The 2008 MIT-NESCAUM Summer Air Quality Symposium on Urban Transportation

August 12 and 13, 2008
Endicott House, Dedham, Massachusetts

Chair: Dr. Robert Slott, Visiting Engineer, Massachusetts Institute of Technology
Co-Chair: Dr. Praveen Amar, Director, Science and Policy, NESCAUM

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Symposium Summary:

Urban Transportation

Sponsored by the MIT Laboratory for Energy and the Environment and Northeast States for Coordinated Air Use Management (NESCAUM)

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August 12th and 13th, 2008
Endicott House
Dedham, Massachusetts

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Session 1: Introduction

Michael Walsh, Consultant & Head of the International Council on Clean Transportation
Introduction to Urban Transportation

The symposium will focus on Urban Transportation. Today, about 50% of the world's population lives in urban areas, and 75% of our energy consumption takes place there or in support of urban activities. Urban populations are continuing to grow.

Cities are great places to live, but they must be made cleaner. Most urban areas in the world have serious air pollution problems; problems in Asia are especially severe. Most Asian cities have PM10 concentrations that greatly exceed WHO guidelines. Urban particulate is a serious problem, and much of that is because diesel vehicles and 2-wheeled vehicles are not yet controlled as well as they could be. As an example, the vehicle population in Hanoi is dominated by 2-wheelers, and riders are exposed to the highest levels of PM10, much higher than other urban dwellers. Diesel exhaust particulate was declared to be toxic by ARB in 1998. Diesel emission standards outside the US are less stringent. The health impacts of air pollution are clearly linked to proximity to traffic.

The congestion in many cities in Asia is tremendous. It's very difficult to get from one side of the city to the other. Cities have a tendency to build roads to try to resolve the congestion problem, but this is not sustainable. Roads lead to more emissions, noise and urban sprawl, which discourages walking/bicycling, and the roads soon become saturated again – this is a spiraling problem. More cars also leads to more roads, which take space, and this moves people further from their workplaces and other destinations, which leads to more people shifting to cars. For example, Beijing is adding about 1000 vehicles per day to its vehicle population.

His International Council on Clean Transportation (ICCT) has adopted "Bellagio principles," which include:

- Design programs and policies that reduce emissions of conventional and toxic pollutants, noise, and greenhouse pollutants in parallel.
- Treat vehicles and fuels as a system.
- New standards for greenhouse emissions and conventional pollutants should be fuel neutral.
- Expect & require the best technologies worldwide.

ICCT's priorities for the transportation sector are:

- Vehicles: low emissions, fuel efficient vehicles.
- Fuels: clean fuels (conventional and toxic pollutants), low carbon fuels.
- Reduced VMT through congestion pricing, Bus Rapid Transit, etc.

Emerging technology can help. For example, the ozone concentration in LA has been declining since 1985. In China the number of electric bicycles has been growing fast since 2-stroke motorcycles were banned. (The only problem is the bicycle uses lead acid

batteries.) In the U.S., we expect more electric drive vehicles to come into the market, starting first with hybrids.

Marketing helps too. An NRDC ad campaign describing the danger of being behind a bus in NYC helped to motivate the conversion of NY buses to use diesel particulate controls and low sulfur fuel.

Discussion

During the Q&A, a question was raised on what causes the variation in Asian PM-10 concentrations. Mike replied that air monitoring techniques differ substantially, and the concentrations could actually be understated in many cities.

When asked how fuel subsidies affect this problem, Walsh said this was a tricky problem. Many countries subsidize the price of diesel fuel; their economies are built on the availability of cheap diesel and this distorts the car market. In developing countries, the subsidies are intended for widespread use of diesel in agriculture for farm equipment. A long lead time would be required in a long-term program for many countries to increase diesel fuel prices. Denmark has very high prices for fuel, and half the Danes commute on bicycles and they tax diesel cars to offset any benefit from diesel being subsidized relative to gasoline.

Regarding sources of PM, in London PM10 from transportation is 12%, while PM-0.1 is 60%. As PM size goes down, the contribution from transportation is greater, and that is what people get exposed to. Although vehicles are a small contributor to the total mass emissions inventory of PM, this may not be the right metric. A study from the UK shows that the percentage contribution from vehicles of very small particulates is much greater than the percentage of larger particles. Exposure is also an issue, because people live their lives close to vehicle emissions, and vehicles are likely responsible for a much greater proportion of human exposure than indicated by straight tons of emissions data.

