Measuring the CO_2 consequences of urban transport projects in developing countries: The blind leading the blind?

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Abstract

All over the world, transportation projects are changing how people and goods move, with direct and indirect impacts on greenhouse gases and criteria pollutant emissions. Transport and environment officials, investors and other stakeholders want to know, with different levels of accuracy and verifiability, how transport interventions will affect traffic, energy demand, and emissions.

Estimating the impacts of projects involving fuel or technology switch is conceptually straightforward but still with its challenges regarding the reliability of available data and the capacity for data collection. Projects affecting modal share, load factors, origin and destination patterns, number of passenger-kilometers driven, driving cycle and others parameters are an even more complex proposition. Without reasonable measurements of results, we are blind to the achievements we have promised ourselves.

This paper provides an overview of the challenges of estimating the impact of transport projects on CO_2 emissions, describes how some key approaches and methods address these challenges, and provides illustrations with examples from cities in Asia and Latin America.

Introduction

The movement of goods and people is critical for economic growth and social well-being. Improvements in mobility not only provide people with access to a broad range of socio-economic opportunities, but also have strong income effects by lowering transport cost and hence the prices of consumer goods and services.

Mobility demand has been shown to be directly affected by growth in population and incomes. In the past decade, the global average per capita income has increased by 26 % and the world population by 20 % (World Resources Institute, 2007) which translated into an increase in passenger mobility demand. Driven by continued strong population and income growth in developing countries, transportation demand is forecasted to continue rising on average by 1.8 % per year, between 2003 and 2050 (IEA, 2006; see also Schaefer and Victor 1997 and WBCSD 2004).

The growth in travel demand has a number of implications for energy use and air pollution. Transport is the dominant sector in terms of oil consumption – it has accounted for nearly all growth in oil use over the past 30 years, and this trend is expected to continue (L. Fulton, 2004). At local level, transport contribution to air pollution is of particular concern for its impacts on health, and effects on buildings and monuments. At regional level, transport trans-boundary pollution contributes to acidification, eutrophication and formation of tropospheric ozone. At global level, transport accounts for 20 % of global CO_2 emissions (World Resources Institute, 2007) being the fastest growing contributing sector to global warming; it also contributes to emissions of other pollutants with global impacts, such as tropospheric ozone, persistent organics compounds, methane, nitrous oxide, among others.

Air pollution has been a public issue for centuries while global warming has seen the lime light only in the past decade. Since the 1992 Rio Summit and the Kyoto Conference of the Parties in 1997, pledges for reduction of carbon emissions have

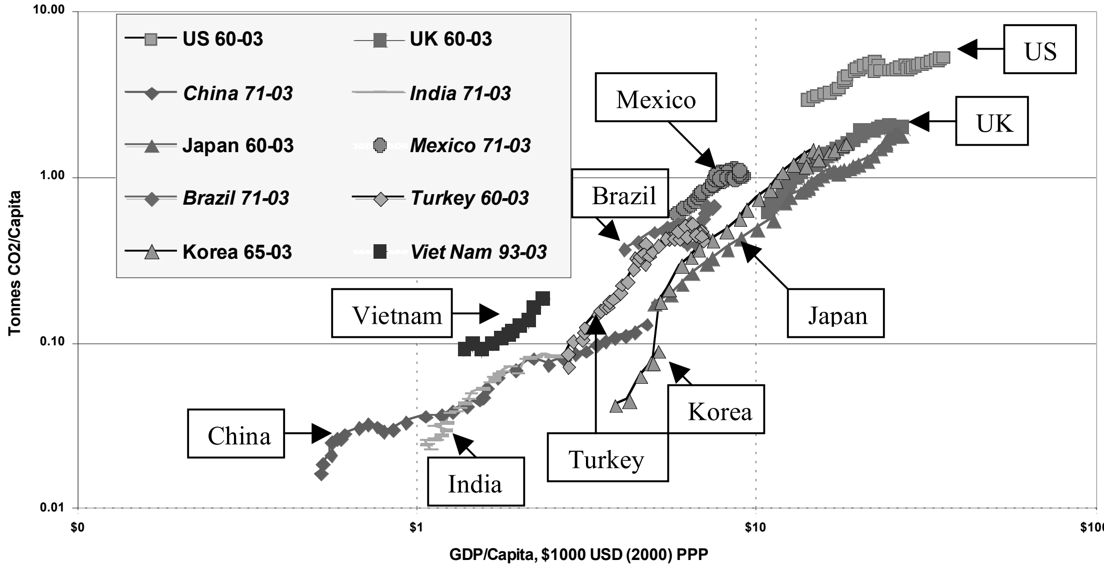

Figure 1 - Fuel Use per capita for road vehicles vs. GDP/capita measuring in Purchasing power Parity for a variety of developing countries (note log-log scale) (Source IEA and OECD national Accounts)

taken a national and trans-national character. More recently with the entry into force of the Kyoto Protocol in 2005, the Clean Development Mechanism and other agreements have been created as market-based instrument to promote greenhouse gases emission reductions. The need to be able to produce credible pledges has generated much investment and effort in the development of methodologies to estimate emissions changes from projects.

Parallel to the rapid growth in volumes traded in the Kyoto-based compliance carbon markets, a wide range of corporate and private voluntary off - set buyers have developed the Voluntary Carbon Markets (VCMs). The growth in VCMs is primarily based on the use of project-based emission reductions by proactive corporations in achieving self-imposed carbon neutrality commitments or in offering low-carbon products and services. Again, measuring the results of such pledges is important for public relations, even if the pledges themselves are not binding.

