg F, Gustavsson P, Jarup L, Bellander T, Berglind N, Jakobsson R, Pershagen G: **Urban air pollution and lung cancer in Stockholm.** *Epidemiology* 2000, **11(5):**487-495.
6. Hoek G, Brunekreef B, Goldbohm S, Fischer P, van den Brandt PA: **Association between mortality and indicators of traffic-related air pollution in the Netherlands: a cohort study.** *Lancet* 2002, **360(9341):**1203-1209.
7. Pope CA: **What do epidemiologic findings tell us about health effects of environmental aerosols?** *J Aerosol Med* 2000, **13(4):**335-354.
8. Pope CA, Dockery DW, Schwartz J: **Review of Epidemiological Evidence of Health-Effects of Particulate Air-Pollution.** *Inhal Toxicol* 1995, **7(1):**1-18.
9. Gauderman WJ, Avol E, Gilliland F, Vora H, Thomas D, Berhane K, McConnell R, Kuenzli N, Lurmann F, Rappaport E, Margolis H, Bates D, Peters J: **The effect of air pollution on lung development from 10 to 18 years of age.** *New Engl J Med* 2004, **351(11):**1057-1067.
10. Stansfeld SA, Matheson MP: **Noise Pollution: non-auditory effects on health.** *British Medical Bulletin* 2003, **68:**243-257.
11. Shield BM, Dockrell JE: **The effects of noise on children at school: a review.** *Journal of Building Acoustics* 2003, **10(2):**97-106.
12. Passchier-Vermeer W, Passchier WF: **Noise exposure and public health.** *Environ Health Perspect* 2000, **108 Suppl 1:**123-131.
13. Schulz TJ: **Synthesis of social surveys on noise annoyance.** *Journal of the Acoustical Society of America* 1978, **64:**377-405.
14. Sukowski H, Meis M, Lercher P, Heydinger D, Schick A: **Noise annoyance of children exposed to chronic traffic noise: results from the Tyrol School Study II.** *8th Oldenburg Symposium on Psychological Acoustics* 2000:571-580.
15. Stansfeld SA, Berglund B, Clark C, Lopez-Bario I, Fischer P, Ohrstrom E, Haines MM, Head J, Hygge S, van Kamp I, Berry BF: **Aircraft and road traffic noise and children's cognition and health: a cross-national study.** *Lancet* 2005, **365:**1942-1949.
16. Miedema HME, Vos H: **Demographic and attitudinal factors that modify annoyance from transportation noise.** *Journal of the Acoustical Society of America* 1999, **105:**3336-3344.
17. Miedema HME, Vos H: **Exposure-response relationships for transportation noise.** *Journal of the Acoustical Society of America* 1998, **104(6):**3432-3445.
18. Miedema HME, Oudshoorn CGM: **Annoyance from transportation noise: Relationships with exposure metrics DNL and DENL and their confidence intervals.** *Environ Health Perspect* 2001, **109(4):**409-416.
19. Cohen S, Weinstein N: **Non-auditory effects of noise on behavior and health.** *J Social Issues* 1981, **37:**36-70.
20. Ohrstrom E, Rylander R, Bjorkman N: **Effects of night time road traffic noise -- an overview of laboratory and field studies on noise dose and subjective noise sensitivity.** *J Sound Vib* 1988, **127:**441-448.
21. Ohrstrom E: **Psycho-social effects of traffic noise.** *J Sound Vib* 1991, **151:**513-517.
22. Babisch W, Fromme H, Beyer A, Ising H: **Elevated catecholamine levels in urine in traffic noise exposed subjects.: Liverpool, UK.** ; 1996:2153-2158.
23. Kabuto MA: **Dose-response between nighttime indoor sound level due to road traffics and risk for insomnia in Japan.** 2002.
24. Babisch W, Ising H, Elwood PC, Sharp DS, Bainton D: **Traffic noise and cardiovascular risk: the Caerphilly and Speedwell studies, third phase--10-year follow up.** *Arch Environ Health* 1999, **54(3):**210-216.
25. Babisch W, Gallacher JE, Elwood PC, Ising H: **Traffic noise and cardiovascular risk. The Caerphilly study, first phase. Outdoor noise levels and risk factors.** *Arch Environ Health* 1988, **43(6):**407-414.
26. Babisch W, Ising H, Elwood PC, Sharp DS, Bainton D: **Traffic noise and cardiovascular risk: the Caerphilly and Speedwell studies, second phase. Risk estimation, prevalence, and incidence of ischemic heart disease.** *Arch Environ Health* 1993, **48(6):**406-413.
27. Xu X, Niu T, Christiani DC, Weiss ST, Zhou Y, Chen C, Yang J, Fang Z, Jiang Z, Liang W, Zhang F: **Environmental and occupational determinants of blood pressure in rural communities in China.** *Ann Epidemiol* 1997, **7:**95-106.
28. Knipschild P: **Medical effects of aircraft noise: community cardiovascular survey.** *Int Arch Occup Environ Health* 1977, **40:**185-190.
29. Stansfeld S, Gallacher J, Babisch W, Shipley M: **Road traffic noise and psychiatric disorder: prospective findings from the Caerphilly Study.** *Bmj* 1996, **313(7052):**266-267.
30. Abey-Wickrama I, A'Brook MF, Gattoni FE, CF H: **Mental-hospital admissions and aircraft noise.** *Lancet* 1970, **1(7644):**467-468.
31. Meechan WC, Smith HG: **Effects of jet aircraft noise on mental hospital admissions.** *Br J Audiol* 1977, **11:**81-85.
32. Guski R: **Personal and social variables as co-determinants of noise annoyance.** *Noise Health* 1999, **1(3):**45-56.

