Cluster 7/Module 2 (C7/M2): Environmental Issues.

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Environmental degradation is an important and growing issue for many cities in the developing world. Use of motorized vehicles contributes to this degradation. This module is intended to help readers understand the basics of the kinds of environmental degradation that are affected by transportation, and what kinds of policies can or should be considered to address them.
Opening Exercise
Different approaches to Environment

• Fixing environmental problems like air pollution from vehicles can take two approaches
• One approach is to reduce the number of vehicle kilometers traveled (VKT) in a city over a day, week, or year
  – What kinds of measures might reduce VKT? List 3
• Another approach is to reduce the amount of pollution that is emitted per VKT
  – What kinds of measures might reduce the amount of pollution emitted per VKT? List 3

This exercise is designed to get you thinking about different ways that urban transport can help improve urban air quality.

Many people think that improving the quality of vehicles – getting newer, cleaner vehicles into circulation, and getting old, clunker vehicles off the street – is the best way that urban transport can contribute to cleaner air.

But there are other ways that urban transport policy can help clean the air, and provide other environmental benefits as well.

Take 5 minutes to think through this exercise, and see if it challenges your assumptions about the relationship between transport and the environment.
Sometimes, environmental problems are serious enough that they should drive policy. Maybe it is worth changing the modal focus of our city not just to provide better accessibility for residents, but also because our air is toxic, the amount of energy we are consuming in urban transport is a drain on the national economy, or there are just too many accidents and injuries.

Sometimes, environmental problems are not what should be driving policy, but knowing the problems may tell us some different way of doing something we were going to do anyway. We may not change our fundamental approach to urban transport because there is excessive noise, but perhaps we can do things a bit differently – put in sound walls or purchase quieter buses.
Air quality

- 2 factors we want to know about
  - Ambient air quality
    - What are the concentrations of which pollutants in the air?
  - Emissions from different sources
    - What are the rates at which pollutants spill out from different sources?

These factors are measuring different things: the first is measuring what people are exposed to. The second is measuring who are the main polluters.

Both of these factors are variously subjected to different limitations around the world.

For example, national environmental agencies typically publish legal limitations or guidelines for ambient air quality. The World Health Organization puts out human health-based guidelines on ambient air quality.

(http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf)

Similarly, many countries limit the emissions rates for different pollution sources, such as power plants, factories, and cars.
So what is air pollution, anyway?

- **Main categories of air pollutants:**
  - Particulate matter
    - Soot
    - Soluble Organic Fraction
    - Sulfates and Nitrates
  - Toxic and carcinogenic gases
  - Ozone
- **All of these are damaging to human health in various ways**

**Particulate matter:** very small, solid particles made up of different substances. These are dangerous, because they can get lodged deep within human pulmonary systems, creating many health problems.

Most PM by mass consists of soot (“black smoke”), which are solid carbon particles that result from incomplete combustion in stoichiometrically fuel-rich environments. For this reason, diesel vehicles are often big sources of particulate matter in urban areas. However, there are other kinds of particulate pollution that are damaging as well. Non- and semi-volatile hydrocarbons can condense to form another important mass-based proportion of PM. For example, improper proportions of lubricating oil in gasoline for two-stroke engines can produce a lot of this type of particulate pollution (“white smoke”).

PM is usually measured by particle size – the smaller the particle, the more health damage it can do. Through the end of the last century, most emissions standards regimes were based on limiting emissions of particles of 10 microns or less (PM\(_{10}\)), but increasingly, emissions standards regimes are regulating particles of 2.5 microns (PM\(_{2.5}\)) or less.

**Toxic and carcinogenic gases:** generally refers to gases such as carbon monoxide (CO), sulfur oxide (SO), sulfur dioxide (SO\(_2\)), nitrogen dioxide (NO\(_2\)) and numerous species of toxic hydrocarbons.

**Ozone:** often called “smog”, O\(_3\) is the result of complex chemical reactions, fed by volatile organic compounds (VOCs), oxides of Nitrogen (NO\(_x\)) and sunlight.
In many developing countries, ambient air quality is monitored against guidelines (such as the World Health Organization’s recommended ambient air quality guidelines), but is not regulated per se.

Emissions rates, however, are often regulated. The main transport-related pollutants that are most often subject to regulation are:

- NOx
- CO
- VOCs (sometimes regulated as Non-methane Hydrocarbons, or NMHCs)
- PM$_{10}$
- PM$_{2.5}$

However, regulating emissions rates from vehicles may not be the most effective (or cost effective) way to improve ambient air quality or reduce the pollutants to which people are exposed.
As noted elsewhere in these self-study modules, avoid, shift, and improve is proposed as a strategic approach to conceptualizing and addressing urban transport problems. The chart above shows that adopting a purely regulatory approach to air quality control from the transport sector – for example, by adopting vehicle emissions standards – only addresses the “Improve” component of the strategy. If only “Improve” is addressed, and there is no effort to reduce total vehicle activity through Avoid and Shift strategies, then:

1) Future growth in vehicle kilometers traveled (VKT) could offset any reduction in specific vehicle pollution intensity; and
2) Continued future efforts to address vehicle pollution through emissions standards could become exorbitantly expensive, because the amount of technical improvement to make up for the volume of VKT could be substantial

Because Avoid Shift Improve is discussed in detail elsewhere in the self-study modules, we do not go into detail here, but readers are cautioned that ASI is a key framework for framing policy responses to air quality challenges in the transport sector.
In many cities, urban transport is associated with as much as one third of ambient PM10 concentrations and is responsible for even more of the ambient PM2.5 concentrations.

