Understanding and Improving Arterial Roads to Support Public Health and Transportation Goals

Arterials are types of roads designed to carry high volumes of motorized traffic. They are an integral part of transportation systems worldwide and exposure to them is ubiquitous, especially in urban areas. Arterials provide access to diverse commercial and cultural resources, which can positively influence community health by supporting social cohesion as well as economic and cultural opportunities. They can negatively influence health via safety issues, noise, air pollution, and lack of economic development. The aims of public health and transportation partially overlap; efforts to improve arterials can meet goals of both professions.

Two trends in arterial design show promise. First, transportation professionals increasingly define the performance of arterials via metrics accounting for pedestrians, cyclists, transit riders, and nearby residents in addition to motor vehicle users. Second, applying traffic engineering and design can generate safety, air quality, and livability benefits, but we need evidence to support these interventions.

We describe the importance of arterials (including exposures, health behaviors, effects on equity, and resulting health outcomes) and make the case for public health collaborations with the transportation sector. (*Am J Public Health*. 2017;107:1278–1282. doi:10.2105/AJPH.2017.303898)

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Motorized traffic is an essential part of modern life, but it also contributes to air and water pollution, fatal and nonfatal injuries, noise, and diminished quality of life related to traffic near residences. These are well-known public health problems in the United States and globally.[1] In response, those in public health and urban planning have attempted to prioritize healthier forms of travel and land development to reduce automobile dependence. The public health profession has supported sustainable transportation policies and programs such as expanding public transit services, investing in transit-oriented land development, expanding opportunities for walking and cycling, implementing complete streets policies to improve infrastructure for all road users, and applying health impact assessments (HIAs) to transportation policies and projects.

However, it is equally important for the public health profession to address cars and other motorized traffic and the settings in which they operate. Doing so requires a complex way of thinking that allows for the idea that high traffic volumes can be managed in a manner that reduces negative effects on health and sustainability. One type of road—the arterial—warrants special attention from public health because its characteristics result in intense automobile use relative to other road types, leading to diverse influences on public health and health equity, and it is subject to ongoing redesign and reconstruction on an actionable time scale.

In this commentary, we define arterial roads and outline the exposures, health behaviors, and resulting outcomes associated with them. We emphasize arterials because, unlike interstates and freeways, they allow for mixed travel modes that present significant and unique challenges for pedestrians, cyclists, and transit riders. Arterial roads are also common sites for redevelopment and transportation upgrades, thus providing opportunities for public health and transportation professionals to work together. We discuss ways in which advanced street designs and technologies could improve arterials' relationship to individual and community health and offer ideas for high-impact, multidisciplinary policy and design strategies to improve arterial roads for public health. Social equity is a critical theme relevant to arterials. Applying a health lens to arterials requires understanding practices in roadway planning and land development that influence inequities and resulting health disparities.

DEFINING ARTERIAL ROADS

Arterial roads have diverse manifestations. They include rural and urban roads and roads with two to 10 lanes, and they may carry between 2000 and 55 000 vehicles per day. In 2011, arterials accounted for between 25% and 73% of all vehicle miles traveled in the United States; the range of this estimate illustrates the difficulty in classifying these roads.[2] Despite their heterogeneity, the field of transportation has generally defined arterials near the top of the hierarchy of streets because they mediate traffic flows between local streets and larger freeways (Figure 1).[2]

The hallmark of arterial design is a compromise between the competing priorities of mobility and access. To optimize mobility, system designers create arterials with wide travel lanes, long sight distances, wide clear zones

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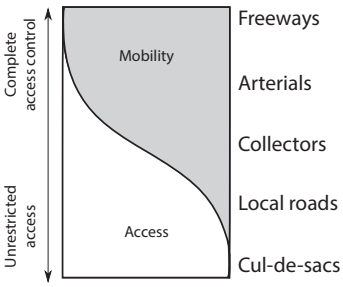

Source. Adapted from the Federal Highway Administration.[2]

FIGURE 1—Functional Road Classification System

without trees or parking, and wide curb radii for easy turning movements. In combination, these physical design elements facilitate high traffic speeds and volumes. However, arterials are also often lined with residential, cultural, and commercial destinations that generate and attract local and multimodal trips. As a means of optimizing access, arterials can have pedestrian- and transit-oriented designs, driveways and parking that make car access safer and easier, and land use nodes that concentrate activity instead of strip development.