33. Job RFS: **The influence of subjective reactions to noise on health effects of the noise.** *Environment International* 1996, **22(1):**93-104.
34. Evans GW, English K: **The environment of poverty: multiple stressor exposure, psychophysiological stress, and socioemotional adjustment.** *Child development* 2002, **73(4):**1238-1248.
35. Balfour JL, Kaplan GA: **Neighborhood environment and loss of physical function in older adults: evidence from the Alameda County Study.** *Am J Epidemiol* 2002, **155(6):**507-515.
36. Satterthwaite D: **The impact on health of urban environments.** *Environment and urbanization* 1993, **5(2):**87-111.
37. Kohlhuber M, Mielck A, Weiland SK, Bolte G: **Social inequality in perceived environmental exposures in relation to housing conditions in Germany.** *Environmental research* 2006, **101(2):**246-255.
38. van Lenthe FJ, Brug J, Mackenbach JP: **Neighbourhood inequalities in physical inactivity: the role of neighbourhood attractiveness, proximity to local facilities and safety in the Netherlands.** *Social science & medicine (1982)* 2005, **60(4):**763-775.
39. Whitfield A: **Assessment of noise annoyance in three distinct communities living in close proximity to a UK regional airport.** *International journal of environmental health research* 2003, **13(4):**361-372.
40. Riediker M, Koren HS: **The importance of environmental exposures to physical, mental and social well-being.** *International journal of hygiene and environmental health* 2004, **207(3):**193-201.
41. US Department of Transportation Federal Highway Administration: **TNM Look-Up Tables.** 2.5th edition. Washington DC ; 2004.
42. Harris CM: **Handbook of Noise Control.** New York , McGraw-Hill Book Company; 1979.
43. ESRI: **ArcGIS.** 8.3th edition. Redlands, CA ; 2002.
44. Holt A, Seto E, Rivard R, Gong P: **Object-oriented detection and classification of vehicles from high-resolution aerial photography.** *International Journal of Remote Sensing* . in review
45. Jarup L, Dudley M, Babisch W, Houthuijs D, Swart W, Pershagen G, Bluhm G, Katsouyanni K, Velonakis M, Cadum E, Vigna-Taglianti F: **Hypertension and exposure to noise near airports (HYENA): Study design and noise exposure assessment.** *Environ Health Perspect* 2005, **113(11):**1473-1478.
46. Stata Corporation: **Stata 8.0.** 8.0th edition. College Station, TX , Stata Corporation; 2003.

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Health, Traffic, and Environmental Justice: Collaborative Research and Community Action in San Francisco, California

Megan Wier, MPH, Charlie Sciammas, Edmund Seto, PhD, Rajiv Bhatia, MD, MPH, and Tom Rivard, MS, REHS

Health impacts on neighborhood residents from transportation systems can be an environmental justice issue. To assess the effects of transportation planning decisions, including the construction of an intraurban freeway, on residents of the Excelsior neighborhood in southeast San Francisco, PODER (People Organizing to Demand Environmental and Economic Rights), a local grassroots environmental justice organization; the San Francisco Department of Public Health; and the University of California, Berkeley, collaborated on participatory research. We used our findings regarding traffic-related exposures and health hazards in the area to facilitate community education and action to address transportation-related health burdens on neighborhood residents. (*Am J Public Health*. 2009;99:S499–S504. doi:10.2105/AJPH.2008.148916)

TRANSPORTATION PLANNING in the 20th century resulted in environmental injustice and significant adverse health impacts.[1,2] In the 1960s, the construction of Interstate 280 (I-280) through southeast San Francisco divided the Excelsior neighborhood,[3] increased local and regional freight traffic, and precipitated diverse neighborhood health hazards mediated through effects on air quality, environmental noise, and pedestrian conditions. Today, I-280 brings almost 200 000 vehicles per day within 100 feet of the nearest residences.[4]

PODER (People Organizing to Demand Environmental and Economic Rights) is a grassroots, membership-based environmental justice organization in San Francisco. With 5 staff members and more than 400 youth and adult members, PODER organizes young people, families, and the elderly to work on local solutions to issues facing southeast San Francisco's predominantly low-income, immigrant communities and communities of color.[5] PODER uses direct action, grassroots advocacy, leadership development, and civic engagement to advocate for urban land reform, community health, youth empowerment, and immigrants' rights.

