Indicators: Reliable signposts on the road to sustainable transportation The partnership for sustainable urban transport in Asia

Lee Schipper, Ph.D.
EMBARQ, the WRI Center for Transport and the Environment, Director of Research
10 G Street NE, Suite 800
Washington DC
schipper@wri.org

Wei-Shiuen Ng
EMBARQ, the WRI Center for Transport and the Environment, Research Analyst
10 G Street NE, Suite 800
Washington DC
wng@wri.org

Cornelius Huizenga
Clean Air Initiative, Asian Development Bank, Secretariat
PO Box 789
0980 Manila
chuizenga@adb.org

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Abstract
Is transportation getting more sustainable? If not, would we know what to do? This paper defines sustainable transport and describes indicators of sustainable transport, which measure the environment impacts of transport (including green-house gas emissions), the financial health of the system, safety, and access. Indicators are particularly important for developing countries because congestion, safety, air pollution, and the economic health of transport providers are usually poor. Illustrative examples are given from cites in the Partnership for Sustainable Urban Transport in Asia, or PSUTA. Future work will reveal the full quantitative picture of these three cities.

As tools, indicators summarize trends and relationships among quantities that describe the most important activities, outputs, and side effects – both positive and negative – of transportation activity. Indicators permit diagnosis, evaluation of costs, benefits, and time frame of cures, prognosis based on the cures implemented, evaluation of progress against a base line, rebalancing of the system if goals are not being achieved, and marketing of results. Indicators also draw stakeholders into an objective discussion of each of these steps. Indicators of governance map their roles in solving problems.

Indicators of sustainable passenger transport are being developed and deployed with authorities in Pune (India), Hanoi (Viet Nam), and Xi'an (China). The paper describes how authorities assess needs to determine what indicators are necessary (at what precision), mapping the gap of information required to develop indicators, bridging the gap of information and funding data and analysis, and crossing the bridge to commit to a quantitative approach to policymaking and evaluation. The paper concludes with recommendations on both the most important indicators required for the cities, and the most important policy steps required to improve transportation, focusing on emissions (including green-house gases) and congestion, or rather, clean air and access.

Introduction

BACKGROUND: SUSTAINABLE TRANSPORT
Taking from and adapting the Brundtland Commission Report's definition of "sustainability[1]," sustainable transportation can be loosely defined as a set of transport activities together with relevant infrastructure that collectively does not leave any negative impact or costs for future generations to solve or bear – present builders and users of the system should pay such costs today.[2] Rapid growth in transport activity that surges ahead of infrastructure development, drastic changes in landscape to provide roads and other transport infrastructure, clouds of air pollution, noise, congestion, and

1. WCED, 1987. Our Common Future. The Report of the World Commission on Environment and Development. Oxford University Press, New York, NY, 400 pp.

accidents are all signs of unsustainable transportation that are attached to significant costs and problems for current and future citizens. Greenhouse gas emissions, careless and irreversible provision of infrastructure, degradation of flora and fauna, and disease from air pollution or injury and death from traffic accidents are some of the major problems left to future generations. A broader definition would hold that sustainable transport serves, not severs, sustainable development.

What does this definition mean in practical, observable terms? Transport is more sustainable when air, noise, and water pollution from transportation are reduced; when fatalities, injuries and accidents (as well as incidents involving personal security in transport) decline; and when congestion falls. For the transport system itself to be sustainable, public and private transport providers should be economically robust, and transport fares made affordable. Above all, a transparent system of laws, regulations, monitoring, and enforcement should govern the system and the users.

How do we know if transport is becoming more sustainable and how can we enact policies to strengthen sustainability? Data that measure both the details of transport activity and its side effects are required. These data can be transformed into useful tools – indicators – to be used for the diagnoses, choice and implementation of cures of transport problems, as well as the prognoses of the impact of implementation, evaluation of progress, corrective rebalancing, and publicity. With such functions, sustainable transport indicators will bolster the policy process all along the way.

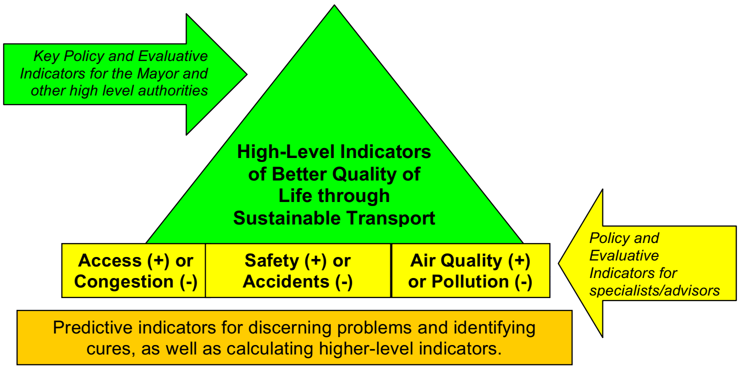

Figure 1. *The Indicators Pyramid for Transport.*

INDICATORS TO MEASURE SUSTAINABLE TRANSPORT

Rapid growth in the ownership and use of private vehicles, the spread of city boundaries, and problems of air pollution challenge authorities and individuals in every large city to make transportation sustainable. Most city authorities have been trying to define strategies to rein in the problems that this rapid growth threatens to worsen. Doing this requires quantitative measures of the performance and problems of the transport system, measures that can be called "indicators". Carefully chosen, a set of indicators can be established to "indicate" to authorities the progress towards broad transport and environmental goals set or in focused policies. Indicators give a broader context measuring the sustainability of a region's transport system. Indicators provoke accountability by measuring the state of a system before, during, and after policies or other forces (including no policies) exert influences on the transport system. At their best, indicators show how transport is contributing to (or detracting from) improved quality of life.

