Measuring the invisible: quantifying the CO_2 emission reductions from transport solutions in Hanoi, Vietnam

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Abstract

Working with local experts, the authors developed a transport emissions model for Hanoi, Vietnam, after collecting transport activity data, developing emissions factors, and assigning emissions values to past, present and future levels of passenger transport activity scenarios. A set of two scenarios were used to illustrate emissions impacts of two alternative transport policies previously outlined in the Hanoi Integrated Development and Environment Program (HAIDEP; ALMEC 2007) Master Plan. One policy emphasized improving public transport, while the other is a business-as-usual scenario with a higher automobile growth. These mutually exclusive policies were thought to represent the most probable future scenarios for the city's transport system. This study assumed changes in the demand and supply of transport services, as well as policies for investment and vehicle emission standards that have been deemed reasonable by various experts. If the government promotes public transport to a higher degree and mandates stricter fuel quality and vehicle emission standards, criteria pollutant emissions may be stabilized in 2020 at 2005 levels, while still allowing the same level of mobility. CO_2 emissions from passenger transport will increase as shown in all scenarios, but less so if vehicles are less fuel intensive and the share of public transport is higher. Nevertheless, the sooner emissions mitigation measures are implemented, the lower future emissions will be. And the dominance of the two-wheeler as the main form of transport invites speculation whether this vehicle might be key to sustainable transportation in dense cities.

Introduction

In 2007, HAIDEP Plan was developed for the government of Hanoi to analyze many of its development and environmental challenges, particularly the problem of increasing traffic. In 2005, 84% of all households owned a motorcycle, and 40% of these had more than two (ALMEC 2007). Although car ownership is still low—only 1.6 % of households own a car - this figure has increased rapidly, posing a threat to fluid traffic flow in some locations. While bus services have expanded quickly, public transport's share in the total urban transport demand is still only 5%. The once important *cyclo* (bicycle rickshaw) started its decline in the early 1990s with the introduction of taxis and the informal but tolerated *xe om* (motorcycle taxi). Rapid economic growth at a rate of 11% per year is expected to further accelerate ownership and use of private vehicles, such as motorcycles and cars.

People's use of transportation has changed drastically in this decade, from walking and riding bicycles to riding motorcycles, to the point where the motorcycle is now the main transport mode in Hanoi. Similar patterns occur in other Asian cities as well, but Hanoi is exceptional in terms of high motorization and degree of private transportation (Schipper at al., 2006). About two-thirds of work commutes are by motorcycle. On the other hand, more than half of school commutes are by bicycles. This study analyzes two scenarios of future traffic and transport. The complete study is found in Schipper et al. 2007.

Methodology

This study adopted the basic approach developed by Schipper, Marie, and Gorham (2000), and elaborated in Schipper, Cordeiro, and Ng (2007), to estimate the impact of an area-wide transport demand pattern on emissions of carbon dioxide