Problems occur when system designers do not achieve balance among arterials' multiple functions. For example, arterials designed to maximize traffic speeds and volumes result in high levels of noise and air pollution and present accessibility challenges for nearby residents, pedestrians, bicyclists, people with disabilities, and transit riders. These roads are also prone to congestion, travel delays, and unreliable travel times that make them unpleasant for all users.

EXAMPLES OF ARTERIALS

Certain arterials can be vibrant, providing mobility as well as access to cultural and economic resources. In the United States, arterials in major cities such as Second Avenue in Manhattan, New York; Rockville Pike in suburban Washington, DC; and Telegraph Avenue in Berkeley, California, are examples of arterials with high traffic volumes, rich economic and cultural resources, and, to some extent, opportunities for pedestrians and cyclists. Recognizing the need to do better, transportation professionals and community groups are now planning the McGrath Boulevard project connecting Somerville and Cambridge, Massachusetts. The proposal calls for removing the existing viaduct and replacing it with an at-grade boulevard that would connect the surrounding neighborhoods, provide land for new housing units, and enable safe access for multiple types of road users.[3]

This case illustrates trends in arterial design that show promise for improving public health through transportation. First, the designers used metrics that accounted for pedestrians, cyclists, transit riders, and nearby residents, in addition to motor vehicle users, to frame the performance of McGrath. Second, the project will involve traffic engineering and road designs that can improve safety, air quality, and livability while accommodating high traffic volumes. Third, the McGrath project focuses on environmental justice concepts, and the design process included an HIA.[3]

Arterial designs such as that for McGrath Boulevard cannot maximize any single function such as traffic volume, accessibility, vehicle speed, or safety. However, by combining design strategies such as roundabouts, bus queue-jump lanes, and bicycle signals, they can serve multiple functions and play a vital and positive role in their communities.

HEALTH IMPLICATIONS OF ARTERIAL ROADS

An extensive health literature has documented the adverse effects of exposure to vehicle-produced pollution, including increased risks of cancer, respiratory and cardiovascular diseases, and poor birth outcomes.[4] For example, research on low birth weights in Europe and the United States has shown that a mother's exposure to traffic on nearby streets increases the odds of low birth weight, and these odds increase with increasing traffic density.[5,6] Over several decades, this evidence has led to the development of cleaner fuels and vehicles and reduced morbidity and mortality related to air pollution. However, high traffic density on arterial roads remains a significant source of negative health effects.

Arterials are generally smaller than major freeways, but they can cause similar levels of noise and air pollution. Depending on specific traffic conditions, these problems may be even greater for arterials than for freeways.[7] Indoor air quality near arterials has also been a major concern as cities and regions increasingly adopt policies that encourage new high-density housing and transit-oriented development along existing arterial corridors (infill development).[8] Corridors classified as arterials cause more noise annoyance than nonarterial roads, although neighborhood-level differences in noise insulation also determine noise annoyance outcomes.[9]

Injury prevention is another area that calls attention to arterials. Arterials expose pedestrians, cyclists, and transit riders to safety hazards because they offer both multimodal access and high traffic volumes without sufficient protection. Transportation injury metrics do not generally include separate data for arterial roads in the United States, but research on road design and traffic suggests that arterials are an injury risk factor.[10] Linking georeferenced crash information (e.g., information from the Fatality Analysis Reporting System, Crash Outcome Data Evaluation System, and General Estimates System) to environmental data would enable detailed safety analyses of arterials.