The indicators pyramid, *Figure 1*, illustrates the path from very detailed indicators at the bottom to meaningful but simple aggregates at the top. The boxes below the pyramid indicate the three broad fields (really externalities of transportation) for which indicators are developed – access/congestion (including land use), safety/accidents, and air quality/pollution. "Policy and Evaluative Indicators" are those used to express both problems ("accidents") and goals ("safety") in detail. "Predictive indicators", noted in the lowest box, are detailed figures used to build models to both foresee problems and measure the impact of solutions in advance.

The top of the pyramid contains high level indicators used mostly by policy makers, both as diagnoses (e.g. "the level of bus use is too low"), as goals (e.g. "50% of trips should be on buses.") and evaluative tools (e.g. "we raised bus trips to 48% this year. Next year we need to try harder."). In this way, indicators *quantify* the policy process. The middle levels contain more complex quantities, while the lower levels contain the original data. The pyramid symbolizes the compacting of information that takes place in going from detailed data and observations, to indicators that help diagnose and predict, and eventually to simple indicators that politicians prefer.

The two arrows in Figure 1 illustrate another dimension of indicators; the users. At the highest policy level, the mayor or other senior policy-makers need simple indicators of problems and solutions or goals. These officials in turn are

2. For a variety of key references defining "Sustainable Transport" see these:
Transportation Research Board, 1997. Transportation for a Sustainable Environment. Washington: National Research Council, US Nat. Academy of Sciences.
Gilbert, R., and Tanguay, H. 2000. Sustainable Transport Performance Indicators Project. From the Center for Sustainable Transport, Toronto. http://www.cstctd.org/CSTadobefiles/STPI%20Phase%201%20project%20final%20report.PDF
Gudmunssion, H. 2003. Sustainable Transport and Performance Indicators. Submitted to Issues in Environmental Science and Technology. Roskilde: DMU.
Littman, T., 2003. Sustainable Transport Indicators. Available from the Victoria Policy Institute, info@vtpi.org or http://www.vtpi.org.
Schipper, L., Marie, C., and Gorham, R., 2000. Flexing the Link Between Greenhouse Gas Emissions and Urban Transport. Washington, DC: World Bank. See http://www.iea.org/pubs/free/articles/schipper/flexing.htm
Schipper, L., and Fulton, L, 2001. Driving a Bargain? Using Indicators to Keep Score on the Transport-Environment-Greenhouse Gas Linkages. Presented at the Transportation Research Board, Washington DC January 2001.
Schipper, L., and Marie, C. 1999. Carbon-Dioxide Emissions from Transport in IEA Countries: Recent Lessons and Long-term Challenges. Stockholm: Swedish Board for Communications and Transportation Research.
EU "European Environmental Agency, 2000. Are we moving in the right direction? Indicators on transport and environmental integration in the EU: TERM 2000. Copenhagen: European Environmental Agency.
OECD, 2001. OECD Environmental Indicators. Development, Measurement and Use. Paris: OECD.
OECD, 1999. Indicators for the Integration of Environmental Concerns into Transport Policies"

