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Sustainable Strategies to Mitigate Toxic Impacts of Transportation System on the Environment

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Toxic pollutants in the air are also called "Hazardous Air Pollutants" or HAPs [1], which may cause or be suspected to cause serious health ailments such as cancers [2-4]. For example, the exposure to airborne participate matter (PM) and ozone is highly correlated with the mortality and respiratory/cardiovascular disease [5]. Transportation is one of the major sources to generate HAPs [6], while there could be at least 188 HAPs from transportation system, as was indicated in The Clean Air Act Amendments of 1990 [7]. The road traffic exhaust emissions adversely impact urban air quality on human health and the production of tropospheric ozone [8,9]. Ninety percent road transportation relies on fossil fuel (natural gas, coal, oil), the burning of which produces 23% of global greenhouse gas emissions [10]. Six of the 21 Mobile Source Air Toxic (MSAT) compounds (benzene, 1, 3-butadiene, formaldehyde, acrolein, acetaldehyde, and Diesel Particulate Matter (DPM)) are with the highest influence on [1]. It is therefore very urgent to develop comprehensive strategies to control the toxic emissions from all aspects of the transportation sector.

A transportation system with "green" vehicle and "green" travel habit as well as the specially designed infrastructure with less social, environmental, and climate impacts are summarized as a popular term of "sustainable transportation", or "green transportation" [11]. The negative impacts of a sustainable transportation system should be sustained into the indefinite future with no irreparable harm to the globe in future generations [12]. The green transportation includes at least the following mode: (1) Bicycle, (2) Electric bike, (3) Electric vehicle, (4) Green trains, (5) Electric motorcycles, (6) High occupant vehicles, (7) Service and fright vehicles, (8) Hybrid cars, (9) New hybrid buses, and (10) Pedestrians [10].

The U.S. Department of Transportation proposed a "connected vehicle" program to address the joint challenges in safety, mobility, as well as environment, where the Applications for the Environment: Real-time Information Synthesis (AERIS) research program is its environmental component aiming to reduce the toxic pollutions from transportation sector via high technologies [13]. The transformative concerts of the AERIS include: (1) Eco-signal operations, (2) Dynamic eco-lanes, (3) Dynamic low emissions zones, (4) Support alternative fuel vehicles operations, (5) Eco-traveler information, and (6) Eco-integrated corridor management [14]. Similarly, the European Federation for Transport and Environment (T&E) also promotes sustainable European transportation, which is environmentally responsible, economically sound, and socially just [15].

The strategies to mitigate transportation toxic impacts can be categorized into the following aspects: (1) Policy related strategies, (2) Planning related strategies, (3) Design related strategies, (4) Construction and maintenance related strategies, and (5) Operation related strategies.

Transportation, environmental, and even economic policies would definitely alter travel patterns and thus possibly reduce the emitted toxic pollutants from the transportation system [16,17]. For example, the Penghu Low Carbon Island policy conserves energy and reduces carbon emissions in the Penghu Island with a population of 85,000 as a test bed [18]. Demand management is another widely used policy that can influence travel behaviors and the level of toxic pollutants [19].

Transportation planning includes the evaluation, assessment, design, and siting of transportation facilities, which also controls the density of roadway network and the assignment of traffic. A proper planning should consider the environmental impacts from all vehicles in the roadway system at all-time intervals. The traffic assignment as well as the used travel demand model should comply with the requirements in environment aspect [20,21]. The United States requires all Metropolitan Planning Organizations (MPOs) must demonstrate the consistency with the commitments to meeting national air pollution standards [22].

Compared with other aspects of transportation development process, there is less attention placed on infrastructure design related strategies to reduce toxic pollutions [23]. Most existing roadway design standards (geometric design, traffic signs and signals…) do not consider vehicle emission as a major factor. Recent studies suggested that, freeway weaving segment design (type and length) should consider the resulted exhaust emission [24], noise [25], and heart rate variability [23]. Besides, You et al. [26] developed a model to characterize the relationship between roadway curve radii and vehicle emissions, which might help to identify the proper geometric designs related to lower emissions. Boriboonsomsin and Barth examined the impacts of the configuration of high-occupancy lane on emissions [27].

Construction and maintenance related strategies evaluate and control the generated emissions from traffic [28,29], from the energy consumption especially for construction and maintenance [30], and even from the construction materials [31-33]. The life cycle based risk assessment [32,34] or a hybrid life cycle assessment approach [35] is often used to evaluate the impacts of construction process on toxic pollutants.

In recent years probably the most popular emission reduction strategies are related to traffic operations, the significant efforts of which are the so-called "eco-driving". Eco-driving provides drivers with a variety of advices [36-38], and provision of signal phase and timing information may enhance vehicle fuel consumption efficiency [39]. In the eco-driving system, the level of emission reduction depends on the real traffic condition, and the automatic vehicle could save up to 20% CO_2 [40].

Clearly, all above-mentioned sustainable strategies work effectively in each reported case, which however lacks systematic efforts to comprehensively design all these and even beyond strategies to significantly reduce the toxic impacts of transportation system on the environment and public health, and even the entire ecological system of the earth. It is time for stakeholders, decision makers, researchers, engineers, technicians, and the public to work together towards a standardized green and healthy transportation system for not only ourselves, but also our great grandchildren.

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