In 2006, concerned with the environmental health and justice implications of transportation planning decisions, PODER asked the San Francisco Department of Public Health (SFDPH) to collaborate on a participatory study of the impacts of building I-280 and of subsequent local traffic patterns on local residents. In response to community concerns, SFDPH has historically collaborated with community organizations and public and private agency stakeholders to assess the health impacts of land use and transportation plans and policies; the results have informed advocacy for health-promoting decisions.[6,7] PODER and SFDPH focused on I-280 and the Excelsior neighborhood after observing a stream of diesel trucks and buses on its narrow, 1-way residential streets (Figure 1). The School of Public Health at the University of California, Berkeley (UCB), which had a relationship with SFDPH, joined the collaboration in 2007. The 3 organizations undertook participatory research to understand the environmental health impacts of past transportation planning decisions on community residents; their findings have informed local policymaking to address health inequities.

PARTICIPATORY RESEARCH IN EXCELSIOR

PODER, SFDPH, and UCB first agreed on principles of collaboration. These included a focus on developing community knowledge and engaging community members; an intent to generate research that could inform actions for community change, not just serve an academic purpose; a commitment to regular communication regarding findings and their interpretation; and an intent to disseminate findings through various media after consulting with all parties. At the outset, PODER also translated community concerns to shape research goals, addressing the need to demystify the science, validate diverse knowledge sources, and draw connections that would challenge institutional paradigms.

KEY FINDINGS

- Exposure to traffic has multiple impacts on the health of community residents.
- Collaborative, community-based participatory research that combines community knowledge with scientific expertise can engage community members, public agencies, academics, and decision-makers in understanding, and taking steps to mitigate, the health impacts of transportation planning decisions.
- A comprehensive qualitative and quantitative assessment of traffic health impacts on air quality, environmental noise, and traffic hazards can support community understanding of environmental health risks and provide evidence that serves as a catalyst for reducing negative traffic-related health exposures and disparities.

The practice of health impact assessment, which seeks to comprehensively predict the health impacts of policy decisions, informed our conceptual framework.[8] Public policy decisions shape local and regional traffic patterns and subsequent traffic-related health consequences. For example, residential proximity to busy roadways results in diverse environmental health hazards. Air pollution associated with roadway proximity contributes to cancer, respiratory disease, and impaired lung development.[9] Traffic-related noise triggers community annoyance and sleep disturbance[10] and is associated with hypertension and heart disease.[11] High traffic volumes and speeds also result in increased risk of injury and death from vehicle collisions.[12] This framework informed our research questions, methods, and mitigation proposals.

Table 1 describes the methods we chose to study traffic and its health effects. We drew on PODER's experience with community assessment and education, SFDPH and UCB's technical capacity, and community members' expertise and experiences. PODER recruited members and Excelsior community volunteers to conduct community surveys, traffic counts, and photo documentation, supporting and engaging community members as researchers (e.g., in traffic counting) and experts (e.g., in surveying). SFDPH and UCB's preexisting collaboration had developed analytic models to relate local traffic to air quality and environmental noise[10,14] and estimate indirect health impacts, and SFDPH had developed a pedestrian environmental quality assessment metric.[13] We applied these tools to the project area. A historical analysis of community sociodemographics before and after freeway construction provided context for our understanding of traffic exposures; census, hospital, mortality, and vehicle collision data helped us understand community demographics, exposures, and health outcomes.

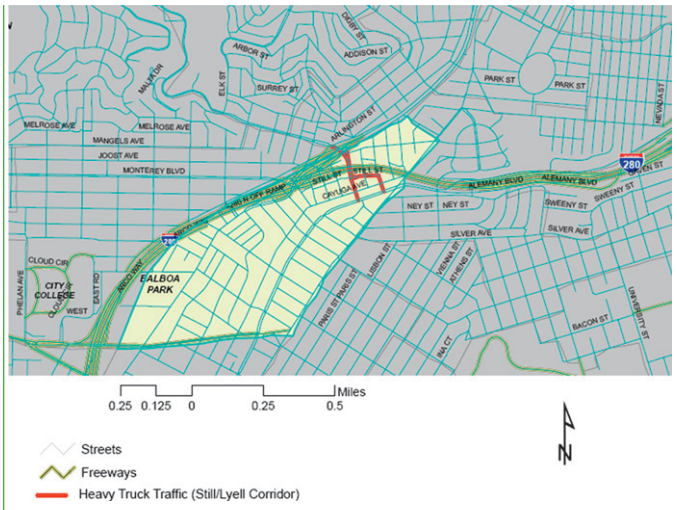

FIGURE 1—Excelsior project area map, including key traffic routes: 2000 census tract boundary.