In the developing world, few nations have taken on commitments or have introduced programs to reduce or restrain GHG emission per se. However, a number of authorities have viewed such controls as an important co-benefit of programs to reduce traffic congestion, fuel consumption, or local air pollution.

As multilateral and bilateral agencies have created technical assistance programs and funds aimed at supporting developing countries to create air quality monitoring systems, cities and countries have adopted policies and have taken steps towards reducing vehicle emissions, such as improving fuel quality; implementing vehicle standards and inspection and maintenance regimes; undertaking traffic management and urban transport planning; among others. Verifying the impacts of policies, whether aimed at traffic or air pollution, often requires the same data and approaches for verifying impacts on CO_2 emissions.

This paper provides an overview of current emission estimation practices; it will review the existing experience in the development of methods and tools, and discuss their limitations and applicability when used for alternative transport policy interventions.

RESPONSES TO THE CARBON CHALLENGE – CAN THEY BE DETECTED?

At a national level, tracking total CO_2 emissions from fossil fuel combustion can be straightforward. If fuel sales reflect actual use, and if the allocation of fuel consumption by sector is correct, IPCC procedures permit the relatively accurate calculation of GHG emissions. Uncertainty in this calculation increases with difficulties in the accountability of fuel stocks and in the tracking of emissions from fuels purchased or smuggled from a different jurisdiction, state or country. When these issues are resolved at the national level, the analysis show that the rising trends of emissions from land (and air) transport in almost every country, either over time or as a function of GDP, are strong, as Figure 2 shows below.

Unfortunately, the aggregation level presented in Figure 1 is too high to reveal all but the largest and most dramatic changes in total fuel use at the national level and unless those fuels can be assigned accurately to each mode (e.g., car, motorcycle, bus, etc.), little more can be said about the transportation-fuel use interaction (Schipper, Price, Figueroa and Espey, 1993). In contrast to many OECD countries, virtually no developing country disaggregates transport sector fuel use by mode but does it only by fuel, i.e., gasoline, diesel, LPG, CNG, and others.

What happens if stakeholders wish to connect or attribute changes in GHG emissions to a particular project, technology, or policy? In the US, for example, there was a clear break in the relationship between transport fuel use and GDP, at the national level, after the imposition of CAFE standards (corporate average fuel economy standards) in 1978 and the big increase in fuel prices a year later. How much was ultimately the result of the standards, how much the consequence of much higher fuel prices is debated (Greene 1994).

Unfortunately most interventions are far smaller in scope and focused on a local scale, as more and more jurisdictions,

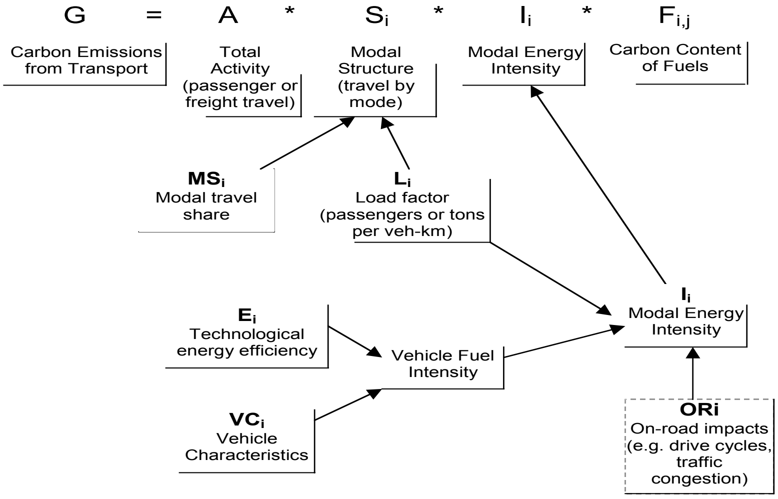

Figure 2 - The ASIF equation in two dimensions (CO_2 case)(Source: Schipper et al 2000)

particularly cities and states (like California) have made pledges to limit greenhouse gas emissions from transport and other sectors. In general, the kinds of interventions carried out at a local scale are invisible using national statistics, or top-down fuel sales data.

One other point bears emphasis. In developing country cities, vehicle numbers are growing rapidly, and their patterns of usage are changing as cities both sprawl outwardly while traffic comes to a halt downtown and on major arteries. Hence "recent" data on vehicles, speeds, fuel, etc. may not reflect the real situation when an intervention is imposed, and the interventions could succeed beyond the wildest goals yet not lead to an observed reduction in traffic or emissions, simply because the latter are growing so rapidly.

Parameters that Affect Emissions from Transport

The transport sector is comprised of a diverse set of activities, connected by their common purpose of moving people and goods. Broadly speaking emissions (G) in the transport sector are dependent on the level of travel activity (A) in passenger kilometers (or ton-km for freight), across all modes; the mode structure (S); the fuel intensity of each mode (I), in liters per passenger-km; and the carbon content of the fuel or emission factor (F), in grams of carbon or pollutant per liter of fuel consumed.

The emission factors can be defined in a number of ways. A CO_2 emission factor can be calculated using the carbon content of the fuel and standard IPCC coefficients to convert fuel (or electricity) used back to carbon emissions. For other pollutants, emission factors can be measured in the laboratory, in a test station as occurs in many US states on a regular basis, on a test track, or (preferably) using on-board or remote sensing equipment to examine vehicles in service in real traffic.