Finally, he concluded that looking at the entire vehicles and fuel system is important. Technology changes will also require behavioral changes and this has to be well-managed in order to be successful.

Session 2: Emissions

Moderator: Larry Cupitt, USEPA (retired)

Cupitt opened the sessions on emissions by stating that although vehicle miles traveled has increased over the years, regulations have caused emissions to decrease. Despite this positive effect, he pointed out that there are new challenges, including global climate change and congestion.

Steven Cadle, General Motors Corp. (retired)
Urban Vehicle Emissions

Cadle began his presentation by stating that we have made much progress on reducing light-duty gasoline vehicle (LDGV) exhaust emissions, so that in newer vehicles most of the emissions come from cold starts. Many factors are important in influencing emissions, including driving cycles, ambient conditions, fuels and lubricants, vehicle deterioration, and vehicle maintenance. Acceleration, high speed, and high load increase emissions. High temperatures increase evaporative emissions of both fuels and lubricants. Vehicle maintenance (especially to reduce high emitting vehicles) is where today's issues are greatest.

Cadle went on to describe the CRC E-23 Program and other efforts to measure emissions for light-duty vehicles. CRC E-23 is a remote sensing program to measure emissions of CO, HC, NO from LDGV. Results show that fleet-average emissions have been decreasing in all cities examined and that 10% of vehicles contribute most (75-95%) of the emissions. This percentage is becoming higher because fewer vehicles are high emitting as we clean up the fleet, particularly for hydrocarbons. Also, deterioration rates are lower than projected. One shortcoming of an on-road measurement method is that it does not include cold starts.

EPA sponsored a study in Kansas City in 2004-2005. This study included equipping vehicles with portable emission monitors (PEMs) as well as dynamometer testing and remote sensing. Evaporative emissions, caused by canister and permeation losses as well as leaks, are believed to be as important as exhaust emissions in hot summer months even though canister and permeation losses are small and there is little information about fuel leaks. The EPA Program E-77-3 has been established to gather more information about high evaporation emission vehicles. They want to identify high evaporative emitters through remote sensing, invite identified vehicles to participate in a study, and then measure hydrocarbon tailpipe and evaporative emissions from these cars in a "shed."

Cadle also addressed exhaust PM, temperature effects, brake wear, tire wear, and re-entrained road dust. In exhaust PM measurements, uncertainty is high. Brake wear contributes to PM emissions (17.6 mg/mi for PM10 and 2.2 mg/mi for PM2.5). Brake pads contain many ingredients, and more studies are needed to understand the impacts of these materials (e.g. potassium titanate, barium sulfate, copper fiber, etc.). Tire wear tends to result in larger particles, but more study is needed. Finally, re-entrained road dust

is estimated to contribute 35 mg/mi PM10 for light-duty vehicles, but there may be double counting in this estimate.

Heavy-duty diesel vehicles are an important source of NOx and PM in urban areas, but emissions studies have also shown major emissions reductions. Chassis dynamometer tests are limited by cost and vehicle availability. Testing diesel vehicles on dynamometers is very expensive, so results are limited. Portable emissions testing systems (PEMS) are sometimes used. Remote sensing is good for NOx, but not PM. Emission rates are coming down significantly for new vehicles.

Chassis dynamometer studies were used to measure exhaust emissions from in-use diesel vehicles in the CRC E55/59 program. The Advanced Collaborative Emissions Study (ACES) was initiated to measure the impacts of PM traps, new vehicles, and lubricants in new 2007 compliant diesel engines. Four engines have been tested, all of which are similar in terms of the exhaust NOx and particulate levels. The particulate levels have been measured reproducibly, but it is unsure whether these results are meaningful because lab conditions do not necessarily reflect what is happening on the road. The half-life for the particles is also relatively small. A study of animal health effects is planned.

Other sources include non-road and two-stroke engines. Non-road vehicle emissions are at least as important as on road sources. Two-strokes are a problem in some areas. Envirofit is running a retrofit program to convert two-stokes into direct injected engines. The program shows a less than one-year payback in fuel savings.