Our methods and analytic approach supported our collaboration's principles of community engagement and education. For example, PODER members and residents conducted traffic counts, data that were required by our air quality exposure model. Collective review and interpretation of the model parameters and outputs increased the transparency of the analytic methods, supporting PODER's ability to translate air quality findings to residents and decision-makers. Geographic information system mapping of spatial analyses facilitated interpretation of the findings.

Key findings produced by each of our methods are shown in Table 2. Our conceptual framework influenced the design of our community survey, which included questions about air pollution, noise, and pedestrian hazards and about potential mitigations. The responses supported this comprehensive assessment of traffic's health effects. Community traffic counts showed that trucks and buses accounted for more than 10% of local traffic. Air quality and noise modeling and monitoring provided evidence that traffic contributed significantly to environmental hazards in the Excelsior neighborhood. These impacts are alarming, especially because the population, largely composed of families with children, immigrants, and people of color, increased after I-280's construction at a much faster rate than in surrounding areas further from freeway traffic. We also found that leading causes of death in the project zip code were illnesses associated with increased exposure to traffic and traffic-related air pollutants and noise,[22–24] including heart disease, lung cancer, and traffic collisions.

Required timelines for community-based action efforts

TABLE 1—Collaborative Research on Traffic, Health, and Environmental Justice: San Francisco, CA, 2006–2008

Method	Description	Project Leader[a]
Air quality modeling	We evaluated roadway-related air quality issues with traffic volume data from the county transportation agency's model (SF-CHAMP)[b] and specific local traffic counts and truck and bus percentages collected by PODER volunteers, known emissions for San Francisco County vehicles (EMFAC2007)[c], and the US Environmental Protection Agency recommended dispersion model (CAL3QHCR)[d] for the traffic associated with I-280 and local streets. The model creates contour maps of annual exposure level for PM 2.5 in excess of the ambient exposure level and associated with the location. These exposure data are then used to calculate the expected health effects associated with PM 2.5 roadway exposure.	SFDPH
Community photography	Community residents took pictures of factors in their daily community environment that affected their health.	PODER
Community surveys	PODER members conducted door-to-door surveys in Spanish and English over 7 census blocks. The completion rate was greater than 35% (52/146 occupied housing units per US Census 2000 data).	PODER
Noise modeling	SFDPH evaluated traffic noise exposure with traffic volume data from SF-CHAMP and noise-level modeling software (SoundPLAN).[e] The model included 3-dimensional buildings and topology.	SFDPH
Noise monitoring	Noise monitoring and dosimetry was conducted at 3 sites by PODER youth interns from a local high school.	SFDPH
Oral histories	PODER members interviewed community residents to learn about their personal stories, experiences, struggles, and successes in the neighborhood.	PODER
Pedestrian environmental quality assessment	We worked with students in an undergraduate environmental justice class at the University of California, Berkeley, to assess the quality of the pedestrian environment in a pilot application of the Pedestrian Environmental Quality Index.[f,13]	SFDPH
Secondary data analysis	We used existing community, hospitalization, emergency room, mortality, and motor vehicle collision data to describe health outcomes in the project area and compare them with other city neighborhoods.	SFDPH
Traffic counting	PODER members worked in teams, standing on street corners in the residential project area to conduct traffic counts during the morning and afternoon peak periods. Members counted cars, trucks, and buses separately on tally sheets.	PODER
US Census analysis	We analyzed historical US Census data to consider how overall population and number of households, median incomes, median house values, and percentages of Whites, children, and homeowners in the population differed in 1960, 1980, and 2000. We compared the trends for 5 different areas: the PODER Excelsior study community, areas 0.5 km north of the freeway, areas 0.5 km south of the freeway, and north and south areas slightly farther than 0.5 km away from the freeway.	UCB

Note. SF-CHAMP=San Francisco County Chained Activity Modeling Process; PODER=People Organizing to Demand Environmental and Economic Rights; EMFAC2007=emission factors 2007 model; CAL3QHCR=Caline 3 air quality dispersion model with advanced features for including hourly meteorological data; PM=particulate matter; SFDPH=San Francisco Department of Public Health, Environmental Health Section, Program on Health, Equity and Sustainability; UCB=University of California, Berkley, School of Public Health, Environmental Health Sciences.

[a]Data analysis and interpretation were collaborative. Information on project leaders is included to aid other organizations interested in replicating this model.

[b]SF-CHAMP is a transportation forecasting model developed by the San Francisco County Transportation Authority for use in various land use and transportation planning applications (Model documentation is available at: http://www.sfcta.org).