Arterials can function as physical barriers that diminish social and economic connections among neighborhoods. Barriers to access are a transportation problem and health problem for many populations, particularly older and younger travelers, people with limited physical mobility, and people living in low-income communities.[11,12] On some arterials, exposure to incivilities such as graffiti, prostitution, and drug and alcohol use limits access and may be associated with stigma and chronic stress.[13,14]

Although many arterials are problematic from a public health perspective because of their heavy traffic and inadequate infrastructure for other transportation modes, better design of arterials could reduce their negative effects on public health (see the box on the next page). Those involved in developing and redeveloping arterial roads should consider not only mitigating the negative effects of heavy traffic but also how arterials can be successful places for social, cultural, and economic interactions.

For example, communities that experience problems related to residential and commercial displacement could leverage planning processes for neighborhood arterials to provide housing and to support neighborhood-serving businesses. Similarly, arterials can be critical opportunities for cities and towns to implement green infrastructure to reduce greenhouse gas emissions, mitigate urban heat-island effects, and improve water quality through stormwater management.[15]

INNOVATIVE TRANSPORTATION STRATEGIES

Because arterials are frequently the object of redesign and reconstruction, they offer an opportunity to implement innovative strategies in corridor planning, traffic management, transit service, land development and redevelopment, and urban design. Although there has been little investigation of how these strategies influence public health, they have the potential to reduce air and noise pollution, mitigate climate change, aid in climate change adaptation, and increase safety and livability. Such strategies could be used to improve public health if more information on their health effects was available.

Traffic operations interventions such as coordinated traffic signals, connected and automated vehicles, and other tools within the broader category of intelligent transportation systems can help achieve higher person flows with the existing road infrastructure, thereby reducing the need to widen lanes or add new construction. Examples of intelligent transportation systems that could have positive effects on public health include traffic signals that prioritize transit, electronic tolling systems that manage traffic congestion, automated speed enforcement and dynamic speed limits that change with traffic conditions, and optimization of traffic flows across the entire road network (not only freeways) during peak travel times.

These tools have the potential to reduce fuel use, decrease emissions, and improve safety.[16] Whereas previous research has focused primarily on their capacity to mitigate congestion, future research should expand the evidence base to include their potential health benefits and adverse health effects when implemented in the context of arterial redesign.[17]

HEALTH EQUITY IMPLICATIONS OF ARTERIAL ROADS

Health equity is the "attainment of the highest level of health for all people . . . with focused and ongoing societal efforts to address avoidable inequalities, historical and contemporary injustices, and the elimination of health and health care disparities."[18] Arterial roads represent a point of entry into some of the larger relationships between transportation, land development, and equity. Estimates of the percentage of the US population living close to high-traffic roads range from 4% to 19%, depending on road type definitions and assumptions about distance. These percentages are higher among people of color and low-income households, as well as people who are foreign-born or who do not speak English at home.[19,20]

In urban areas, the building of highways through low-income neighborhoods combined with past discriminatory housing policies has had disproportionately negative effects on people of color, individuals experiencing poverty, and people with disabilities. There are numerous examples of how transportation and land development policies have resulted in gentrification and displacement of historically marginalized populations.

Promoting health equity through arterial roads involves addressing the underlying institutional, political, economic, and social factors that have historically determined levels of transportation service and investment, as well as the distribution of service and investment across people and places.[21] Future design of arterials can advance health equity by directing transportation investments to areas that are historically underserved and by implementing policies that promote environmental, social, and economic justice and ensure safe and healthy communities for all.

Promoting health equity via design of arterial roads requires incorporating a broader set of performance measures than traditional transportation metrics such as motor vehicle speed and volume. Policies at multiple levels (federal, state, regional, and local) determine arterial design, thereby necessitating a concerted effort to alter performance criteria.