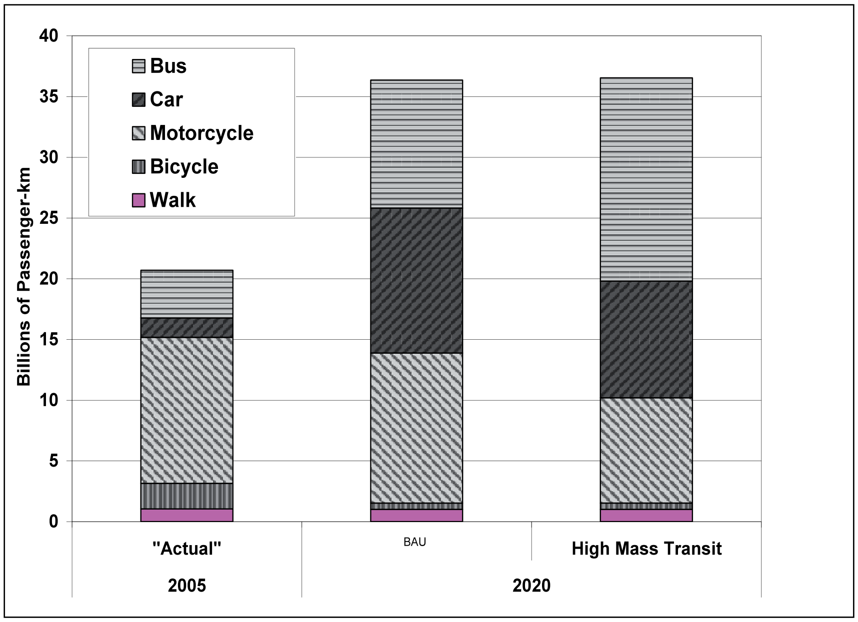

Figure 1. Passenger kilometers by mode. Passenger kilometers by mode shown for 2005 and projected by the HAIDEP study for 2020. (Source: Elaborated from ALMEC, 2007)

(CO_2) and other pollutants. This approach covers direct emissions from exhaust emitted at the tailpipe. The total road transport activity in the study area was classified according to the following transport modes: walking, bicycle, motorcycle, car, truck, bus, and urban rail (the last of which was not treated here because of a lack of data). The emission coefficients were developed by Le Anh Tuan of the Hanoi University of Technology. We used the following "ASIF" equation, where the summation is overall vehicle types and fuel types (Schipper, Marie, and Gorham, 2000).

$$\text{Aggregate Emissions By type (g)} = \sum \left[\text{Distance Traveled by vehicle type (km)} \times \text{Emission Factor by vehicle type (g/km)} \right]$$

This study analyzed transport activity, fuel use and vehicle technology data for 1995 and 2005 to calculate the corresponding emissions generated in Hanoi by the transport sector. In 1995 an origin-destination survey was undertaken as part of the previous Hanoi urban transport study, and the ALMEC study provides activity data for 2005. This study developed estimates of emissions for 2020, based on two activity scenarios provided in the HAIDEP study and four vehicle emission standards chosen by *EMBARQ*. The main difference between the two traffic activity scenarios analyzed was the scale of the public transport system.

- The first traffic scenario, Business as Usual, adopts the current trends in public transportation penetration. Public transport will continue to be supplied by buses in mixed traffic, and the number of trips taken on public transport will continue to increase from 6.7% of all trips today (almost 20% of total distance traveled) to 14.5% in 2020 (nearly 30% of total distance traveled). In terms of distance traveled, bus trips are longer than those on mopeds or by foot, explaining why the share of distance traveled is greater than the share of trips. The 43% growth in passenger km, coupled with continuing trends in a shift from motorcycles to cars will lead to severe congestion. This will reduce vehicle speed by 46-55% (ALMEC, 2007) and increase stop-and-go accelerations in traffic jams, thereby increasing the emission coefficient by an estimated 35% (25% for diesel) (Schipper, Unal and Zachariadis, 2007).
- The second traffic scenario, High Mass Transit, considers the implementation of the ambitious program to promote public transportation, as described in the HAIDEP study. The HAIDEP study recommends an upgrade of the urban transport infrastructure - urban rail rapid transit, bus rapid transit, and regular bus - fostering increased capacity and safe mobility. An element of transport demand management is also considered - namely, the implementation of economic measures, such as area licensing, registration fees, parking fees, and increased fuel prices, with clear priority given to public transport. Under this scenario, the public transport share of total trips will reach 30%, of which two-thirds are on buses and the rest are on electric rail (metro and tram). Overall, these modes will provide 45.8% of total passenger km traveled - 30% on buses and 15% on the electrified rail system.

Figure 1 shows total passenger km in 2005 and 2020 under the projected HAIDEP scenarios. Note that passenger kilometers are related to vehicle kilometers adjusted by the vehicle's load factor. Vehicle kilometers were used in the actual calculations of fuel use and emissions.

Most of the increase in transportation demand from current levels to 2020 will be captured by a tremendous swell in car and bus use. Walking will stay low, and bicycling will see a strong cutback from already-low levels primarily because of competition from two wheelers. Present sidewalks in Hanoi are constantly blocked by parked bikes.