[c]This model was developed by the California Air Resources Board and is used to calculate emission rates from all motor vehicles operating on highways, freeways, and local roads in California. EMFAC2007 is the most recent version (Software and additional information is available at: http://www.arb.ca.gov/msei/onroad/latest_version.htm).

[d]CAL3QHCR is an air dispersion modeling software package for predicting air quality impacts of pollutants near roadways, developed by Scientific Software Group. Sandy, UT. (Additional information is available at: http://www.scisoftware.com/products/calroadsview_overview/calroadsview_overview.html).

[e]SoundPLAN LLC. Shelton, WA. (Additional information is available at: http://www.soundplan.com).

[f]Results are being analyzed at the time of writing. Upon completion, findings will be posted online.[13]

TABLE 2—Key Issues, Findings, and Methods for Collaborative Research on Traffic, Health, and Environmental Justice: San Francisco, CA, 2006–2008

Issue	Findings[a]	Methods[b]
Traffic	The ratio of trucks and buses to overall traffic in areas where families live and children play exceeded 10%. At the corner of Still and Lyell streets, > 107 medium and big trucks passed in 1 hour.	Traffic counting
	Of the 18 city bus routes serving southeastern San Francisco, 83% were diesel bus lines and 17% were electric lines.	Personal contact, SFMTA
	Project-area residents documented the following negative health effects of traffic in their community: idling trucks, garbage and debris, air and noise pollution, freeway noise, traffic congestion, concentration of gas stations, and parked commuter cars.	Community photography
Air quality	Community survey participants reported smelling car, truck, or bus exhaust on their block in the past 6 months at least weekly (41%), daily (25%), or in the past 6 months (46%).[c]	Community surveying[d]
	Forty-four percent of respondents reported smelling car, truck, or bus exhaust in the places where they go to school, go to work, play in parks, or go elsewhere in their daily routine.	Community surveying[d]
	In the Excelsior neighborhood, 23% of residents live within 500 feet of busy roadways (≥ 100 000 vehicles/day), a significant source of air pollution; the citywide figure is 4%.	Secondary data analysis[e]
	More than 20% of respondents reported smelling car, truck, or bus exhaust in their homes in the past 6 months.	Community surveying[d]
	Roadway and freeway traffic modeling found PM 2.5 exposures 0.2–0.4 ug/m^3 greater than ambient levels. These elevated levels are associated with significant increased risk of heart, lung, and circulatory diseases for nearby families.[15]	Air quality modeling[f]
	Community traffic counts showed that truck traffic on Lyell and Still Streets was the greatest contributor to PM 2.5 exposure on those streets.	Air quality modeling,[f] traffic counting
Environmental noise	Neighborhood noise levels were in excess of those that the San Francisco General Plan deemed acceptable for new residential construction.	Noise modeling and monitoring[f]
	The project site was highly affected by noise in excess of 70 Ldn, which can increase blood pressure, elevate cortisol level, increase stress responses and associated heart disease, and cause annoyance, sleep disturbance, and reduced learning in children.	Noise modeling and monitoring[f]
	More than 35% of respondents reported that traffic noise from city buses, trucks, I-280, and neighborhood traffic interfered with the sleep of people in their household. An additional 37% reported the noise used to disturb their sleep, but they'd gotten used to it.	Community surveying[d]
	Areas at the end of Cayuga near I-280 had noise levels in excess of 70 Leq, attributable almost exclusively to freeway traffic.	Noise modeling and monitoring[f]
Pedestrian hazards	Twenty-seven percent of respondents reported that either a household member or neighbor had been hit by a vehicle while walking in the neighborhood.	Community surveying[d]
	In 2001–2005 in the project area, 55 motor vehicle collisions with pedestrians resulted in pedestrian injury or death. Only 15 of the 176 San Francisco census tracts had more such incidents in the same period (range = 0–191 collisions).	Secondary data analysis[g]
	Of respondents with children, 57% reported that neighborhood traffic dangers affected their willingness to let their children walk or play outside.	Community surveying[d]
Community demographics	From 1960 to 2000, the percentage of White persons living in the areas close to the freeway went from 98% to 39%.	US Census analysis[h]
	The proportion of foreign-born persons in the Excelsior area was 52% (37% citywide); the largest groups were from Mexico, El Salvador, China, Philippines, Nicaragua, and Guatemala.	US Census analysis[h]
	From 1960 to 2000, the number of children living in the project area and in areas close to the freeway dramatically increased.	US Census analysis[h]
	Two thirds of respondents were immigrants; >75% spoke a language other than English at home.	Community surveying[d]
	From 1960 to 2000, the population in the southeastern part of the city became more concentrated, particularly in neighborhoods closer to the freeway.	US Census analysis[h]
	I-280 became a barrier, or color line, because the dynamics on opposite sides of the freeway were very different.	US Census analysis[h]
Community health outcomes	In 2006, the neighborhood had the highest number of emergency department visits for asthma of all San Francisco neighborhoods (n = 266).	Secondary data analysis[i]
	According to 2000–2001 death data, the top neighborhood causes of death and illness were ischemic heart disease, stroke, lung cancer and other cancers, and chronic obstructive pulmonary disease, all of which are associated with increased risk from long-term exposure to air pollution as well as noise. Traffic collisions were among the top 10 causes of death and injury.[c]	Secondary data analysis[j]
	The neighborhood had the highest overall number of asthma hospitalizations of all San Francisco neighborhoods (538 hospitalizations with asthma as the principal diagnosis from 2001 to 2006).[c]	Secondary data analysis[i]
Community solutions	Almost 50% of respondents reported that reducing the number of trucks passing through their neighborhood would improve the community's health "a lot."[k]	Community surveying[d]
	Sixty-nine percent of respondents reported that ensuring their children have safe routes to and from school would improve the community's health "a lot." Among families with children, 82% felt that safe routes to and from school would improve the community's health "a lot."[k]	Community surveying[d]
	More than 75% of respondents reported that having nonpolluting buses would improve the community's health "a lot." Among those who reported smelling exhaust on their block in the past 6 months, 83% believed that having nonpolluting buses would improve the community's health "a lot."[k]	Community surveying[d]
	More than 50% of respondents reported that improving access to health care services would improve the community's health "a lot."[k]	Community surveying[d]
	More than 50% of respondents reported that building a sound wall next to the freeway would improve the community's health "a lot."[k]	Community surveying[d]