The relationship between these parameters is represented mathematically by the "ASIF" equation (Schipper and Marie 1999; Schipper, Gorham and Marie 2000) as illustrated in Figure 2.

The relative importance of each of the components to total changes in emissions varies with project type. The transportation system is much interconnected and interventions such as policies, programs, and projects, can affect directly and indirectly one or more of these components.

A – Passenger travel has increased in the past three decades and forecasted economic and population growth will contribute to a similar future trend. Freight haulage levels have increased substantially on a per capita basis. Most observers agree that without a substantial shift in vehicle/km per passenger, large cuts in emissions cannot be achieved from urban transport projects. Interventions that affect load or km run to satisfy a specific travel demand can have a very strong impact on emissions – moving more people per vehicle in fewer vehicles reduces emissions. It is common to encounter in operation inefficient collective urban transport – where the ratio of supply and demand is not optimized. Great savings on emissions and km driven can be obtained with improvements in system operation and route design.

S – Modal structure is represents the share of travel (in km) in each mode. Because fuel or emissions per passenger km (I) differ by more than a factor of ten between a large loaded bus or train with a modern engine and an old, large car with only one occupant, shifts in travel or traffic from one mode to another have an important impact on overall emissions. Choices of mode are affected by the availability of transport modes (particularly car ownership and distance to trunk or rail lines), mode speed, and the resulting travel time between origin and destination. Other important factors affecting choice include prices of fuels and vehicles, legislative and fiscal policies in effect, speed and travel time provided by each mode, personal security, and social/psychological dynamics. Care should be taken when conceiving public transportation systems as the actual impact on fuel and CO_2 emissions of measures favoring modal shifts are not always as effective as planned in terms of fuel savings and emissions abatement, because of (e.g. impacts on surrounding traffic, modal shift from non-motorized to motorized transportation, etc.).

I – modal energy intensity is closely linked to income growth, changes in fuel prizes (e.g. with fuel taxes), vehicle standards, public incentives, among others. Income growth may affect in a positive manner the energy intensity of vehicles as older units are replaced by newer, more efficient ones. Countries with relatively high fuel prices tend to have less fuel intensive automobiles, which are also driven less (Schipper et al. 1993). In the 1970s and 1980s, fuel intensity of cars in North America plummeted, but it has remained constant since the early 1990s. By contrast, fuel intensity of cars in Europe moved downward slowly, but that pace picked up after the Voluntary Agreement on CO_2 emissions per km from the late 1990s (IEA 2004). A new EU agreement calling for even lower emissions is under discussion at present.

On-road fuel economy is affected by road conditions and congestion levels – worse congestion means worse fuel economy. This may have in turn effects on activity - a substantial reduction in congestion on a road, as observed in Mexico City's Insurgentes BRT Corridor (Rogers 2006), could lead to enough speed increases that more car trips are made than otherwise.

Finally, F, the carbon content of fuels used has changed very little in most regions, except in Brazil, where sugar-cane based alcohol now accounts for 40 % of automobile fuels. We do not consider this parameter any further in this paper, but it is becoming increasingly important to scrutinize with full fuel cycle analysis as many so-called biomass fuels are associated with considerable amounts of CO_2 released in harvesting and preparation, often offsetting most or all of the GHG emissions from the fuels replaced.

EMISSIONS ELSEWHERE – INCLUDING LEAKAGES

A transport project causes changes in emissions outside its sector. These emissions may be "Upstream", related to how different vehicle are manufactured or different fuels are produced. For instance, the substitution of petroleum based fuels per CNG brings different greenhouse gas upstream emissions. The need to build infrastructure also has an emissions cost. A number of life cycle models have been developed to model these effects (Wang 1999; Delucchi 2002). These models can be used to gain an understanding of their relative importance but would need local data to estimate the size of any particular effect in a specific country. For lack of space we do not consider them here, but note where they could be important.

Another component of leakage may be the unanticipated changes in traffic or travel outside the project boundary, such as traffic that could be induced by the reduction in congestion from a project like BRT. We will return to these leakages below, as they may raise or lower the overall figure for changes in CO_2 emissions.

Data sources and the management of uncertainty

NUMBER OF VEHICLES AND DISTANCES TRAVELED

Most developing countries have records of the numbers of motor vehicles taxed and registered, usually at the national level. Frequently, the registration is attached to a state or city. However, registration happens once, i.e., when the vehicle is purchased or when it is imported legally. With few countries or jurisdictions levying yearly taxes, there is almost no way to distinguish between vehicles registered and actually in-use. Consumer/household surveys give some indication of the ownership of cars or two-wheelers, but in low income countries a large fraction of "cars" are not owned by households. Only where vehicles are inspected, such as Mexico City, it is possible to count vehicles that are truly in use.

Vehicle activity is not recorded. Whereas the utilization of vehicles in fleets (buses, delivery vehicles, taxis) is usually recorded carefully by owners or managers, the usage of the vast majority of cars, three wheelers in Asia and two wheelers everywhere are simply not recorded. Police, insurance, and manufacture warranty records could provide enough information to reconstruct patterns of overall use; however, no one in our knowledge has attempted this yet. The only regions of the developing world where data is available are where yearly inspections are required and odometer settings are carefully recorded, such as in Mexico City (Rogers 2006).