This study modeled alternative emission levels based on various transportation and environmental policies. The study

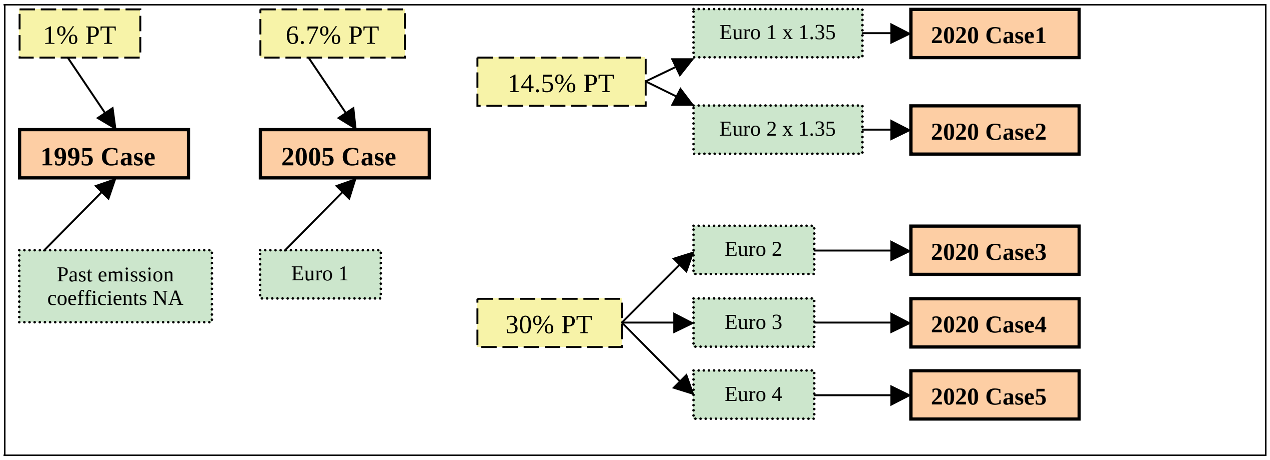

Figure 2. Schematic diagram of the five scenarios developed by the study. PT refers to public transport, while Euro refers to Euro emission levels (Dieselnet 2004).

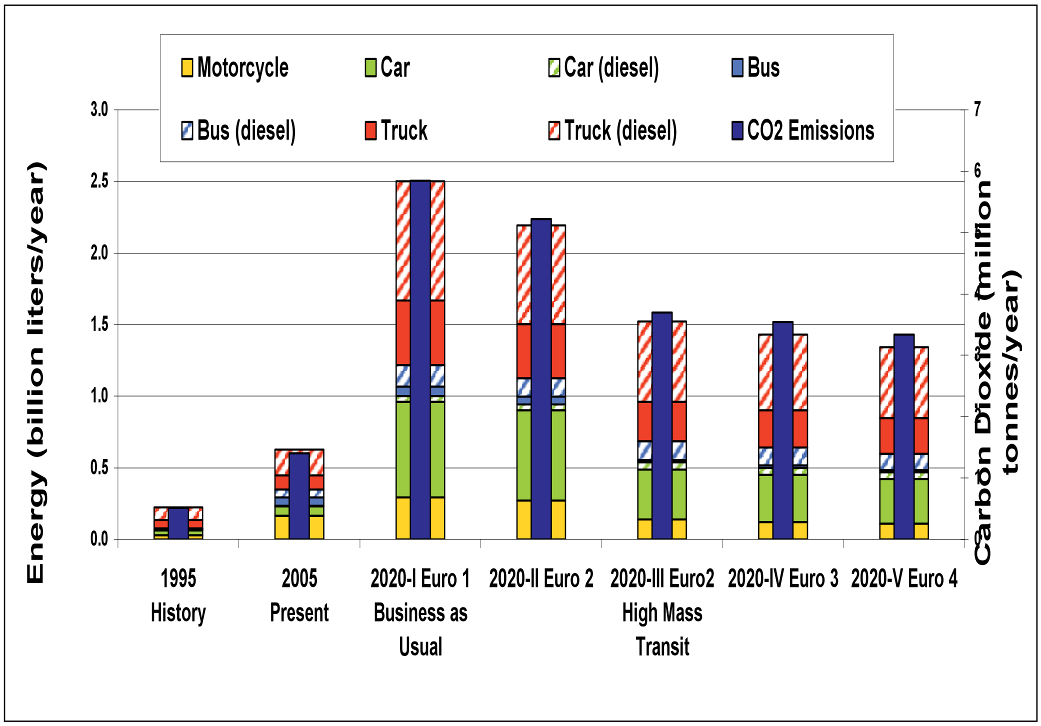

Figure 3. Fuel use by vehicle mode and total CO_2 emissions. Note the project did not address diesel consumption in trucks