Note. SFMTA=San Francisco Municipal Transportation Agency; PM=particulate matter; Ldn=day–night average sound level; I-280=Interstate 280; Leq=equivalent constant decibel levels; respondents=participants in a community survey.
[a]The geographic area analyzed varied with different research methods and was largely determined by the availability of aggregated secondary data and project resources.
[b]Methods are described in Table 1.
[c]Finding cited in San Francisco Board of Supervisors. Resolution 081397[16]
[d]Community surveying targeted a 7-census block area proximate to the truck corridor (Figure 1). The completion rate was greater than 35% (52/146 occupied housing units in US Census 2000 data).
[e]Data are for the Excelsior Planning Neighborhood and were obtained from the Healthy Development Measurement Tool, a comprehensive evaluation metric to consider health needs in urban development developed by the San Francisco Department of Public Health.[17]
[f]The modeled area included the location of the freeway as well as the 1-way truck and traffic feeder routes for the Still–Lyell corridor and I-280 underpass (Figure 1).
[g]Data are for the census tract detailed in Figure 1. Pedestrian injury collision data obtained from the California Highway Patrol, Accident Investigation Unit, Statewide Integrated Traffic Records System.[18]
[h]Data are for the census tract detailed in Figure 1. Data for 1960 to 2000 obtained from Minnesota Population Center, National Historical Geographic Information System.[19]
[i]Data are for the Excelsior community zip code, 94112. Asthma hospitalization and emergency room data by resident zip code for San Francisco obtained by request California Breathing, a program in the California Department of Public Health's Environmental Health Investigations Branch.[20] Although differences between neighborhoods in population size and age composition do not allow for direct comparison, 2000 US Census data show that more than 12% of the city's asthma hospitalizations and 11% of asthma emergency room visits involved residents of this neighborhood (but only ~9% of all city residents).
[j]Data are for the Excelsior community zip code, 94112. These data were accessed from the San Francisco Burden of Disease and Injury Web site.[21]
[k]Community survey response options for these questions were "a lot," "a little," and "not at all."

(months) relative to health research (years) created an early challenge. The partnership created a key findings document (from which Table 2 was adapted) and incorporated findings as they emerged to resolve this tension, agreeing that partners could disseminate findings to external stakeholders with all collaborators' approval.

TRANSLATING RESEARCH TO ACTION

Our retrospective health impact assessment of I-280's construction on current transportation and health conditions created an opportunity to connect community knowledge, scientific research, and community action. PODER leaders used the key findings to create popular education activities to disseminate the message that health is dependent on the environment where we live and to demystify scientific information about pollution and health. Activities included workshops and training involving youth and adult community members, skits at community movie nights in the park, and a pamphlet containing community stories, comic art, and research findings. Media events at City Hall also educated residents and policymakers about traffic's health effects and the need for action. These activities allowed members to disseminate findings to audiences in diverse contexts.

Unlike freeway traffic, which is regulated by the state, local street traffic is under the purview of the local transportation agency, the San Francisco Municipal Transportation Agency (SFMTA), and can be regulated to address concerns about local health impacts. Community action thus focused on local policymakers, emphasizing health effects from the high volumes of diesel buses and trucks channeled along residential streets on their way to and from I-280 (Table 2).