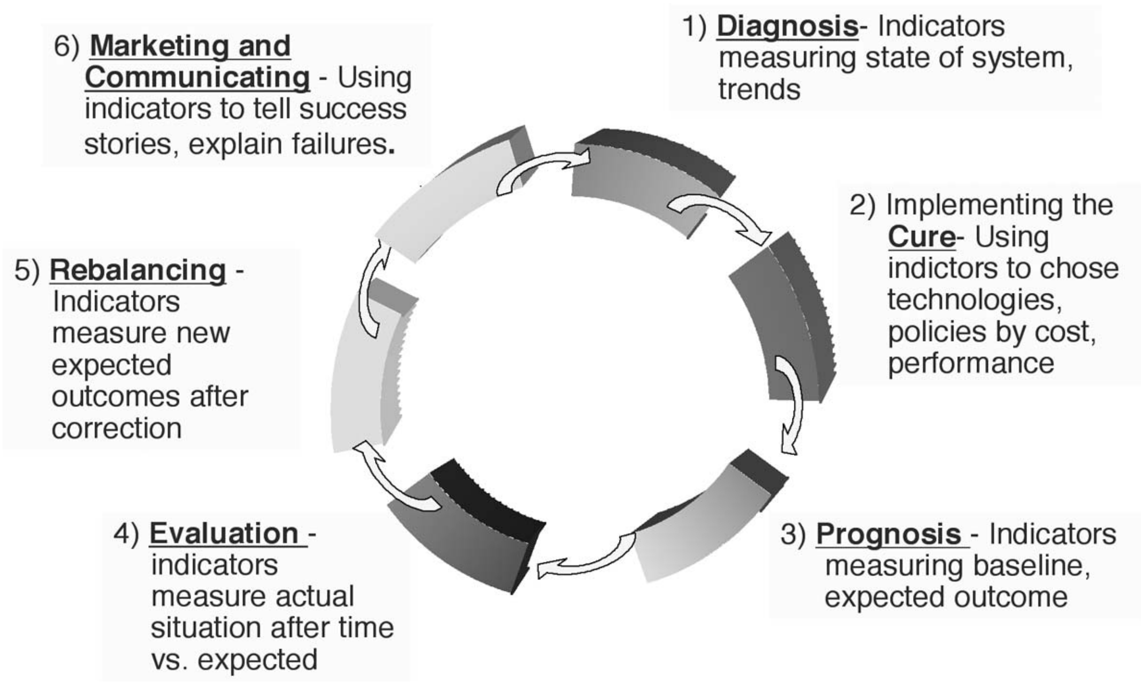

Figure 2. *The Policy Cycle.*

supported by specialists and advisor, who draw on the large body of indicators in the lowest box to produce key messages in the three fields, access (including land use and other geographic variables), safety, and air quality (including public health). Needless to say these three fields can be described by their negative duals, congestion, accidents/fatalities, and air pollution.

Policy indicators describe many characteristics of transport and environment that are directly related to problems and their solutions. For example, the Mayor of Taipei proposed a goal of raising the share of daily trips taken by mass transport. One reason for his concern was rising congestion, usually measured as time lost in traffic relative to travel at unconstrained speeds. The goal of greater bus travel represented a means to a greater end, less time wasted in traffic. Similar policy indicators deal with the reduction in air pollution (measured by concentrations of pollutants or numbers of days where pollutant concentrations exceed norms) through the means of reducing traffic or reducing emissions/km of vehicle activity. Thus, policy indicators describe situations, quantify solutions and describe end points.

Just as important are predictive indicators. These are the basic parameters of the system, such as the number of vehicles or number of kilometers people travel each day. Such indicators may be single data, time series, or comparative, e.g., a comparison of the same indicator over many cities in Asia. Socio-demographic characteristics of the population and households and their spatial distribution (population densities, proximity to fast transit stations) are also keen predictors of travel behavior. Trends used for forecasting and for scenarios assumptions are built from these indicators. As such, however, indicators are not valuable for policy formulation. Instead they are used to form diagnostic indicators. Diagnostic or consequential indicators indicate problems with the system (such as pollution arising as a consequence of using motor vehicles).

As a form of predictive indicators, causal indicators suggest relationships showing cause-and-effect, such as the strong relationship between rising per capita income and rising ownership of private motor vehicles, or the association between rising traffic and rising air pollution. Such indicators can be used to project today's system to tomorrow, or build scenarios illustrating policy choices. The same indicators can be used to illustrate the potential impact of introducing new technologies or policies to a transport system.

Uses of Indicators to Improve Transportation: Diagnosis, Cure, Prognosis, Evaluation, Rebalancing, and Marketing

It is convenient to think of six steps in improving local transportation and environmental problems such as those described above. The steps are shown below in Figure 2. These steps are guided by indicators. Most transport/environment improvement programs take a year or two in formulation, approximately a year or two to fully implement, and from years to decades before results are clear. From the policy maker point of view, staying abreast of the actual situation, options that unfold, and the results actually obtained, is crucial for success and a strengthened effort in the future. Indicators are necessary to this process. These steps are explained in more detail in Schipper et al. 2005.[3]

CLASSES OR FIELDS OF INDICATORS

Figure 3 below, illustrates in greater detail some of the policy and predictive indicators that belong to each of the three fields of transport issues. Table 1 also gives some examples, as well as common sources. The high level indicators in the

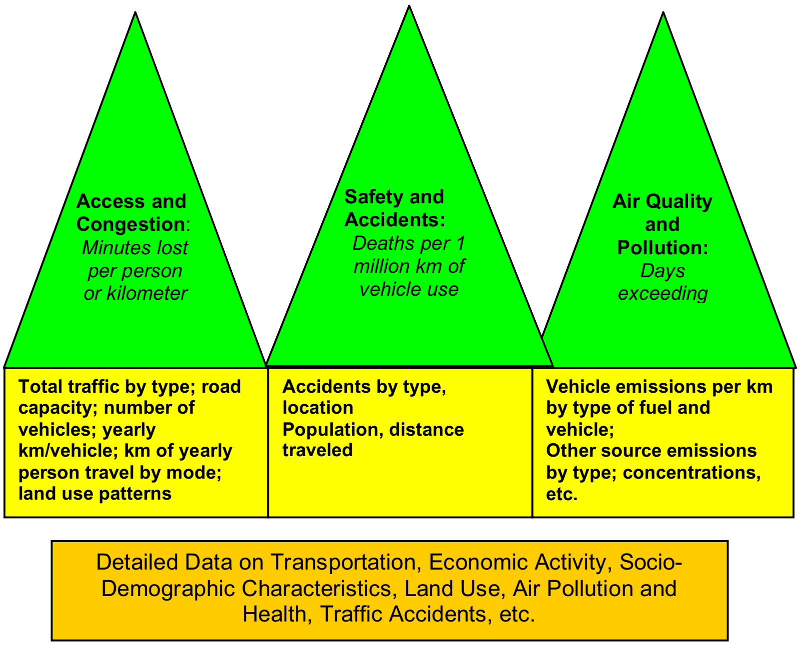

Figure 3. *Three Classes of Indicators.*

three triangles are among the most commonly used. Below in the rectangles are some of the kinds of data used to construct indicators in that group, and often used for indicators in other groups. More detailed data are suggested in the large rectangle at the bottom.