One import tool developed to deal with this problem is the vehicle activity survey carried out by the International Sustainable Systems Research Center in Diamond Bar, California (ISSRC). The International Vehicle Emissions Model was built on surveys of vehicle stocks, utilization, and driving cycles (represented as the OR term in Figure 2) in over a dozen cities around the world, and measurements of fuel use and emissions in half of them (ISSRC, 2007). A key feature of the ISSRC approach is that it can observe vehicles and traffic in the zone of influence of a project and compare activity with other places in a city, and measure changes in speed, acceleration, and other characteristics of traffic before and after an intervention has taken place. By observing the odometer readings of hundreds, if not thousands of vehicles and using license plates, the exact age and distance driven of each vehicle can be determined by authorities. The results give a general curve of utilization as a function of the age of the vehicle, which can be extrapolated to represent the entire fleet.

FUEL USE AND SALES DATA

Transport sector fuel consumption and emissions data is physically difficult to collect due to the highly dispersed nature of the sector's emissions. The decision making for the use of transport is highly decentralized and because transport is closely linked to practically all other economic activity, it is extremely complex to forecast the trajectory of transport-related carbon dioxide emissions for a given situation. In fact almost all official fuel "use" data are from reported fuel sales.

Unfortunately fuel sales data, usually inferred from fuel tax receipts, often is underestimated due to tax evasion. In addition, it is not always easy to know the amount that is used for transportation or to define the regional boundary for fuel use. Differences between regions in fuel tax policies and vehicle registration requirements can cause distortions in the regional data on fuel use and vehicle ownership as well.

Even if fuel sales in a region were known, inaccuracies could be larger than affects expected from projects. This is because some fuel sold in a region may not be consumed in the region (or conversely) because of differences in fuel prices, traffic transiting a region, or even fuel smuggling or adulteration with unknown fuels. The most infamous example is Luxembourg, the city-state whose low fuel taxes attract drivers from surrounding countries, leaving Luxembourg with one of the highest per capita sales of road fuels in the world yet no signs of an abnormally high consumption by residents. The same effect faces sanctions in Singapore – cars may not leave with nearly empty tanks and fill up on cheaper fuel in Malaysia. But in much of the United

States and Europe, fuel prices across state lines differ modestly as they differ between expensive down-town areas and more distant suburbs. Even if these price differences do not drive cross border sales as much as noted above, they still mean that fuel is not likely consumed where it is purchased, introducing potentially large errors in measuring CO_2 emissions from land transport.

Above all, projects affect only small amounts of overall fuel sales in a region, often within the limits the uncertainties and distortions noted above present. Thus, we must rule out changes in region-wide fuel sales as any kind of reliable guide to measuring changes in vehicle use unless a region has been subject to such radical transport projects (such as Transmilenio in Bogota, Colombia) that a large reduction in automobile use has occurred. If these were true, however, authorities should also be able to measure noticeable drops in traffic counts.

In almost every region, total gasoline sales are dominated by those to car and two-wheeler users. The most reliable fuel use data are developed by surveying large numbers of these vehicle users (Schipper, Price, Figueroa, and Espey 1993; IEA 1997). By tracking fuel purchases and distances driven over a period of time, reflecting both the typical vehicle use and several fillings of the tank, an accurate picture can be gathered to be extrapolated to the entire vehicle stock (if known), yielding both utilization of the vehicles and fuel consumption. The broadest of these is carried out every few years by the Australian Bureau of Statistics at the national level, and yearly by the Dutch Central Bureau of Statistics. Unfortunately these are exceptions; few other developed countries survey motor vehicle fuel use to derive the energy intensity for each class of vehicle.

Fuel use per kilometer, or fuel intensity, for a given vehicle depends on speed, acceleration and other parameters of driving conditions; obviously every kind of vehicle has its characteristic average fuel consumption under a given set of conditions. Surveys in some OECD countries have measured this by asking drivers to fill out diaries recording both fuel use and distances driven, and so obtain yearly averages (Schipper, Price, Figueroa and Espey 1993). But that average has significant variation. Since the "conditions of driving" vary significantly, tests of vehicles usually give different results from those obtained by ordinary drivers in day to day traffic, the so called "mileage gap" that appears in averages listed for new vehicles (Schipper and Tax 1994). Needless to say, the instantaneous consumption varies even more, hence without detailed measurements it is hard to say how much fuel is consumed by a group of cars driving in a given stretch of road or even zone of influence. In addition, the actual condition of the car's engine affects fuel intensity. Because of these problems, it is virtually impossible to estimate on-road fuel intensity for cars (or two wheelers) in developing countries, where the mix of cars, their test fuel economy, actual driving conditions, and the condition of the vehicles is so poorly known.

Given the many kinds of vehicles and even greater number of makes and models of cars, the most one can hope to estimate is the average fuel consumption per km for all vehicles of a given kind, based on a stratified sample of cars by vintage, make, model, engine size etc. (NRCAN 2006) represents a typical survey where drivers record their distances and fuel consumption during a number of weeks, often during a warm part of the year and again during a cold part of the year.

At the other end of detail, individual cars could be metered continuously in real traffic or on a dynamometer to measure actual fuel consumption second by second under tightly specified driving conditions. Either way, there is significant variance in the results for fuel economy for virtually identical cars, not to mention an entire sample of cars surveyed or metered.