selected two alternative emission standards for the Business as Usual public transportation scenario and three alternatives for the High Mass Transit scenario, generating a total of five different emissions scenarios for 2020, named 2020Case1 through 2020Case5 (Figure 2). The energy intensity of each mode was lower in Case 2 than 1 and even lower in Cases 3, 4 and 5 respectively.

Results and Analysis

The 2020 Business as Usual scenario represents a 7.5-fold increase in car traffic, while the High Mass Transit scenario predicts a 6-fold increase in car traffic, which is still formidable. Based on the historical relationship between income and car ownership, we believe these increases are realistic (Schipper and Ng, 2004). Yet, it is difficult to imagine how a significant number of cars—say an increase to 100 cars per 1,000 people – could be accommodated given today's congestion levels. An increase in car use will ultimately increase fuel use, emissions, and congestion (Figure 3).

It should not be surprising that fuel consumption in the High Mass Transit scenario coupled with the stringent vehicle emission standards is still higher than fuel consumption in 2005. We anticipate all vehicles to become more fuel efficient in the most aggressive scenarios. However, the disproportionately large increase in car use outweighs the expected gains in fuel economy and drives total emissions up. Still, the higher fuel economy in Case V reduces fuel and CO_2 use below that of other cases.

Emissions are lower in the High Mass Transit scenario when compared to the Business as Usual scenario because we have assumed buses are well organized into a BRT system with fewer emissions per passenger km, and slightly fewer total bus km, in spite of somewhat higher passenger km on buses. Fuel consumption for cars and motorcycles is lower in the High Mass

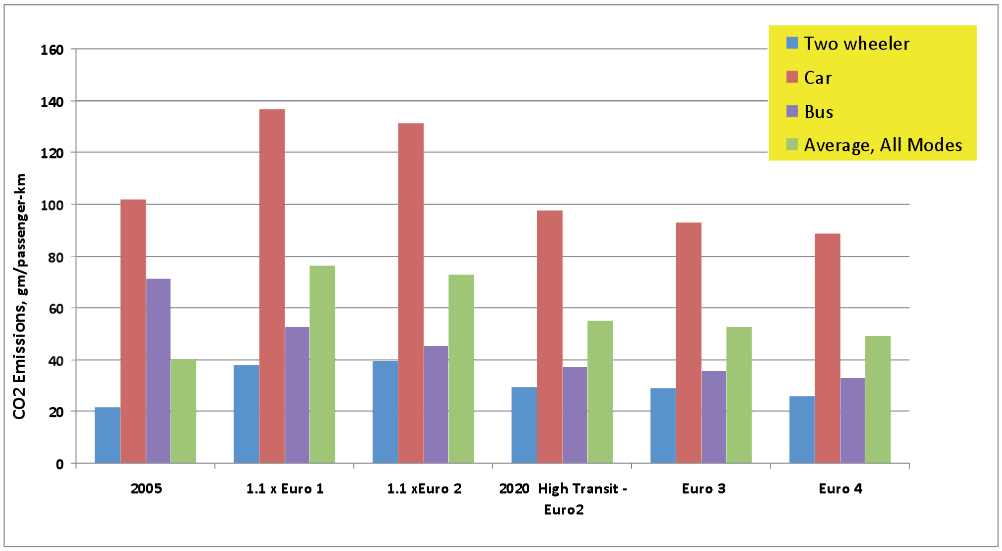

Figure 4. CO_2 Intensity by modes across scenarios.

Transit scenario, both because we have introduced more fuel-efficient cars and because traffic is simply more fluid, permitting more efficient operation.