With the evidence provided by our research, PODER mobilized community members to attend a SFMTA public hearing to demand action to reduce pollution and protect community health, such as deploying hybrid electric buses and creating a truck route network to keep trucks off residential streets.[25] Community members subsequently presented to SFMTA staff the southeast community bus lines they identified as of greatest concern for community exposure to pollution. SFMTA confirmed that hybrid buses are being deployed more often on those bus lines relative to the citywide system; however, they did not adopt a formal policy for priority deployment.

PODER youth and adult leaders lobbied the San Francisco Board of Supervisors to draft and adopt a resolution urging the SFMTA and SFDPH to consider health and environmental justice in transportation policymaking. At a Board committee hearing, PODER members and staff, SFDPH, community residents, and a key community ally, the Chinese Progressive Association, testified about the need to reduce the adverse health impacts of local truck traffic on southeast communities.[26] On November 25, 2008,[27] the Board unanimously passed Resolution 081397:

> [U]rging the Municipal Transportation Agency and the Department of Public Health to collaborate and create health protective truck route planning in Southeast Neighborhoods. Encouraging cooperation between DPH and SFMTA and the local community in identifying and correcting health and safety related issues associated with truck traffic. Urging DPH to create a truck related exposure map identifying areas of significant exposure to air quality, noise and traffic hazards. Urging SFMTA to create a mitigation plan to address the impacts of local truck traffic on residential communities of southeast San Francisco that protects community health and provides efficient routes for commercial vehicle traffic.[16]

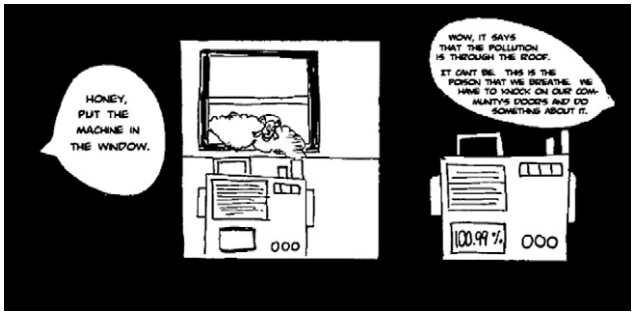

Image 1—Artwork by Ceci Baeza.

Image 2—PODER members translated their technical research experience into everyday language and creative expression about the community's real and perceived exposures with representations reflected in popular education materials including collages as well as comic art.

The resolution cites key participatory research findings (Table 2), among other community conditions and traffic-related health impacts. The resolution also reflects critical city political support for collaboration between the community, SFDPH, and SFMTA to expand the analysis of truck traffic's impact on residents'

health. One legislator invited city agencies and community stakeholders, including PODER, to meet in January 2009 to coordinate their response.

CONCLUSIONS

Our participatory research suggests the need for increased attention of public health agencies and environmental justice organizations to transportation planning. In an established urban residential neighborhood, the combination of a freeway and busy thoroughfares resulted in disproportionate, traffic-related health and environmental burdens. Although reversing such infrastructure decisions may not be feasible, our case study shows that participatory research can engage local public health and community partners in policy-relevant research that can inform solutions to transportation-related health hazards. Over time, we hope decision-makers will recognize that transportation decisions have multiple health impacts and will identify and avoid such disproportionately shared risks. ■

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Contributors

M. Wier coordinated the research project and conducted analyses. C. Sciammas led the community data collection, analyses, and research translation. E. Seto conducted data analyses and contributed to study design. R. Bhatia supervised and provided guidance to SFDPH researchers. T. Rivard originated the study and conducted data analyses. All authors contributed to writing the article, led by M. Wier and R. Bhatia.

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Human Participant Protections

This article describes a study carried out by community volunteers whose activities were not subject to protocol approval.

References

1. Frumkin H, Frank L, Jackson R. Urban Sprawl and Public Health: Designing, Planning, and Building for Healthy Communities. Washington, DC: Island Press; 2004.

2. Bullard RD. The anatomy of transportation racism. In: Bullard RD, Johnson GS, Torres AO, eds. *Highway Robbery: Transportation Racism & New Routes to Equity.* Cambridge, MA: South End Press; 2004:15–31.

3. San Francisco Planning Department. Glen Park community planning workshops: existing conditions memorandum. June 2003. Available at: http://www.sfgov.org/site/uploadedfiles/planning/citywide/pdf/gp_existingconditions_1.pdf. Accessed December 14, 2008.

4. California Department of Transportation. Traffic Data Branch. 2007. Available at: http://traffic-counts.dot.ca.gov/. Accessed July 30, 2008.

5. Applied Geographic Solutions, Inc. Spring 2007 Update: Current Year Estimates. San Francisco, California. Newbury Park, CA; 2007.