In the final analysis, the only way to arrive at some kind of average fuel economy is through on-board tests of different kinds of vehicles under average operating conditions, coupled with a large survey of vehicle users and fleets to get recorded distances and fuel purchases. A modest number of on-board tests coupled with a large survey ought to pin down the key fuel intensities of typical vehicles and yield information on average driving distance.

A TALE OF TWO CITIES – SINGAPORE AND MEXICO CITY

Singapore

Singapore transport management tools have been implemented as early as in 1973. The Land Transport Authority (LTA) is a statutory board under the Ministry of Transport that manages land transport developments in Singapore (LTA, 2007). The two major challenges are land scarcity and the high aspiration to own private motor vehicles. Current solutions evolved around prevention, enforcement, monitoring, and education strategies, all with the same goals of controlling vehicle population growth in order to prevent serious traffic congestion and deterioration in ambient air quality.

Effective transport management models and tools, which are heavily dependent upon Intelligent Transport Systems (ITS), are used to monitor and control traffic flow and to measure transport activities. Surveys are also used as a data source, in addition to the Expressway Monitoring Advisory System (EMAS), loop detectors, and surveillance and detection cameras.

LTA's models are designed for economic evaluation, from a multi-criteria aspect. The categories include time efficiency, which implies cost-benefit analysis that take travel time saving, value of time (wage rate), vehicle operating cost savings, and accident cost savings into account. Other aspects of the models are emissions, opportunity cost of land development and visual intrusion. Transport models are mainly used to estimate impacts, benefits, and non-benefits of transport projects. They are usually used for both pre and post project implementation review and are regarded as a type of evaluation technique. Transport emissions are often of the lowest priority in the cost-benefit analysis based on such models.

Since good traffic data are available, the models are used to estimate total daily distance traveled based on modal splits. Travel demand forecast is another application of the transport models used in Singapore. Additionally, OD-surveys (household) are conducted once in every 5 years, and are focused on transport behavior, speed, distance, and transport mode. Data are used to manage existing traffic condition on a day to day basis. Transport models are also used for changes in schemes and impacts, to predict demand and supply, e.g. when changing one-way streets to two. Model evaluation is based on a need basis. Therefore, regular updates are often carried out more than once a year, as it is also used to determine road improvements.

There are also various vehicle and transport regulations that have been implemented by the government of Singapore. These regulations include the Vehicle Quota System, Electronic Road Pricing, Off-peak Car Scheme, Classic Car Scheme, Private Car Rental Scheme, and Vehicle Entry Permit Fees and Tolls. In short, Singapore has a deep and accurate understanding of its traffic and vehicles. Since there are few diesel cars, and since fuel tanks of cars crossing the border to Malaysia are routinely checked, Singapore can related fuel sales of gasoline to its stock of gasoline two- and four-wheelers. Hence Singapore can estimate fuel intensity of key vehicles relatively easily.

Mexico City

Because it lies in an isolated basin surrounded by mountains, Mexico City has always suffered from air pollution and traffic problems. Mexico City's most recent vehicle emissions and fuel use inventory of 2004 used the models MOBILE5-MEX and MOBILE 6.2-MEX for PM and toxics measurement, and derived SO_2 and CO_2 levels from fuel sales. Data required for vehicle emissions inventory in Mexico City included fuel sales, fleet size and composition, fleet age and technology, vehicle activity, and emissions factors. Fuel sales were used to estimate fuel consumption for gasoline, diesel, LPG, and CNG. Fleet size and composition, as well as fleet age and technology were derived from vehicle inspection and maintenance (I/M) programs, and were reliable as there is good enforcement.

Private car activity data have been obtained from odometer readings in inspection and maintenance (I/M) programs. These data require extensive filtering due to mechanical problems. As for emissions factors, the Instituto Mexicano de Petroleo (IMP) calculated HC, CO and NOx emissions factors and only straight averages were used. Emissions factors were not weighted by fleet composition and no adjustments by total kilometers or test date were performed.

All the data collected was then analyzed and used as MOBILE input data, which also included average speed, ambient temperature and altitude, humidity and solar load, air conditioning, automatic transmission, mileage accrual, evaporation factors/cold start, and anti-tampering. US default factors were used for humidity and solar load, evaporation factors/cold start and anti-tampering input data. While the bottom-up totals for fuel consumption do not match sales exactly, the agreement is good enough to give a fair ASIF breakdown for all components of emissions (Schipper and Golub 2003).

Estimating the Emissions Impacts from Transport Interventions

Let us assume we are satisfied with the data and set of estimation procedures as giving a good enough picture of the link between transport activity and emissions. What do we need to do to measure how a transport intervention would change CO_2 emissions?

A first step is to define the emissions baseline, a measure of the emissions that would have occurred in the absence of a project. Then, make an estimation of the emissions resultant from the project and finally compare the results in terms of tones of greenhouse gases emitted relative to an appropriate index. This is to ensure that the emissions estimation are not underestimated or inflated by variables such as population and economic growth which are influenced by events and trends outside the project activities.

Since a transport intervention can have significant impacts on project and non-project vehicles and people, it is important to have a good understanding of the magnitude and signal of implications for emissions. The impact on non-project vehicles and people can be difficult and expensive to calculate. One may decide to ignore this secondary effects but experience in some cities indicate that the impact on emissions can be significant and constitute an increase or a decrease in emissions (Rogers and Schipper 2005). This suggests that a less accurate estimation could be helpful to assess the significance of secondary impacts, before big investments in measurements are made.