The Kansas City study mentioned previously also measured air toxics for light-duty vehicles. There is little toxics data for heavy-duty vehicles, though ACES will provide some data for 2007-compliant heavy-duty vehicles.

These studies led to several conclusions according to Cadle. More data is needed on evaporative and heavy-duty emissions. In-use emissions require further study. New heavy duty diesel vehicle emissions will be relatively clean due to new after-treatment control methods like PM traps, but long-term effectiveness should be monitored. Brake wear, tire wear, and road dust should not be ignored for their PM contributions. PM emissions can be measured reproducibly in the laboratory but what that means for ambient concentrations is an open question. We need a real-time, accurate method to measure PM mass emission rates. Alternative fuels, new vehicle technologies, and rising costs will all affect emissions and will need to be reflected in emissions inventories. EPA's replacement for their MOBILE emission inventory computer model, MOVES, will need validation studies once it is complete.

Discussion

A participant asked whether the potential health impacts are dominated by non-tailpipe sources of PM10 and PM2.5. No one has yet studied the health effects of brake wear and other non-tailpipe sources, though there are concerns.

Another participant asked about a buy-back programs that pays to remove high-emitters/smokers. California still has some buy-back programs, but they are expensive. Increased inspection and maintenance is another strategy.

Dr. Jamie Schauer, University of Wisconsin-Madison
Mobile Source Contributions to Atmospheric PM

Schauer discussed a forensic approach to measuring emissions in ambient air, which involves collecting samples and then discovering what the sources are based on source profiles. Analysis of particles on filters can identify ions, mass, elemental carbon/organic carbon (EC/OC), and trace metals. His talk focused on carbonaceous aerosol (OC and EC).

Schauer gave background on measuring atmospheric PM (which is included in his slides). He stated that elemental and organic carbon area a major indicator of soot and tire wear. Trace metals which come from brake wear and road dust, while not discussed in this presentation, are important to consider.

Organic compounds speciation is a key driver for source apportionment studies. It involves identifying particle-phase organic compounds collected through source testing. e.g. from tunnel tests, and road sampling, to understand source fingerprints. There have been significant advances in the last 10 years in the use of particle-phase organic compounds for source apportionment. Molecular marker source apportionment methods were developed in the mid-1990s and applied to studies in California. More fingerprint compounds have been identified and multi-variant methods have been developed.

Molecular markers include levoglucosan, cholestanol, pimaric acid, hopanes, picene, and steranes. Levoglucosan makes up 20% of wood smoke. Pimaric acid is also an indicator of wood smoke. Cholestanol is a marker for burning cow dung. Hopanes and steranes are present in lube oil; in different distributions they are also indicators of coal combustion. Picene is a unique PAH present due to low-temperature coal combustion.

A Lake Michigan Air Directors Consortium (LADCO) study in six Midwest cities in 2004-2005 concluded that mobile sources, particularly in urban areas, are very important in terms of PM contribution. The excess above concentrations in rural locations demonstrates the importance of local emissions and helps in the placement of monitors. Tests at other sites show that source fingerprints are similar across clean and polluted cities in the world, and mobile sources are consistently a major issue, although the relative impacts of diesel, gasoline, and smoking engines vary considerably from place to place.

Atmosphere oxidation of gaseous emissions leads to secondary organic aerosols (SOA), another topic of the presentation. The oxidation processes are complex, but understanding of these processes is improving. Existing atmospheric transport models don't adequately explain sources of SOA because we don't understand the chemistry that

forms SOA, and we don't account for aging of SOA or precursors. Tracers for biogenic SOAs have been measured but there is a lot of uncertainty and disagreement.

In response to a question from Praveen Amar regarding Allen Robinson's recent article in Science last year that indicates that semi-volatile compounds are a major driver for the formation of SOA, Schauer noted that Robinson's work is based on laboratory work rather than field studies. Schauer is not sure he agrees with all the results, because biogenic oxidation can explain a lot of the SOA formation. If Robinson is correct, the impact of mobile sources could be much greater than if Schauer is correct.

Discussion

There was some discussion about specific tests and mixed results. There was also additional discussion of the Robinson paper regarding SOAs, which showed that primary organic aerosols are not inert and participate in many chemical reactions in the atmosphere. Schauer stated that their evidence does not show primary sources are drastically changing. Measuring semi-volatiles is important, but he doesn't agree with it being a major factor in SOA production. The disagreement between the studies could be based on a problem of scale.