Note that there is intermixing: many key indicators of safety or environment normalize a quantity by distance driven or traveled. This integration is important, but potentially unfortunate. Most often, the data that are used to form indicators come from two or more authorities, bureaus, or experts. Getting them to cooperate with each other for the exchange of data is often difficult. We return to this issue below.

A key characteristic of indicators is that they are constructed from the combinations of data describing different aspects of transportation. The basic indicator of road safety, for example, is accidents, injuries, or deaths per 1 million km of vehicle use. The numerator gives a quantity related to accidents, and the denominator normalizes this quantity to a rough measure of transport activity in the system. Without this normalization it would be difficult to compare traffic safety problems among regions of different sizes, or in the same region over time. For example, the number of people killed in traffic accidents in the entire U.S. in 2003 was somewhat over 43 000. This is close to the number killed in 1970, but the total number of kilometers traveled by vehicles circulated in the U.S. in 2003 was well over twice the 1970 level. In other words, the rate of highway accidents, deaths, or injuries in 2003 was well below its 1970 value. By comparison 105 000 people were killed in China, with only 1/5th the motor vehicles, 40% the per capita trip making per day and roughly 1/5 to 1/4 the distance covered per day. China is far less safe on the roads than the US, and roughly half of all those killed in China were pedestrians or cyclists.

This comparison is important for policy making. The number of accidents, injuries, or deaths is proportional to total vehicle circulation. Most policies or technologies aimed at increased safety can only reduce the rate of accidents, injuries, or deaths per vehicle-km. However, other policies or technologies can reduce the number of injuries or deaths per accident. For traffic safety policies in regions with rapidly growing mobility, the sheer increase in the number of people moving and the distances traveled, as well as the increased numbers of pedestrians or cyclists exposed to risks from motorized traffic, challenges all measures to improve safety and reduce accidents. In North America and Europe the absolute number of deaths has fallen during the period when "new" technologies (seat belts for example) reduced the rate of fatalities (deaths/km) faster than the traveled distance was increasing. Policy-makers should design indicators that give them proper credit for reducing problems "better than otherwise".

For access and congestion, access could be measured by literally counting what fraction of the population lived within 500 m of a fast rail, bus, or metro stop, an indicator of land use. This would be done using a GIS-based population or household register. Studies suggest that people living (or working) this close to major transport system nodes are much more likely to use the nearby systems than those living or working farther away. An economic measure could be derived from household expenditure surveys to measure the share of household budgets used for transportation of all forms. In this case, a higher value for the indicator might suggest transport is a burden on some groups. Congestion,

3. Schipper, L., Ng, Wei-Shiuen, Chen, J. And Huizenga, C., 2005. Indicators: Reliable Signposts On The Road To Sustainable Transportation. The Partnership for Sustainable Urban Transport in Asia. In the Proceedings of the International Exhibition and Conference on Sustainable Transportation in Developing Countries, Abu Dhabi, Jan 29, 2005.

the opposite of access, might be measured by the time lost by vehicles on a course consisting of a number of main streets, relative to free flow traffic. Time can be measured with cameras and vehicles. Congestion can also be measured on a city-wide scale by modeling all of the trips people take to work and estimating how long they really spend relative to a free-flow condition. This lost time is often converted into economic values, giving a macro-economic estimate of the losses from congestion. The key facet of indicators shown here is that a few simple quantities or indices can contain a very large amount of information.

Air quality/pollution or emissions from vehicles can also be portrayed with indicators. Air quality often is measured by concentrations of known pollutants, such as nitrogen oxides (Nox), ozone, or particulate matter (PM). These measurements are compared to emissions of pollutants from vehicles and fixed sources, using atmospheric circulation and chemical models to calculate how emitted pollutant is converted into smog and other irritants, spread around, and in some cases diluted or washed from the air. The actual concentrations can be compared with "maximum" levels recommended by international authorities. Instead of giving an indicator measuring concentration, some give the number of days the "maximum" is exceeded. From the "source end", inspections and tests of in-use emissions from a wide number of vehicles can reveal what share of the vehicle population meets or exceeds a certain emissions standard for a key pollutant, or by how much newer vehicles are improved over older ones. Again, a wide variety of technical data can be combined into a few key indicators of air quality, air quality relative to a widely known health standard, and vehicle emissions standards.