Once the project boundary is defined, emissions changes can be calculated as before and after the project, as snap-shots in time. However, emissions five or ten years after the project implementation, may be higher than before the project was undertaken, yet less than if the project had not been undertaken, i.e., "without project". Needless to say, the with/without project estimation offers a more comprehensive understanding of the short, medium and long term impacts of the project, but adds to the complexity of the estimation due to forecasting uncertainties. As Niels Bohr once said, predictions are risky, especially those about the future,

The parties making traffic and emissions predictions must agree to the time frame and the counting of unforeseen, exogenous events. Major changes in population in the region (or the zone of influence), changes in the national rate of economic growth, unforeseen changes in land use as would be the case of the implementation of a large development, or even affecting thousands of daily trips appears in the zone of influence and raises traffic in one mode or another; unforeseen political events, in the case of Mexico City months of demonstrations, severely perturb traffic in the zone of influence.

Figure 3 shows the without project scenario, frequently called the (dynamic) baseline, that is based on a forecast of that may have accounted for the exogenous factors mentioned above. The discontinuity in the "project line" represents the possibility that during actual project construction traffic could be severely perturbed, which might lead to delays and detouring temporarily increasing overall emissions. The emissions in the project line grow slower than the projected "without project" emissions, which indicates that the impact increases over time, even if actual emissions with the project eventually reach a level greater than emissions before the project started. This illustrates the importance of using the with/without instead of the simpler before/after approach for estimating the impact of a project on emissions.

Clearly other situations could occur, including a rebound effect where the project impact wears off or "backfires", analogous to a case defined by Saunders (2000) whereby a project inadvertently stimulates a higher level of emissions than if there had been no project. Examples are cases like a BRT line or a popular pedestrian zone could induce more investment in housing or commercial property in the zone of influence, attracting people from outside the zone of influence (Steiner 1996). Some skeptics claim that ring roads, bypasses and motorways in general

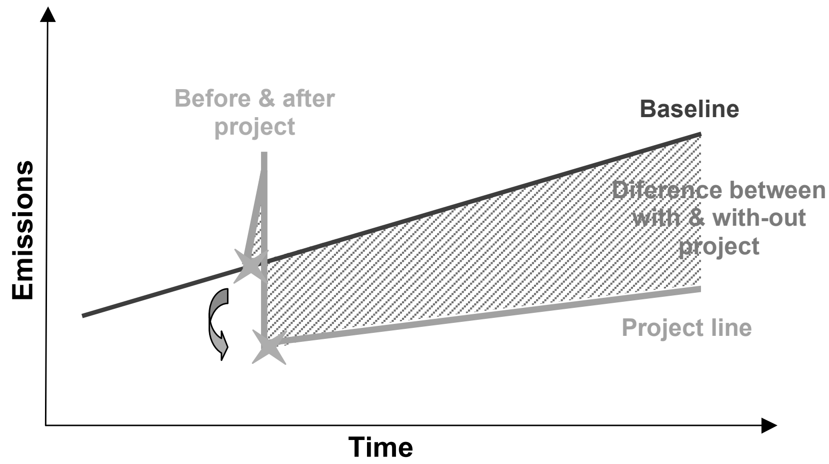

Figure 3 – The Dynamic Baseline (from Rogers and Schipper 2005)

save emissions by smoothing traffic. Should these effects be counted? Clearly any agreement on how to measure "impact" has to define clearly the boundary of the project and what impacts are significant to include in the estimation.

INSURGENTES METHODOLOGY

Estimating the difference in emissions between the "with project" and without project case is not straight forward. The changes caused by switching project vehicles (say mini buses replaced by BRT) can be estimated by projecting how much fuel mini buses would have required to carry the same number of BRT passengers at a future year. However, other changes are not observed, only inferred from traffic in general and characteristics of vehicles in that traffic. Take the case of emissions changes from the Mexico City BRT "Metrobus" (CTS 2006) by Rogers (Rogers 2006, Rogers and Schipper 2005; INE 2006).

The main feature of this system is a BRT corridor along Mexico City's central Insurgentes street (See also Schipper 2005). This system entailed the replacement of 262 microbuses and 90 buses by 97 buses with capacity for 160 passengers. The large buses use less than 40 % as much fuel as the smaller ones for the same numbers of passengers hauled.

As Figure 4 illustrates, Rogers found that overall this new system would save 46,500 tonnes of CO2 per year, with nearly 40% of the emissions reduction coming from changes in buses and nearly 40 % from changes in vehicles in the affected corridor; and nearly 30 % of the reduction due to modal shift. The introduction of the BRT corridor increased emissions by 3 % due to the imposition of left-turn restrictions and due to some hindrance of traffic crossing Insurgentes. Counts of traffic flows were used to estimate "without project" emissions.

As an interesting note, later measurements of fuel use in the Metrobus showed actual consumption almost 33 % higher than that foreseen from tests of Metrobus (INE 2006). This reduces the "actual" carbon savings by roughly 25 %, and brings out the importance of maximizing the amount of measurement in the determination of fuel consumption and other variables as a project unfolds.