Another participant inquired whether there is a difference in importance in semi volatiles in urban and non urban areas. Schauer responded that the answer may vary according to whether the goal is to apportion PM or to investigate the health effects.

Niranjan Vescio, Environmental Systems Products
On-Road Emissions in Cities around the World

On-Road remote sensors measure ratios of pollutants (polluntant/CO2). The technique is good for characterizing fleets, emissions distributions, and quantities of classes of vehicles contributing to pollution in various areas. Estimates of emission inventories can be made using data about fuel type, estimates of VMT, and assumed emission rates per mile. Vescio described on-road remote sensing studies in three cities: Singapore 2004, India 2004, and Dubai 2007, using RSD data to show how that fleet emissions distribution are characteristic of the quality of fuel burned, the technology in the vehicle operated, and inspection/maintenance programs at work.

According to Vescio, for any large city to have low emissions from vehicles it needs three emissions control strategies: clean fuels, strict tailpipe standards, and in-use inspection/maintenance.

Environmental Systems Products (ESP) did a study in Singapore in 2004, a place where all three of these strategies are in place, enforced, and low- sulfur fuel is used. Even Malaysian vehicles are addressed through a pullover program. In addition, road pricing and vehicle taxation provide disincentives to owning and operating a vehicle.

The Singapore study showed that emissions increase with vehicle age. Diesel emissions are less age dependant—characteristic of a more modern fleet. They start low and remain low in HC, CO, and NOx emissions but smoke emissions from diesel engines increase with the age of the engines. Gasoline vehicles also have higher PM with age but emit less than diesel engines. Petrol vehicles emit the majority of HC and CO. Middle aged petrol NOx is fairly high.

Singapore light duty vehicle (LDV) emissions were quite comparable to US LDV emissions, perhaps resembling a US fleet about 2 years older.

Only one anomaly was found in a vehicle class where the newest age group has higher PM emissions that the next oldest vehicle class. Further analysis suggested the greater numbers of newer Hundai, Mitsubishi, and Mercedes within that class brought with them higher average PM emissions.

India has a "pollution under control" program. They are approaching Euro 2 level fuel (high sulfur) and vehicle technology, and inspection is limited to CO and is not well enforced. ESP did remote sensing in Pune and Delhi in 2004 and gathered 20,000 measurements in each city in a 4 testing days in each city. They had a hard time matching license plates to registrations in India, which made identification of vehicle model year difficult. They classify the information only by vehicle class and use average fuel economy provided by the government to estimate vehicle class contributions.

In the India study, HC, CO and smoke contribution was disproportionately highest from two- and three-wheelers. Heavy duty diesels emitted most of the NOx. Delhi concluded a significant CNG conversion program before the 2004 study (all city buses, and all 3-wheel autorikshaws). HC emissions from three-wheelers seem to be lower as a result when compared to unconverted Pune fleet, but NOx increased as a result of the program. CNG busses in Delhi had high NOx emissions (there is no bus information for Pune). More work is needed to understand the mass contribution of NOx from the fleets. Smoke substantially diminished from converted three-wheelers and busses when compared to the unconverted Pune vehicles. India's emissions distribution resembles a U.S. of more that a decade prior.

Their Dubai study of 2007 showed a very new vehicle fleet which is only approaching EURO 2 fuel and technology emissions standards. Dubai has only a rudimentary emissions inspection. There are petrol taxes. 78,245 measurements were taken, mostly on light-duty vehicles. These measurements were binned in the same classes as the Singapore measurements.

In Dubai, the diesel vehicles weren't as age independent, particularly in smoke emissions; indicative of an older vehicle fleet. Light duty vehicle emissions rose quickly with age, and the percentage of high emitters was several times higher than the 2007 US fleet, despite being a newer fleet. Deterioration was more rapid. Fewer cars failed the idle standards than expected (12% of the fleet would fail the gaseous and 10% smoke). However, the inspection test is based on measurements while the vehicle is idling. This

kind of testing is not meaningful to describe on-road behavior. It may be that the cars are not as clean as required by the current US standards, or it may just be because there is a different fuel. The fleet emissions were similar to a 1989 Denver vehicle fleet.