SELECTED DESIGN CHARACTERISTICS OF ARTERIALS THAT POTENTIALLY PROMOTE OR HINDER HEALTH

Health-Promoting Design	Unhealthy Design
Neighborhood asset for access and commerce	Physical barrier that divides neighborhoods
Supports neighborhood social and cultural connections	Exhibits neglect and physical decay
Safe travel speeds for all users	Traffic speeds too high to be safe for all users
Comfortable for all users to cross	Difficult to cross because of design and traffic
Link within pedestrian and bicycle networks	Barrier within pedestrian and bicycle networks
Designed to mitigate air pollution	Near-roadway air pollution
Designed to mitigate noise	Source of noise
Accessible to users of all abilities	Inaccessible to users with disabilities
Supports green infrastructure systems	Impervious paving materials, lack of shade
Contributes to revitalization without displacement	Location of residential and business gentrification

DECISION-MAKING AND POLICY

An examination of arterial roads offers insight into the larger question of how shared governance between health and transportation can be

implemented. With respect to decision-making, research and practice in the area of arterials have shown that better designs result from increased cross-sector engagement. However, previous experience also shows that the process will be more complex and time intensive than is the case with traditional transportation planning. It will also require more funding and resources, better methods for working with the general public and the private sector, and discretion to work outside of older design standards and adopt new ones.[22] Tools such as HIAs have been used to guide transportation corridor designs, but their use has been driven by the public health sector with inconsistent support from transportation.[23] Therefore, we should consider a variety of decision-making models to bridge disciplinary knowledge as well as scales of intervention.

Multidisciplinary education and models of professional practice have been critical in advancing environmental issues in transportation, and this is also true for the health–transportation nexus. There are a small number of multidisciplinary transportation, planning, and public health programs in the United States (e.g., at Portland State University; the University of California, Berkeley; and the University of Colorado Denver), and intersections between health and transportation are the focus of several professional conferences (e.g., the Active Living Research Annual Conference and the International Conference on Transport and Health). More could be done to institutionalize these themes at established health and transportation research forums such as the annual meetings of the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine and the American Public Health Association.

Research and evaluation of design options for arterials that include both health and transportation concerns are also needed. For example, the National Institutes of Health has funded several projects evaluating transit via a "natural" experiment approach, but these initiatives have largely focused on outcomes related to physical activity and body weight. Nevertheless, such studies could serve as a model for funding research on arterials. Health researchers are also developing novel approaches to assessing built environments and behavior; one example is the Archive of Many Outdoor Scenes Web cam time series, which has been used to analyze pedestrians' and cyclists' use of streets before and after reconstruction.[24] In addition, there are opportunities to link surveys and survey questions to combine individual-level health measures with built environment variables.[25]

CONCLUSIONS

Practitioners in transportation, urban planning, and public health have a desire for guidance and evidence to make decisions about arterial roads. When roadway designers, operations engineers, public health professionals, and sustainability planners work together, they may ask what makes for a "high-performing arterial." However, researchers, practitioners, and planners have different criteria for performance. The key opportunity is to bring together transportation and public health, and continue to incorporate different performance measures into decision-making about arterial design, balancing the complementary and competing demands of transportation- and health-related goals.

As health policy increasingly includes transportation among the larger set of social, political, and economic determinants of health, it should focus on elements of the transportation system that have widespread effects on health behaviors and outcomes, and that have the potential to advance health equity. Accomplishing this aim requires engaging directly with the various issues regarding the relationship between health, health equity, and motorized traffic. Arterial roads have a profound influence on local and regional transportation and health, and integrating health and transportation goals to improve arterials could have significant effects on diverse health, transportation, equity, and economic goals. AJPH

CONTRIBUTORS

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REFERENCES

1. World Health Organization. Healthy transport in developing cities. Available at: http://www.who.int/heli/risks/urban/transportpolicybrief2010.pdf. Accessed May 25, 2017.

2. Federal Highway Administration. Highway functional classification concepts, criteria, and procedures. Available at: https://www.fhwa.dot.gov/planning/processes/statewide/related/highway_functional_classifications/fcauab.pdf. Accessed May 25, 2017.

3. Massachusetts Department of Public Health. Health impact assessment of the Massachusetts Department of Transportation Grounding McGrath Study. Available at: http://www.mass.gov/eohhs/docs/dph/environmental/hia/hia-mcgrath-final-report.pdf. Accessed May 25, 2017.