PM has been associated with respiratory and cardiovascular disease, and is a suspected carcinogen. It is also associated with elevated incidence of asthma, especially among vulnerable populations like children and the elderly. Unlike gaseous pollutants, particulates can get lodged deep within lung tissue, thereby persisting in damage long after the initial exposure incident is finished. For this reason, they are a particularly concerning public health risk, particularly in developing country cities where population densities make exposure particularly acute.

Vehicle emissions contributing to particulate urban air pollutions have been linked to 1.2 million deaths annually world wide.
There are a lot of options for addressing PM in a city, but a key in figuring out appropriate solutions is **understanding the nature of the problem.** Is the particulate problem caused by the transport sector? If so, what are the main culprits: diesel vehicles? 2-stroke vehicles? Freight vehicles? Passenger vehicles?

The first bullet point above is relatively straightforward. Here, the strategy is to try to keep very polluting vehicles from circulating where people are. This can be done by reducing the number of older diesel vehicles allowed to circulate, restricting where they can circulate, or proactively seeking to organize city logistics in a manner such that these vehicles have no reason to be circulating near people. (For example, the city could incentivize through PPPs transhipment or logistics staging centers around metropolitan areas outside of city centers.) In many cities, the objective of this bullet can also be met by encouraging circulation of larger vehicles, to consolidate and replace services previously provided by (many more) smaller vehicles.

The second bullet requires very careful consideration. Any requirement (e.g. through regulation or obligation, in the case of concessioned services) for improved vehicle technologies that control pollution impose a cost to operators. They will either absorb this cost or pass it onto users. If the cost is too burdensome to be absorbed by the group that must ultimately bear it, it will produce unanticipated (probably undesired!) consequences (e.g. reductions in service or maintenance, reduced ridership in favor of other modes, etc..)
Technological solutions

- Expand use of more sophisticated exhaust after-treatment technology (e.g. Euro III, Euro IV)
  - Requires low-sulfur diesel fuel to be effective
- Replace diesel with alternate technologies that do not produce as much particulate emissions
  - At present, only Compressed Natural Gas (CNG) vehicles are even somewhat commercially competitive with diesel for heavy-duty applications, such as bus-based public transport

There are two technological fixes to diesel engine’s proclivity to produce particulate emissions
1. Use more sophisticated engines, with advanced fuel injection technology and computer-controlled cycle timing. Widespread use of this technology is often not feasible in the political economy of many developing countries.
2. Use more sophisticated exhaust after-treatment technology, such as oxidation catalysts and particulate filters. It is feasible to envision more widespread use of this technology, but the technology will only function if there are very low levels of sulfur present in the fuel. So in order to enable use of this technology, supply of low-sulfur and ultra-low sulfur diesel has to be coordinated with rollout of the technology.

In addition to technological fixes to diesel vehicles so that they emit less, a second strategy is to change the technology. For heavy duty applications such as bus-based public transport, the only technology that is commercially ready enough to replace diesel is compressed natural gas (though in some limited applications, electric-traction buses, with overhead catenaries – known as trolley-buses – could be also be considered feasible.)
CNG vehicles use spark-ignition technology, like gasoline vehicles, but are more able to deliver the power and torque required for heavy duty uses, such as public transport, than gasoline vehicles. Because they use spark-ignition rather than compression-ignition engines, they are less prone to generation of NOx or soot than diesel vehicles.

However, CNG vehicles such as buses are generally more expensive than conventional diesel buses (on the order of 2 to 3 times more costly for initial purchase.) This is particularly true if certain vehicle types, like low-floor buses, are being utilized, because of structural changes that must be designed into the CNG buses. Being a spark-ignition technology, CNG vehicles are generally less energy efficient, because spark-ignition vehicles have lower compression ratios than compression-ignition vehicles. In addition, CNG buses require carrying relatively heavy canisters, which add weight to the vehicle in addition to the weight of the fuel itself. This also results in a fuel efficiency penalty.

The natural gas and natural gas vehicle industries are quite aggressive at marketing their products as good solutions to the particulate matter problem in many cities. Whether CNG is an appropriate solution will depend on particular circumstances, but the decision must be weighed in the context of an entire system, its service plan, the nature of the passenger demand it is trying to capture, and the availability of (and hence, the expected stream of costs for) natural gas. The technical characteristics of a single bus compared with another should not drive the decision to use CNG or diesel, but rather whether the system as a whole, using those vehicles, at prevailing or foreseeable prices at the time of the analysis, is capable of meeting the kind of demand expected at the fares that passengers can be expected to pay. It may be fine to have a fleet of low-emission CNG vehicles, but they will
do little to reduce PM emissions if no one is actually using them.
Noise

- Has received attention in EU, but in many developing countries, attention to noise pollution is considered a luxury.
- Excessive noise pollution associated with: sleep dysfunction, impaired school performance and communication, hearing impairment, hypertension, ischaemic heart disease, and increased annoyance and aggression.
- Traffic is an important source of noise.