On-road emissions are less the result of inspection and maintenance and more the result of the fuel and vehicle technology in place at the given time. The system of fuel and technology has a strong influence on overall emissions, which one published paper suggests roughly correlates to the country's GDP.

Discussion

One participant commented that cheap diesel is causing people in Delhi to buy diesel cars, which do not have PM controls, and PM is now increasing despite the use of CNG in busses.

Another participant pointed out that the studies look at emission rates, but it is important to remember that these rates are multiplied by vehicle kilometers traveled (VKT) to get actual emissions. There are substantial benefits to gain by reducing VKT, not just looking at technology to reduce the unit emissions.

Another participant mentioned the importance of testing for durability. Clean vehicles of low quality may deteriorate quickly and produce more emissions. He said that these remote sensing studies are a good technique to carry out such tests. U.S. mandated recalls and guarantees for in-use durability have also had an important impact on reducing emissions from deterioration. These manufacturer recall requirements are much weaker outside the US.

One participant asked whether the on-board diagnostic version 2 (OBD2) requirement exists outside the US. Another participant answered that there is a lag in Europe, but EURO 3 and 4 make some progress in this regard.

It was pointed out that these results are for warmed up vehicles, and other presentations argued that with newer vehicles, cold starts are most relevant for emissions. Another participant pointed out that the cold starts for new vehicles are still better than older vehicles.

Finally, a participant pointed out that there is a huge variation in the quality of the fuels that can affect emissions. For example, cheap kerosene is often added to diesel fuel in India. Without looking at fuels, interpreting these measurements may be premature.

Session 3: Congestion

Moderator: Susan Wierman, MARAMA

Wierman introduced this section by pointing out that advances in technology have created opportunities for congestion management that challenge urban transportation policy. Public acceptance of congestion management techniques is necessary to their implementation. Disincentives are important to motivate desirable behavior. For example, Singapore's electronic road pricing charges each individual for their transportation.

Tim Lomax, Texas Transportation Institute
Congestion: The Type that Claritin Doesn't Cure

Lomax began with his conclusions. Congestion is growing. It is rarely "typical." It is getting worse in cities of all sizes by affecting more times of day and more forms of transportation, but it is worse in larger cities. Smaller cities are reaching congestion levels in larger cities ten years prior. Congestion is wasting more time (4.2 billion hours) and fuel (2.9 billion gallons) in 2005 than in 1982. Less than one out of two trips is not congested (this statistic used to be three out of four trips were uncongested). Congestion also affects freight, especially with 'just-in-time' manufacturing, which is dependent on a reliable system.

In the US, the increase in fuel prices has reduced congestion as VMT has declined about 2% to 4% since 2007. The issue is how long this will last when gas prices decline and when school comes back in session.

Congestion has many causes, which suggests that there may be many solutions. Some causes include bottlenecks (national average of 40%), traffic incidents (25%), work zones (10%), bad weather, poor signal timing, and special events. Building more capacity, improving system efficiency, and managing the demand are some of the key solutions. Solutions also include managing construction, diversifying development patterns, and recognizing that we have to accept some level of congestion.

Road growth reduces congestion but is not the whole answer: places that have provided supply at pace with demand have experienced slower growth in congestion than other places (70% worse versus 400% worse since 1982). But this was mostly accomplished by those places not growing much. Other solutions should also be considered.

Better operations have helped reduce congestion, but hundreds of millions of hours less do not make much of a dent in the billions of hours of congestion. Public transportation provides benefits, but would have to grow alarmingly to handle the increases we see in travel demand. Personal choices (rubbernecking) are part of the issue.

Lomax pointed out that accepting some level of congestion is important because free flow is not the desirable state from economic, environmental, etc. standpoints. Therefore, it is important to convince people of the role they play in the system.

Local areas will choose different strategies depending on the nature of the problem and the political climate. The solution may differ from inner cities to suburban areas. There are huge benefits from increased mobility, which people need to understand in order to make the investment in reducing congestion. Lomax argued that we need to get as much out of the transportation infrastructure system as we can by using the tools available.

The long-term strategy should be to improve a whole range of issues while engaging the public in a discussion of what better we can all do. This requires operating the system well first so that the public doesn't think we're already wasting money.