GOVERNANCE INDICATORS

The question arises – can authorities deal with the problems of transport and environment? The answer is described by indicators of governance. Governance indicators point to the legal authority to regulate or control transport and environmental problems, the funding of diagnostic and monitoring capability, and the legal basis for enforcement. For example, is there any criminal or civil sanction against motor vehicles drivers involved in traffic accidents, especially when the other party is pedestrians? Does driving require a government issued license? Are there motor vehicle and road safety laws? How are these enforced? Are speeders caught by electronic means? Figure 4 suggests indicators that help answer these kinds of questions.

Construction of Indicators: A Tale of Three Cities

The PSUTA encompasses three city partners in Asia – Hanoi (Viet Nam), Pune (India), and Xi'an (China). These cities have many similarities and many differences. Their populations lie between 2 and 4 million, depending on how one draws boundaries and counts commuters from outlying areas. In 2005, Pune has over 1.5 million motor vehicles, Hanoi well under a million and Xi'an around 350 000. Pune and Hanoi have rivers dividing them, while Xi'an is divided internally by its city wall. All cities face major challenges and choices in making transportation more sustainable. Table 1 gives basic data and indicators of population, economic development, transport (vehicles, activity), and traffic fatalities. These data and the indicators will be addressed in the following section. But a cursory comparison with the US or Europe for some of the indicators shown in the table suggests profound differences between the developing cities and cities in the US or Europe. Corrected for purchasing

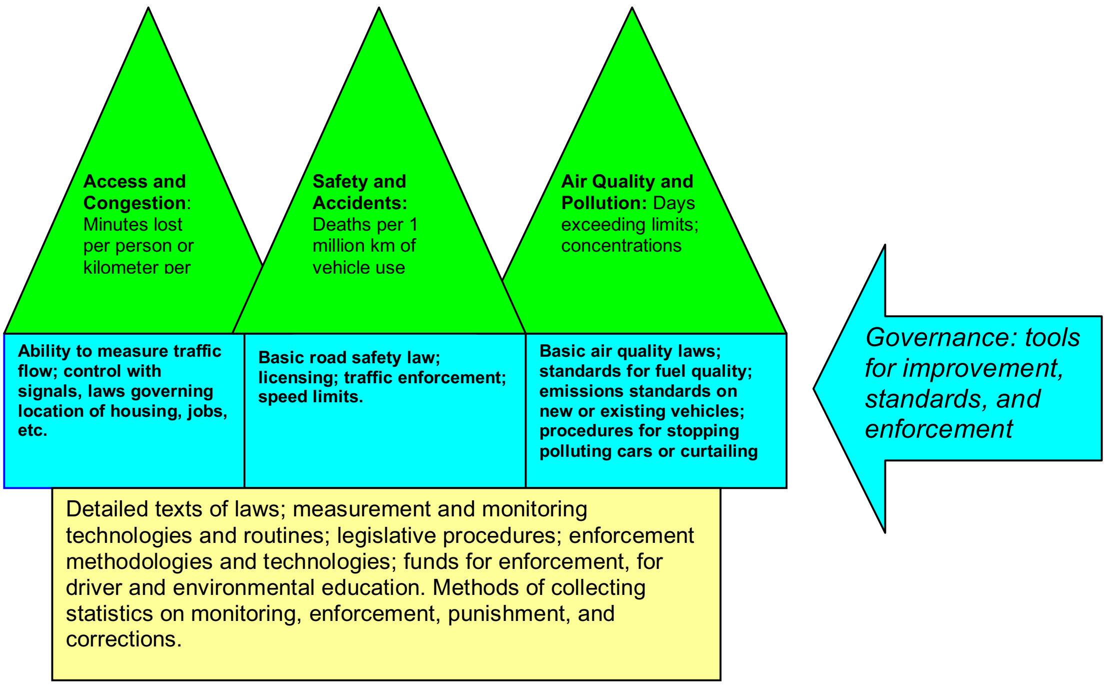

Figure 4. *Governance Indicators.*

Table 1. Examples of Basic Indicators (to be completed when project finishes, 31/3/05)*

Sample Indicators	Hanoi	Pune	Xian	US/Europe Cities	Notes
Population (2003), millions	1.43	2.70	5.1		
Population, Metro Area (2003)	3.02	4.25	>7		
Area, metro area, sq. Km	921	244	3 547		
Share as roads	6%	4.0%	7.9%	10-25%	
GDP/capita, local	15 670 810 (Dongs)	22 817 (Rupees)	15 155 (Yuan)		
GDP/capita, PPP 1995 USD **a)**	2 051	4 140	3 277		
Motor Vehicles per 1000 people	433	391	73	700/500	Includes personal SUVs
Cars and Two wheelers/1000	392	277	58	10/50-75	
Distance/day a person travels, *km*	7	12.4	10	40/30	Local travel only
Modal Split: -trips/capita/day	1.99	2.7	1.95	4.5/3.8	
% walk	22	29	23	5/10	
% bicycle, other NMT	25	14	25	1/ 4	
% two wheeler	42	29	5	1/3	
% three or four wheeled taxi	3	7.4	4.9	1 / 2	
% car	5	5	4.8	85/65	
% bus	5.6	14	37	3/15	
% rail, metro, tram	0	2	0	1 / 4	
Traffic Fatalities/year	460	300	281		
Traffic Fatalities/1000 vehicles/year (all vehicles)	3.5	2.2	5.6	2.0 (US)	US for entire country