Noise pollution has received a great deal of attention in EU, leading to adoption of a noise directive in 2002 (2002/49/EC), but in many developing countries, attention to noise pollution is considered a luxury, or at least not something that merits high level policy attention, compared to other environmental problems urban residents are facing.

Traffic is an important source of noise; generally, the faster the traffic, the higher the ambient noise level (except for increased horn-use associated with congested traffic conditions). This means, however, that, all else equal, measures that address congestion solely by facilitating traffic flow will tend to increase noise pollution in a city. However, this relationship is not monolithic; heavy duty vehicles tend to produce more noise than light vehicles, so replacing many smaller light-duty vehicles with fewer, heavy-duty ones may not necessarily lead to a reduction in ambient noise. Rather, specific measures need to be developed for particular circumstances. In order for that to happen, however, noise has to be identified as an issue to be addressed.
The relative contribution of transportation to urban water quality degradation is probably lower than its contribution to urban air quality degradation, but it is not negligible. The transport system deposits pollutants in soils and on road surfaces through a number of mechanisms, including poor environmental management and handling of vehicle servicing refuse (including poor or inadequate maintenance of the vehicles themselves), vehicle lubrication system losses, vehicle exhaust emissions, load losses, degradation of vehicle tires, road surface cleaning and degradation, de-icing compounds in certain environments, and (to the extent transport contributes,) acid rain deposition.

At the same time, expansion of the road network and parking facilities reduces the area of permeable surfaces, through which storm water runoff might percolate into natural filtration and cleaning systems, such as sand and soil. The result is that surface oils and contaminants are loosened directly into storm water runoff, which flows directly into urban areas’ natural water systems.

This degradation is often exacerbated by other environmentally deleterious urbanization processes, such as loss of wetlands from either poorly planned or unplanned urban growth, and improper refuse disposal.
A study of the Atlanta area in 1999 found that each hour spent driving was associated with a 6 percent increased chance of being obese (as measured by Body Mass Index), while each additional kilometer walked was associated with a 4.8 percent lower chance of being obese.

The above figure shows that measured incidence of obesity (BMI > 30 kg m\(^{-2}\)) varies by country, and that it also highly and inversely correlated with the proportion trips made by walking, cycling, and public transport.

The studies cited above generally relate to car driving as the primary source of physical inactivity in the transport sector. In developing country cities, an analogy can be made to the growing prevalence of intermediate means of transport, such as motorized two and three-wheelers, as a provider of very localized access. There is a risk that the extensive growth of IMT services could be having a deleterious effect on urban populations, by provoking inactivity.
There are two ways that environmental improvements from urban transport interventions can be measured.

One is to measure against an absolute standard – did we meet some norm that is expected?

The other is to measure against a relative improvement. Are we relatively better off because we undertook an intervention, even if we did not meet an objective standard?
The World Bank

There are also two ways of understanding the concept of “improvement”.

One is to determine if we are better off than we used to be. The second is to determine if we are better off than we would have been, if we had not undertaken an intervention.

Suppose we put in place a series of measures that are supposed to make air quality better in three years. Three years later, we go back and measure, and find out that, actually, air quality has pretty much stayed the same. Should we interpret that our measures have been ineffective?

No, because in the interim period, the number of cars or vehicle kilometers traveled by those cars may have increased precipitously. In that case, air quality would have become substantially worse if we had not put in place those measures.

* The term “counterfactual” literally means the scenario “against the facts” – that is, the scenario representing what the world would look like today if actions taken in the past had not been taken. If a city built a BRT line 5 years ago, for example then the counterfactual might be what would the city look like today if the BRT hadn’t been built.
Many analysts would like to measure the “co-benefits” of transport interventions – that is, simultaneously measure the local air quality and the global greenhouse gas emissions benefit of a solution or package of solutions. Doing so often leads to a methodological incompatibility, because local air quality improvements are traditionally gauged against before and after conditions, while greenhouse gas emissions improvements are traditionally measured against the counterfactual case.

In order to measure co-benefits, even local air quality benefits will need to be measured against a counterfactual improvement – that is, how do project interventions taken at some time in the past affect what air quality would be today, if those interventions had not been applied?
Key lessons

• The most intuitive solution for addressing environmental problems from transport isn’t always the right one
  – Just focusing on vehicle technology without thinking how it affects the economics and service patterns of the whole system can have perverse effects.
  – Environmental solutions have to address the entire accessibility / mobility package

• Sometimes we intervene to make things better than they were before; other times, it is appropriate to go beyond, to look at which solution from an array of possibilities, will be best in the future