4. Landrigan PJ. Air pollution and health. *Lancet Public Health*. 2017;2(1):e4–e5.

5. Pedersen M, Giorgis-Allemand L, Bernard C, et al. Ambient air pollution and low birthweight: a European cohort study (ESCAPE). *Lancet Respir Med*. 2013;1(9):695–704.

6. Wilhelm M, Ghosh JK, Su J, et al. Traffic-related air toxics and term low birth weight in Los Angeles County, California. *Environ Health Perspect*. 2012;120(1):132–138.

7. Ryan PH, LeMasters G, Biagini J, et al. Is it traffic type, volume, or distance? Wheezing in infants living near truck and bus traffic. *J Allergy Clin Immunol*. 2005;116(2):279–284.

8. Garzón C, Dominie W, Gordon M. Pollution-free housing for all: coalition-based research, education, and advocacy for healthier housing in transportation and land use planning in the San Francisco Bay Area. *Environ Justice*. 2014;7(6):186–190.

9. Seto EY, 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.

10. Dumbaugh E, Gattis JL. Safe streets, livable streets. *J Am Plann Assoc*. 2005;71(3):283–300.

11. Anciaes PR, Boniface S, Dhanani A, et al. Urban transport and community severance: linking research and policy to link people and places. *J Transp Health*. 2016;3(3):268–277.

12. Decker A. Stuck at home: when driving isn't a choice. Available at: http://www.accessmagazine.org/wp-content/uploads/sites/7/2016/07/Access-29-05-Stuck-at-Home.pdf. Accessed May 25, 2017.

13. Loukaitou-Sideris A. Inner-city commercial strips: evolution, decay—retrofit? *Town Plan Rev*. 1997;68(1):1–29.

14. Kondo MC, Gross-Davis CA, May K, et al. Place-based stressors associated with industry and air pollution. *Health Place*. 2014;28:31–37.

15. US Environmental Protection Agency. Managing wet weather with green infrastructure. Available at: https://www.epa.gov/sites/production/files/2015-10/documents/gi_munichandbook_green_streets_0.pdf. Accessed May 25, 2017.

16. Shaheen SA, Lipman TE. Reducing greenhouse emissions and fuel consumption: sustainable approaches for surface transportation. *IATSS Res*. 2007;31(1):6–20.

17. Jordan B, Makler J, Bertini R. State of knowledge and practice: opportunities for intelligent transportation systems in the energy arena. *Transp Res Rec*. 2014;2423: 1–9.

18. US Department of Health and Human Services, Office of Disease Prevention and Health Promotion. Disparities. Available at: https://www.healthypeople.gov/2020/about/foundation-health-measures/Disparities. Accessed May 25, 2017.

19. Rowangould GM. A census of the US near-roadway population: public health and environmental justice considerations. *Transp Res D Transp Environ*. 2013;25: 59–67.

20. Tian N, Xue J, Barzyk TM. Evaluating socioeconomic and racial differences in traffic-related metrics in the United States using a GIS approach. *J Expo Sci Environ Epidemiol*. 2013;23(2):215–222.

21. Bullard RD, Johnson GS, Torres AO, eds. *Highway Robbery: Transportation Racism & New Routes to Equity*. Cambridge, MA: South End Press; 2004.

22. Porter CD. Coordinating transportation and land use. *ITE J*. 2006;76(6): 28–32.

23. Dannenberg AL, Ricklin A, Ross CL, et al. Use of health impact assessment for transportation planning: importance of transportation agency involvement in the process. *Transp Res Rec*. 2014;2452:71–80.

24. Hipp JA, Adlakha D, Eyler AA, et al. Emerging technologies: webcams and crowd-sourcing to identify active transportation. *Am J Prev Med*. 2013;44(1): 96–97.

25. Cavoli C, Christie N, Mindell J, et al. Linking transport, health and sustainability: better data sets for better policy-making. *J Transp Health*. 2015;2(2): 111–119.