TRANSMILENIO METHODOLOGY

Gruetter (2006) applied a different technique to the Bogotá BRT system. He defined the unit of saving as the trip, and compared the number of trips taken by travelers in a BRT System similar to that in Bogota, with trips they would have taken previously, whether on smaller minibuses or in cars. Surveys of passengers determined how the trips would have been taken and provided indication of the fuel type and fuel efficiency of the cars they left behind. Gruetter finds the interference with other traffic, induced traffic, etc a minor consideration but includes terms to represent them. He even suggests estimating changes in load factors of buses and taxis that might lose passengers to the new BRT. Gruetter's method is the first and only methodology approved for certifying CO_2 savings in BRT projects, to date.

ALTERNATIVE FUTURE EMISSIONS: THE CASE OF HANOI

As a variant of estimation, consider a proposal for different transport futures, using various models to sort out different levels of vehicle and passenger activity. One such study has been presented to the City of Hanoi by the consultants of ALMEC as part of a Masterplan supported by the Japan International Cooperation Agency JICA (JICA 2006). The Master Plan was valuable because it laid out two stark alternatives for Hanoi's transport, one based predominantly on two wheelers and cars - 2020 Trends - another with a 30 % share of trips on mass transit (today more like 10 %) - 2020 High Public Transport. The alternative levels of transport activity and modal shares for passenger travel are shown in Figure 5.

This kind of product is common, but may omit environmental impacts. To remedy this omission, EMBARQ and its consultants, Hans Oern of Transconsult (Gothenburg) and Dr. Tuan Le of the University of Hanoi Combustion Laboratory took the original material from the Master Plan, extracted the vehicle kilometers estimated for 2005 and modeled for 2020. With assumptions on fuel use/km and emissions factors in 2005 and in 2020, fuel use, local emissions and CO_2 emissions can be illustrated for these future scenarios. While the figures are as noted only illustrative, the results help show authorities the differences in pollution and CO_2 emissions between a world with relatively high use of mass transit and one without. As an extra feature, we added scenarios emphasizing imposition of

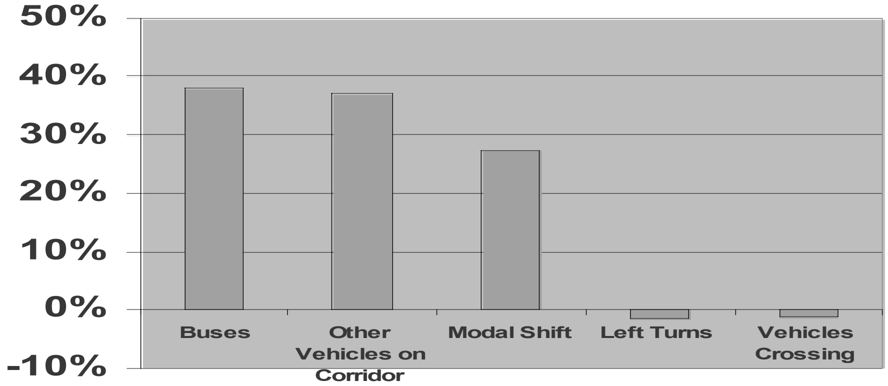

Figure 4: Allocation of CO_2 Reduction in the Metrobus Corridor on Insurgentes, Mexico City (Source Rogers 2006)

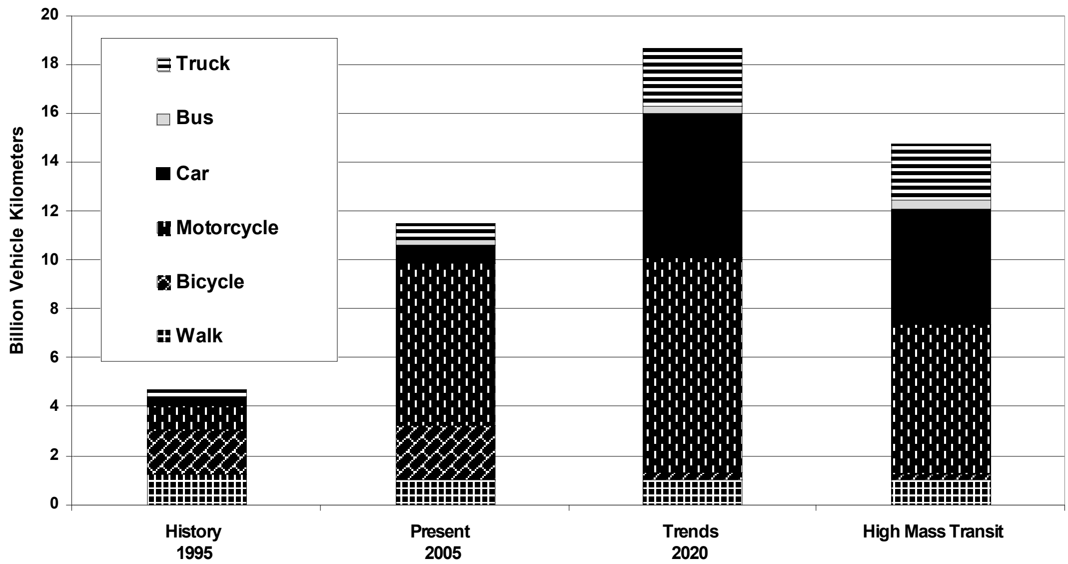

Figure 5. Approximate Historical and Forecast Vehicle Activity for Hanoi.

both stricter local emissions standards as well as considerably greater fuel economy.