***a)** PPP or purchasing power parity, expresses the value of the local per capita GDP or income in terms of what can be bought – for these cities, the PPP $ values are much higher than those given by ordinary exchange rates, as any visitor to China, India, or Viet Nam will see.*

Sources are the individual cities, their Statistical Year Books, Transportation Dept. Reports, and Environment Department reports, as brought together by the PSUTA partners. A full list of sources will be given in the final draft.

power parity, the GDP or incomes of people in these cities is roughly a tenth of what it is in the US or Europe, and the daily mobility is roughly a quarter to a fifth. Nearly half of all trips are by foot or cycle, and in Pune and Hanoi most motorized trips are by two-wheeler. For two of the three cities, far more people are killed per vehicle than in the US, and even fewer per kilometer traveled or driven. In short, transportation in the PSUTA cities is nothing like it is in the wealthy countries. And air pollution, not described quantitatively in the table, is much worse.

THE PSUTA CITIES

With a ring road project in place and a recent call to the national government for the funding of a metro project, Xi'an faces many new decisions which will require the evaluation of a set of maintained sustainable transport indicators. As a city sometimes forgotten in the face of the financially attractive cities on China's eastern seaboard, Xian is the economic, cultural, political center of north-western China. As the doorway into the "Go West" campaign in China, the economy is booming, implying more motor vehicles. It is crucial to collect accurate emissions and traffic data relevant for Xian's growth strategy. Xian is also preparing to build a metro system and implementing Bus Rapid Transit (BRT) within the next few years. The indicators would help determine the impact each will have on urban transport patterns.

Hanoi is in a different position. As the capital of Viet Nam, a rapidly urbanizing country, Hanoi has generated the interests of international aid that will rebuild the traditional bus system, tram construction, and expansion of the bus system into a BRT system. With relatively few cars and only a small bus fleet, Hanoi depends almost totally on private two-wheelers and even two-wheeler taxis. Crowded streets and sidewalks full of merchants, restaurants, and above all parking for two-wheelers and bicycles means pedestrians often walk in the streets. The constant flux of people means high road fatalities, and exposure to pollution emanating directly from motor vehicles. Will the new larger systems take the pressure off crowded streets?

Pune is in many ways the most motorized of the three cities, with nearly 1.5 million motor vehicles. With tens of thousands of three-wheeled, two-stroke auto-rickshaws and well over 1 million two-wheelers, almost all of these are equipped with polluting two-stroke engines. Pune has far more private cars than either Xi'an or Hanoi, and much of its downtown road network is narrow and winding.

A little consideration suggests challenges for each city as transportation expands. But each city has different challenges, although the overwhelming numbers of vehicles in both Hanoi and Pune are striking. Each of the key policy issues each city confronts can be diagnosed and remedied using indicators as policy tools. The PSUTA partnership will help the cities prioritize challenges, respond with forward-look-

Figures 5, 6 & 7.

Figures 8, 9 & 10.

ing policies, and make its own transport system more sustainable.

From left to right, a "green" taxi running on CNG in Xi'an, a new car on a chassis-dyno set to measure emissions in Hanoi, and a three wheeler in Pune emitting smoke. (Photos by L. Schipper)

AIR POLLUTION

Xi'an city has a number of buses whose engines run on compressed-natural gas (CNG), as well as CNG taxis. These vehicles are painted green to indicate their "low emission status". But do they really reduce emissions? There have been no careful and systematic emissions tests to provide the basic data that would yield emissions factors, in grams/km, for each pollutant from vehicles before and after conversion. There is no detailed transportation-related air pollution emissions inventory, which measures the total amount of each pollutant put into the air by the transport sector. What is the average reduction in emissions from each CNG vehicle? What is the impact of each conversion on the total inventory in the air? To answer these questions, one needs a good data base on numbers of vehicles by engine and fuel type, distances the vehicles run in a day or a year, and the aforementioned emission factors from each combination of vehicle-engine-fuel-emissions controls. Indicators could also measure the impact (likely to be positive) of a BRT system on overall air quality.

With relatively few older cars on its streets, heavy vehicles and two-wheelers constitute most of the transport related air pollution sources. Fortunately most of the two wheelers have relatively clean four stroke engines. Still, their volume of traffic leads to a regular layer of pollution in the city that only exacerbates pollution already exists from industries and other sources.

Pune's ever-present two and three-wheelers are predominantly two-stroke motors that use low-grade mixing oil. Direct exposure to riders and nearby pedestrians is high, while air pollution is a severe problem. Delhi has converted many of the three-wheelers to CNG. What are the results? With no CNG available, should Pune convert to LPG? By contrast, Hanoi's two-wheelers mostly have four-stroke motors, with less pollution. But like Pune, they are everywhere and their numbers are still growing. What should Hanoi do about two-wheeler pollution?