6. Bhatia R. Protecting health using an environmental impact assessment: a case study of San Francisco land use decisionmaking. *Am J Public Health.* 2007;97:406–413.

7. Corburn J, Bhatia R. Health impact assessment in San Francisco: incorporating the social determinants of health into environmental planning. *J Environ Plann Manage.* 2007;50:323–341.

8. Kemm J, Parry J, Palmer S, eds. *Health Impact Assessment: Concepts, Theory, Techniques, and Applications.* Oxford, UK: Oxford University Press; 2004.

9. Air Quality and Land Use Handbook: A Community Health Perspective. Sacramento, CA: California Air Resources Board; April 2005. Available at: http://www.arb.ca.gov/ch/handbook.pdf. Accessed May 27, 2009.

10. Seto EYW, Holt A, Rivard T, Bhatia R. Spatial distribution of traffic induced noise exposures in a US city: an analytic tool for assessing the health impacts of urban planning decisions. *Int J Health Geogr.* 2007;6:24 Available at: http://www.ij-healthgeographics.com/content/6/1/24. Accessed November 17, 2008.

11. Miedema HME, Vos H. Exposure response for transportation. *J Acoust Soc Am.* 1998;104:3432–3445.

12. Ewing R. Fatal and non-fatal injuries. In: Raimi M, Patrick S, Ewing R, Frank L, Kreutzer R. Understanding the Relationship Between Public Health and the Built Environment: A Report Prepared for the LEED-ND Core Committee. 2006:33–68. Available at: http://www.activeliving.org/files/LEED_ND_report.pdf. Accessed December 21, 2008.

13. San Francisco Department of Public Health. Pedestrian environmental quality index. Available at: http://www.sfphes.org/HIA_Tools_PEQI.htm. Accessed May 29, 2009.

14. Bhatia R, Rivard T. Assessment and Mitigation of Air Pollutant Health Effects from Intra-urban Roadways: Guidance for Land Use Planning and Environmental Review. San Francisco, CA: Department of Public Health; 2008. Available at: http://www.sfphes.org/publications/Mitigating_Roadway_AQLU_Conflicts.pdf. Accessed December 21, 2008.

15. Jerrett M, Burnett RT, Ma R, et al. Spatial analysis of air pollution and mortality in Los Angeles. *Epidemiology.* 2005;16:727–736.

16. San Francisco Board of Supervisors. Resolution 081397. November 25, 2008. Available at: http://www.sfgov.org/site/uploadedfiles/bdsupvrs/committees/materials/081397.pdf. Accessed December 10, 2008.

17. San Francisco Department of Public Health. Healthy development measurement tool. Available at: http://www.theHDMT.org. Accessed May 29, 2009.

18. California Highway Patrol. Accident Investigation Unit. Statewide Integrated Traffic Records System. 2008. Available at: http://www.chp.ca.gov/switrs/index.html. Accessed April 7, 2008.

19. Minnesota Population Center. National Historical Geographic Information System: Prerelease Version 0.1. Minneapolis: University of Minnesota; 2004.

20. California Department of Public Health. Environmental Health Investigations Branch. California breathing. 2008. Available at: http://www.californiabreathing.org. Accessed May 29, 2009.

21. San Francisco Dept of Public Health. San Francisco burden of disease and injury study: health outcomes. 2007. Available at: http://www.healthysf.org/bdi/outcomes/index.html. Accessed December 21, 2008.

22. California Air Resources Board and American Lung Association. Recent research findings: health effects of particulate matter and ozone air pollution. 2007. Available at: http://www.arb.ca.gov/research/health/fs/pm_ozone-fs.pdf. Accessed December 21, 2008.

23. van Kempen EE, Kruize H, Boshuizen HC, Ameling CB, Staatsen BA, de Hollander AE. The association between noise exposure and blood pressure and ischemic heart disease: a meta-analysis. *Environ Health Perspect.* 2002;110:307–317.

24. Lovegrove GR, Sayed T. Macrolevel collision prediction models for evaluating neighbourhood traffic safety. *Can J Civ Eng.* 2006;33:609–621.

25. San Francisco Municipal Transportation Agency. Public hearing. City Hall. May 20, 2008. Available at: http://www.sfmta.com/cms/cmta/SFMTABoardMay202008minutes.htm. Accessed May 29, 2009.

26. San Francisco Board of Supervisors, Land Use & Economic Development Committee. Meeting. City Hall. November 17, 2008. Available at: http://sanfrancisco.granicus.com/ViewPublisher.php?view_id=12. Accessed November 26, 2008.

27. San Francisco Board of Supervisors. Full board meeting. City Hall. November 25, 2008. Available at: http://sanfrancisco.granicus.com/ViewPublisher.php?view_id=10. Accessed December 24, 2008.