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Can traffic management strategies improve urban air quality? A review of the evidence

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ABSTRACT

This paper reviews the effectiveness of traffic management strategies (TMS) for mitigating emissions, ambient concentrations, human exposure, and health effects of traffic-related air pollution in urban areas. The objective is to summarize the evidence base for a range of moderate-scale strategies broadly relevant to municipal and regional government decision-making. A systematic literature search was carried out to identify empirical studies of TMS effects on emissions, air quality, exposure, or health. Identified studies were reviewed to assess the state of evidence that TMS can improve urban air quality and pollution-related health outcomes for exposed populations. Overall, the evidence base is weak for these effects. There is limited evidence of effects on emissions for 7 of the 22 studied strategies, and limited evidence of effects on air quality for 2 of the strategies: area road pricing and low emission zones. Insufficient evidence exists for all other TMS and effects. Existing evidence suggests that aggressive area-based TMS such as low emission zones are needed to generate substantial air quality benefits, and that TMS must be implemented with care to avoid unintended detrimental and rebound effects. The evidence base is limited by a lack of ex post evaluations of implemented strategies, lack of evaluation of exposure and health impacts, small intervention effects relative to the influences of other factors, and insufficient evaluation of spillover and indirect effects. Evolving vehicle fleets add further uncertainty to the long-range effects of TMS on air quality. Effects of TMS on measured population exposure and public health outcomes have not been well-studied. An evidence-based approach to transportation systems planning necessitates additional resource allocation to ex post evaluations and performance monitoring for air quality impacts of traffic management strategies.

1. Introduction

On-road motor vehicles are a major source of air pollution in cities. There is a large and long-established body of literature demonstrating substantial negative health effects for urban populations exposed to traffic-related air pollution. In addition, our knowledge about the health impacts of exposure to certain components of motor vehicle emissions is still evolving, especially for small particles and toxic compounds. Various efforts are underway in urban areas around the world to mitigate the impacts of traffic-related air pollution. Those efforts are typically focused on development and deployment of new vehicle and fuel technologies and on management of traffic and travel activity. Through decades of efforts, substantial reductions in vehicle emission rates have been

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Table 1
Categorization of traffic management strategies used in this review.

Operating restrictions & pricing	RCP	Road, congestion and cordon pricing: tolling, distance pricing, or pricing based on time-of-day or congestion levels
	LEZ	Low/zero emission zones and eco-zones: pricing or restrictions based on emissions status of vehicles
	VOR	Vehicle operating and access restrictions: by zone, time-of-day, or route
	PKM	Parking management: supply and pricing strategies
Lane management	HOL	High occupancy vehicle (HOV), High Occupancy Toll (HOT), and eco-lanes
	TBL	Truck and/or bus lanes
	LCC	Lane capacity changes (road diets, peak shoulder running)
Speed management	LSL	Lower speed limits
	VSL	Variable speed limits
	SCD	Speed control devices: traffic calming such as humps, chicanes, micro-roundabouts
	SED	Speed enforcement devices & programs
	ED	Eco-driving, eco-routing (not requiring significant new technology)
Traffic flow control	RM	Ramp meters
	ETC	Electronic toll collection
	IMS	Incident management systems
	ICD	Intersection control device: roundabout, signal, stop signs, etc.
	TST	Traffic signal timing: signal coordination, adaptive signal systems, transit signal priority, etc.
Trip reduction strategies	SRP	Shared-ride programs: carpool/vanpool/rideshare programs, incentives, and services
	EP	Employer programs for trip reduction: flex-time, telework
	TI	Transit improvements: pricing, service quality, etc.
	PBF	Pedestrian and bicycle facilities: roadway & trip-end facilities
	OM	Outreach & marketing (to reduce auto use)

achieved in some countries, largely through vehicle and fuel regulations and technology development. However, traffic-related air pollution still poses a substantial public health risk in many cities around the world, including in North America where emissions rates have decreased dramatically (Beelen et al., 2014; Brauer et al., 2012; Cheng et al., 2016; Denier van der Gon et al., 2013; Grigoratos and Martini, 2015; Health Effects Institute, 2010; Lelieveld et al., 2015; McDonald et al., 2013; Moussa et al., 2016; Pascal et al., 2013; U.S. U.S. Environmental Protection Agency, 2015).

This paper reviews the effectiveness of traffic management strategies (TMS) for mitigating emissions, ambient concentrations, human exposure, and health effects of traffic-related air pollution in urban areas. The objective of this paper is to summarize the evidence base for a range of moderate-scale strategies broadly relevant to municipal and regional government decision-making, particularly in the North American context. From the perspective of a city or region seeking direct and immediate action to reduce traffic impacts on air quality, only a subset of potential mitigation strategies is available or viable within typical governance structures. Examples include vehicle operating restrictions, road pricing, traffic operations improvements, traffic calming, and soft measures such as the promotion of active transportation and carpooling. TMS that involve extensive capital investments, such as new transit lines or roadways, are beyond the scope of the review, as are strategies focused on vehicle and fuel technology (e.g. vehicle and engine emission regulations), which are typically implemented at higher levels of government and affected by broader economic and technical factors.

A systematic literature search is carried out to identify empirical studies of TMS effects on emissions, air quality, exposure, or health. Identified studies are reviewed to characterize the state of evidence that TMS can improve urban air quality and pollution-related health outcomes. Knowledge gaps, methodological issues, and implications for practice and research are discussed.

1.1. Traffic management strategy categorization

The categorization of TMS in this review (Table 1) is distilled from taxonomies of Travel Demand Management (TDM) strategies, Transportation Control Measures (TCM), Congestion Mitigation and Air Quality Improvement Program (CMAQ) projects, and other relevant analyses (Adler et al., 2012; Battelle and Texas Transportation Institute, 2014; Cambridge Systematics, 2009; Hitchcock et al., 2014; Hodges and Potter, 2010; ICF International, 2006; Litman, 2003; U.S. U.S. Environmental Protection Agency, 2011a, b). Inevitably, there is some potential for strategies to cross over multiple categories. In addition, the following strategies are beyond the scope of the review and so excluded from the categorization: large infrastructure projects such as new transit lines and roadways, new vehicle and fuel technologies, new transportation services and sub-systems such as bike-share car-share systems, anti-idling infrastructure such as truck stop electrification, land use planning, shielding strategies to reduce exposure such as noise and vegetative barriers, as well as strategies not within the scope of direct action by municipal and regional governments (e.g. fuel prices).

1.2. Principal effects pathways

The principal effects pathways through which TMS can lead to pollution-related health effects are illustrated in Fig. 1. Only effects within the scope of this review are illustrated, so pathways such as health effects through changes in physical activity resulting from travel mode choices and access to healthcare are excluded (Brown et al., 2017; Neutens, 2015). TMS can influence travel activity (the number of trips generated and their distribution in space and time), travel mode choices (principally single-occupant vehicles versus multi-occupant vehicles, public transit, or non-motorized modes), vehicle speeds (including speed dynamics such as accelerations and