Policies that reduce distances traveled, or increase load factors so that fewer vehicle km are required to transport the same number of people, reduce energy consumption and CO_2 emissions. Figure 4 displays the estimated emissions per passenger km by transport mode for 1995, 2005, and 2020 in the Business as Usual (Cases 1 and 2) and High Mass Transit (Cases 3, 4, and 5) scenarios.

The average CO_2 emissions per passenger km for all modes increased between 1995 and 2005 as a result of a significant increase in automobile use. Average CO_2 emissions from two-wheelers also increased between 1995 and 2005, as more powerful engines emitted more grams of CO_2 per passenger km driven.

The 2020 Business as Usual scenario suggests that speeds will fall markedly as traffic congestion worsens, which implies either more time spent in traffic (with more exposure to pollution), shorter trips, or some combination of both. Subsequently, the average emissions for all modes are projected to fall for each 2020 scenario, as fuel intensities lower. On a passenger km basis, as displayed here, that effect is even stronger, as more highly loaded buses deliver more passengers. In the future, two-wheelers will be modestly less energy intensive, which will lead to some reduction in emissions per vehicle km. We assume the same load factor of 1.4 across all 2020 scenarios, a decrease from the 1.8 load factor used for 2005.

Conclusions and Recommendations

Despite limitations and uncertainties of the model and data available, this study demonstrated a process for combining a set of real-world transport activity observations and projections of future activity with estimations of emission factors and fuel intensity to provide present and future levels of total emissions and fuel consumption. Not surprisingly, a future with demographic and economic growth in Hanoi and without significant improvement in vehicle efficiency or emission controls will lead to almost a doubling of passenger km travelled by 2020, more than twice the amount of current CO_2 emissions, as well as more than triple the emissions for all local air pollutants considered. Given the explosive growth in individual motorization all over Asia, and our judgment that we probably underestimated the real emission coefficients for Hanoi, the outlook there is for much greater air pollution from transport, unless strong measures are taken both to reduce emission factors and to restrain the shift to more individual motorization, particularly cars.

This study suggests that there are two primary components to mitigating air pollution and reducing CO_2 emissions from a baseline value. Government officials can tighten vehicle tailpipe emission standards and mandate superior fuel quality. Transport management policies can have a large impact on emissions as they can significantly affect the number of vehicle km traveled, which is a key driver of emissions, as illustrated in the High Mass Transit scenario.

Transport policies that favor modes with higher load capacity over individual modes, or lead to greater use of the more efficient modes (e.g. two- rather than four-wheeled private vehicles), will result in reduced fuel use and overall emissions as shown in the scenarios.

Although this study is built from poorly known quantities—numbers of vehicles, yearly vehicle use, vehicle fuel intensity, and vehicle emission factors, the results illustrate the obvious: more vehicle activity means more fuel use and emissions, while more stringent emission standards and more fuel-efficient vehicles mean less fuel and emissions (relative to the first case). But the development of the scenarios helps to illustrate that if officials decide to promote public transportation to a higher degree and to mandate stricter fuel quality and vehicle emission standards, it will be possible to keep emissions at 2005 levels while ensuring the same level of mobility to Hanoi residents. This study also showed that the stronger the standards for fuels and exhaust, and the sooner they are imposed, the lower the emissions in the future.

Faced with the deteriorating air quality in Hanoi City, officials from the transport and environmental sectors are finally starting to worry and coordinate their efforts to improve the situation. In addition to stimulating a public health debate, the Vietnamese parties involved acquired a new appreciation of the value of calculating local emissions and fuel consumption of different kinds of vehicles, as well as the importance of understanding actual traffic patterns through the development of this study and its results.

Finally, study of Hanoi suggests an important path for those concerned both about transport related problems (congestion, access) as well as CO_2 emissions. As one of the most motorized cities in the developing world, Hanoi does demonstrate the viability of a world based on two wheelers. The main concerns to date have been the low traffic safety of two wheeler usage, and high CO and PM emissions (Schipper et al., 2006). If these problems are ameliorated and two wheeler usage is integrated into the coming BRT and rail systems, Hanoi could demonstrate the viability of a unique combination of individual and collective mobility at reasonable, safe speeds in a thriving, densely populated city. Perhaps this is a model for the future that has almost arrived today?

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