Figure 6 shows the results for CO_2 emissions (dark bars and right-hand axis) with the underlying fuel use by vehicle shown as the wider stacked bar. In addition to the base year of 2005, the estimated fuel use for 1995 is shown as well. The rapid growth in fuel use and emissions between 1995 and 2005 is a result of a more than doubling of the number of motorcycles, while the even larger increase to 2020 follows from a high growth rate in car ownership.

In Figure 6, the "Trends" and "High Mass Transit" scenarios from Figure 5 are split into 3 variants representing differing (and progressively improved) levels of fuel efficiency and local emissions. A key point to decision makers is that the lower level of individual vehicle travel in "High Mass Transit" leads to considerably lower energy use and CO_2 emissions than the most fuel efficient scenario in "Trends."

Since this calculation is based on two alternative scenarios for an entire city, its validity is only speculative. Yet the stark differences in the CO_2 and fuel use implications of what experts and authorities see as two valid alternative visions of transport show how important transport is to future CO_2 emissions. Clearly, authorities would not want to usher in the scenario with higher fuel use and CO_2 emissions blindly, would they?

Conclusions and recommendations: Next steps

From this mostly qualitative analysis we propose the following general steps for emissions estimation, which we will be investigating in our work in the near future. We believe that depending on the context, this set of steps would yield reasonable estimates of the changes in CO_2 emissions arising from urban transport projects:

- Measuring the impact of transport policies and other measures on GHG requires tracking the components of total traffic and fuel use in a reasonable zone in which the transport policies have noticeable impact. Unfortunately this means identifying small changes in overall traffic and fuel use, so city wide data will not do.
- "Measurement" or "estimation" means examining traffic and GHG emissions in the zone of influence. Some kind of

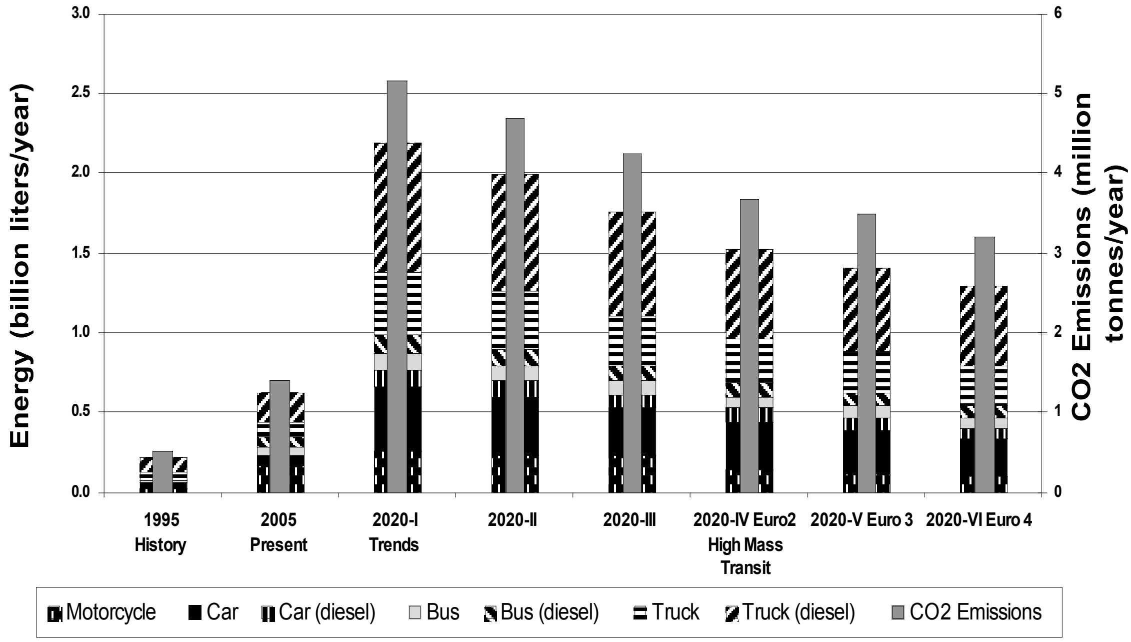

Figure 6. Past, Present and Future CO_2 emissions in Hanoi.

transport model for the region is usually required in order to gauge how large that zone must be before we can say that the impact outside of that zone, is not significant – does not change business as usual emissions scenario.

- Because traffic is continually evolving (and usually increasing) what is relevant is not only "before/after" estimates of traffic and emissions in the zone, but rather, "with/without" the intervention or project. As a control, however, city-wide trends can be useful for judging the impacts of large scale, exogenous forces, such as higher or lower than expected population and economic growth, a building boom, natural or human disasters, etc.
- Estimating the with and without project scenarios requires a definition of what exogenous events to include in the calculation, such as changes in population growth, other urban planning or transport projects whose effects impinge upon the zone of influence of the project in question.
- In addition to estimating direct impacts of transport measures on CO_2 emissions, one may have to estimate indirect effects. A project can cause downstream leakages by inducing new transport demand or affected vehicles outside the project boundary. Building a road or guide way, early scrapping of vehicles, changing fuel type, and other may have a significant impact on upstream emissions. How much of such impacts should be included in the calculation is a matter of debate, but they should not be ignored. In some cases reasonable assumptions may be used.
- With cameras or other devices we could measure vehicle types, speeds, and even infer fuels used from random checks using remote sensing. Doing this gives a fair estimate of the volume of vehicles and their characteristics that may have been affected by an intervention, particularly those crossing the path of a project.

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