From left to right, rising congestion looking north to the Bell Tower in Xi'an, mopeds dominate every intersection in Hanoi, and traffic chaos in Pune. Note the pedestrian trying to climb over the barrier in the center of the road in Xi'an, the first picture from the left. Sadly this common site in all three cities leads to many unneeded pedestrian deaths. (Photos by L. Schipper)

CONGESTION

Xi'an is an old city with an intact, high wall of 4 km on a side. There are four main gates to the walled city. Not surprisingly, traffic is lined up from the main entrances to the famous Bell Tower in the center during many hours of the day. How many minutes longer does a journey through the city by car or cycle take today compared with in 1990? How long are buses stuck in this traffic? How much will the new ring-road, a metro, or BRT change this congestion?

Hanoi, with fewer large vehicles, is a well-laid out city with what appears to be a great deal of road space. Yet the swarms of two-wheelers dominate the streets and the sidewalks. Most experts list this congestion as a minor inconvenience yet it increases each year. Because sidewalks are so crowded, citizens take two-wheeler taxis for even just 2 blocks in order to move about. Many worry that the replacement of even only 25% of the two wheelers by cars would clog the city's narrow streets unsustainably.

With more motor vehicles than Mumbai yet only one fourth the population, Pune is one of India's most congested

Figures 11, 12 & 13.

cities. Like Hanoi, Pune has essentially 1 two-wheeler per household, but its roads are winding and has weaker infrastructure. Congestion is almost round the clock and almost everywhere, even on country roads. Yet much of central Pune is so compact that walking is a realistic way to move around, assuming sidewalks are available. What would reduce traffic in Pune?

From left to right, cycle-borne freight on a main street in Xi'an, parked mopeds on a sidewalk in Hanoi blocking passage for pedestrians, forcing them into the street, bus accident on a bridge in Pune. (Photos by L. Schipper)

SAFETY

In addition to many two and three-wheeled bicycles, Xi'an has had a modest number of two-wheelers, as well as a rising number of cars. Not surprisingly, there are increasing numbers of traffic accidents and fatalities, with pedestrians and cyclists often the victims. While this is certainly true in most developing country cities, the constraints on space within Xi'an's walls make the problem critical there. What are the odds of a fatal accident to a cyclist inside or outside the walls? How much would a BRT system, by improving traffic, improve the odds for the cyclist in the picture shown above? How easy is it for pedestrians to use sidewalks or other paths?

Hanoi and Pune have similar safety problems to Xi'an. Because both have much higher rates of two-wheeler ownership, citizens of these cities are also at great risk in the chaotic mixed traffic of large vehicles, ox-carts, and motor cars. What compounds the problem for Hanoi is that two-wheeler popularity is very recent. Neither authorities nor individuals have really had a chance to adjust their behavior during the spectacular 10 year rise in popularity of these vehicles. The sidewalk shown above is blocked by parked two-wheelers, a common scene in Hanoi. One key indicator of safety is simply a map of the region showing "black spots" where accident rates are highest. In both cities fatalities are much higher in the low-density suburbs. This is mainly due to motorcyclists moving at dangerous speeds outside of congested areas. A quantitative, spatial indicator set of accident frequencies and locations is a key indicator for action to reduce traffic accidents.

Pune is the home of Bajaj, one of the world's most important manufacturers of two (and three) wheelers, and is considered one of the homes of India's motor vehicle industry. When a bus ran off the roadway on a bridge (fortunately no fatalities), as shown above, the other traffic passing by moments later seemed unfazed. Note how close the two-wheelers are to the bus on the left. This is not a good indicator of safety!

Developing Indicators: The Policy and Analytical Process

Developing indicators of sustainable transport from basic data follows a chain that starts with a question: "What key decisions will leaders make that require information about the system and where it is going?" For example, a pollution index that is getting higher (i.e., higher concentrations, or more days exceeding limits) signals to policy makers that something has to be done about fuels, vehicles, and/or vehicle use. Another question is whether the transportation system is becoming increasingly congested because of poorly organized buses, or thick traffic in cars or two-wheelers. This could result in measurable time loss to vehicles and travelers. In both cases, indicators denote the changes in the system that are making everyone worse off. Finally, indicators can be developed from models and scenarios to answer the question, "What actions would change the direction of certain trends in the transport system?" Not surprisingly, the same indicators that measure degradation can measure change and improvement. In all cases comparing what is known (and what indicators can be calculated) with the indicators required for good decisions and evaluation is called "Mapping the Gap".

Exactly which indicators to choose, and how technical or complex they are, depends on who needs to know. For example, most of us need only to know an average pollution index made up from a group of many pollutants, but some decision makers and scientists will need to know the actual concentrations of each pollutant. Still others only care about the number of days a certain health limit is exceeded. Some are concerned about the uneven impacts of pollution on rich and poor, both by location and whether the exposed people are primarily in cars, walking cycling or inactive at home. Some authorities only care about the total number of vehicles on the streets, while others need to know the numbers by kind and size, and how far each are driven on average. The indicators pyramid allows very detailed information to be compressed into one or two simple summary indicators, yet points back to the original detailed information. This allows precision about what new data need to be collected to "filling the information gap".

The next step is to ask "who has the data". This requires cooperation among public authorities, and often private authorities as well. Economic and social data are usually collected by a public authority, as are some data on vehicle registrations. But data on vehicle and personal movements are often held by public or private companies that provide transportation, or gathered by special surveys. Some key traffic data are kept by the police departments. Information on land use is usually collected by a public authority, but often real-estate enterprises and others do private surveys. Information on pollution is almost always collected by public authorities; public authorities also often measure the quality of fuels, but it is the fuel providers (public and private) who must cooperate with information on real fuel specifications. Road safety and injuries are usually collected by private authorities. A key problem facing all countries, however, is that "public authorities" usually imply a variety of ministries, directorates, or other agencies at the national, regional, or local level. One goal of this project is to map "who knows what" in each partner city and foster collaboration among them.

Indicators are calculated from basic data on the population, vehicles, daily trips by purpose, emissions, location of infrastructure, homes, office, and safety. The detailed formulae must be transparent, and the data must be available so that alternative indicators can be calculated. This project will discuss the various formulae and alternatives. The diversity of each city will result in most important indicators to differ. Transparency requires that we understand how each city calculates its indicators so that results may be compared.

The needed accuracy of an indicator depends on what effects authorities want to observe. Discerning new Euro-2 emissions from those of 15 year old vehicles requires little accuracy; by contrast, deciding whether conversions of gasoline vehicles to LPG or CNG has lowered emissions overall may require more sophisticated testing that demands greater accuracy. Deciding whether a new ring road has reduced or increased overall traffic circulation may require a few traffic counting stations to determine the impact of the ring road, while measuring whether a new bus corridor has caused increases in traffic congestion both in the corridor and on cross streets may require far greater accuracy of traffic measurement than a city currently posses. How accurate the indicators should be is a political decision. Whether the data permit this accuracy is to be made by analysts.

A good set of indicators serves monitoring/evaluation as well as outward communication, as Figure 2 implies. If for example, implementation of Euro 2 norms on new vehicles fails to reduce emissions to expected levels, is this because the fuel is bad, the drivers have defeated the devices, or the calculations are wrong? If provision of new metro or BRT stops fails to capture riders who live close by those stops (as would be expected), is that because the potential riders already have two-wheelers or cars, because the estimate of those living close to the new stops was wrong (a technical error), or the new service is too infrequent or uncomfortable to win new riders (a consumer acceptance issue)? By quantifying expectations and outcomes, insights on both success and failures can be gained rapidly, and the strategy in question can be strengthened, revised, or scrapped.

An additional issue in evaluation is whether the original expectations of policy-makers reflected all the boundary conditions. Suppose for example there is an economic boom, stimulating more car use than expected? Or an economic bust, that slows the pace of motorization? Or an unexpected rise in fuel prices drove significant numbers of individual vehicle users to use public transport, as is the case in 2004/5 in Hanoi? Policy makers need to be prepared to both show what really happened, and whether or not relatively exogenous changes offset their efforts, or perhaps masqueraded as them.

Conclusions: Indicators Show the Way Forward to Sustainable Transport

Indicators have been used in all sectors of the economy for many years. Indicators of sustainable transport are formed from basic data and estimates describing the transportation system and the people who use it, the physical infrastructure of the region, the economic activity transport generates, as well as the pollution and other measures of environmental problems associated with transport. Used properly, transport indicators provide a powerful tool box for understanding how today's transport system evolved from that of the past, and how it could change in the future. Above all they illustrate our power to improve future systems and to achieve sustainable development.

In the preliminary work that provided the indicators for this paper, officials were surprised to see the various figures juxtaposed. For example, in Hanoi, the absolute number of traffic deaths, after peaking in 1994, fell slowly. Relative to the number of motor vehicles, however, which skyrocketed, traffic deaths (mostly pedestrians and two-wheeler riders) fell rapidly. While the absolute decline is more important for public policy, the fact that the decline per unit of "cause", i.e., motor vehicles, suggests road safety is improving, albeit slowly. For congestion, leaders were surprised to find that two-wheelers and cars together dominate both Hanoi and Pune's streets, and actually take 50% of all trips in Hanoi. More shocking was that the average speed for a journey in Pune was less than 10 km/hr, even for journeys taken by car or two-wheeler! For air pollution, all three cities have to confront the fact that they have very sketchy data on air quality, and for Hanoi and Xi'an, almost no indicators of emissions from individual vehicles, i.e., emission factors for cars, two-wheelers, etc. These findings suggest that the most important indicators indeed include traffic fatalities (and the pedestrian/cycle/two-wheeler share), distance traveled per day by each mode, average speed by mode, ambient air quality (as concentrations of major pollutants), and emissions factors (in gm/km) of major pollutants for important vehicle/fuel combinations, which are all necessary to both read the health of the transport system and monitor improvements.

The PSUTA has high expectations from its partner cities to act on the major problems the work so far has highlighted. The high fatality rates, high levels of congestion (and for most, long commute times), high levels of air pollution, and lack of large, strong bus systems in all there cities "indicated" to authorities that transport and environment are in need of strong reform. Hopeless congestion in Pune and the inner parts of Xi'an, and the slow but snarled pace of dominant two-wheeler traffic in Hanoi all argue for fast mass transit – some combination of inexpensive rail, bus rapid transit, and other measures (including routes for ever-present bicyclists and pedestrians that protect them from motorized traffic of all sorts) need to be implemented now. The indicators will show the results – safer mobility, lower pollution, and lower travel times.

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