Web site: http://mobility.tamu.edu

Discussion

The discussion began with the question of whether US behavior will return to previous patterns after gas prices decline. Lomax drew attention to the return to typical behavior after the energy crisis in the 70s. He pointed out that whether this happens again will depend on how much we keep hammering home the change in people's behavior and providing them with incentives. Clearly many people are ready for that, or enough people to provide a niche market in the set of solutions. However, higher fuel prices were argued to be the real incentive to reducing traffic. Gas prices have made people more attuned to the day to day choices, options.

One participant pointed out that systems may be flawed in terms of their funding mechanisms. For example, RIPTA, the bus system in Providence, Rhode Island, receives less funding when people drive less. Thought must be put into how these mechanisms are engineered.

Next the question of the link between increased capacity and increasing VMT and congestion was raised. Lomax stated that Cevero did a study of induced demand literature. More road capacity causes more travel. But Lomax thinks that those people aren't just driving around because there is more capacity (leisure drives take place in uncongested times). This issue has more to do with development of rural land inducing longer trips or capacity allowing travel to a better job or other opportunities such as less expensive shopping. Some choices concerning where to live are made based on the quality of the school district. Spending highway funds on inner city schools might help reduce congestion more than building more roads, because it's often the school system that draws people into the suburbs. Lomax argued that if an area is projected to grow 1.5 million people, increased capacity is necessary, but it is important to have balanced programs.

Finally, a participant suggested that this is a problem to do with pricing externalities that are currently not priced. Lomax concluded that there could be a public policy debate to convince people to pay for these externalities they are causing by driving.

Frank Kelly, King's College, London
Policies to improve transportation in London – Congestion Charging

A million people enter central London each day. Traffic has increased enormously since 1980; however, traffic into central London has been decreasing since 1991. Light vans are a big part of the issue, but private cars are considered most important. Transportation in general is recognized to be a major source of pollution; 66% PM10 and 38% NOx emissions are associated with mobile sources. The central section of London experiences the greatest problem.

In 2000 the first directly elected Mayor of London in 400 years came to office and was given power over certain regimes, including environmental issues. The document "Cleaning London's Air" published by the Mayor's office in 2002 set the goal of decreasing congestion and pollution arising from road traffic by decreasing the number of vehicles and emissions from individual vehicles. The document included two proposed schemes: Congestion Charging (CCS) and a Low Emission Zone.

The Congestion Charging Scheme was implemented to reduce congestion for the benefit of businesses in the Central Business District. The Mayor's legislative control includes 33 boroughs. The congestion charging scheme was implemented in the central financial zone, and later expanded to include an area to the west (consisting of residual and commercial areas). The initial zone was introduced in February 2003 covering 22 square km (about 1.5% of the greater London area) and the subsequent expansion in 2007 (combined area of 2.6% of the greater London area). The entry fee started at 5 pounds, and is now 8 pounds. It applies weekdays 7 am to 6 pm.

On the first day of the program congestion decreased 20%, and subsequently it fell by 30% however this has not been sustained as there has been year-on-year increases. The larger area included in Feb 2007 created resistance, but the residents in that area received a 90% decrease in the fee to enter the original zone, and this contributed in part, to the increased in traffic.

The fee was coordinated with other actions to reduce traffic. At the same time the fee was imposed, much of the revenue generated was used to increase the bus fleet and provide better public transport in general. The number of taxis working in central London also increased by 20% and by 2008 all London taxis were required to meet Euro III standards for NOx and PM.

Lots of people bought motor bikes, since those were exempt from the tax. Traffic on the ring road around the zone increased slightly, as some people detoured around the zone. Bus ridership increased because the bus fleet was expanded (with cleaner vehicles including a 90% reduction in PM10) and run more regularly. In 2008, 18,000 people enter London using bikes, some bringing them in on trains.

The problem is that things are not getting better, they're just different. Construction and increased bus and taxi traffic has contributed to congestion increasing to near 2003 levels.

Oxford St. which is restricted to buses and taxis is often lined full with these vehicles. Since both are diesel powered vehicles there is still a lot of exposure to emissions, (even though the buses and taxis are cleaner than they used to be). The number of personal cars entering London is still down. However, Kelly posed the question whether this change in transportation mix affected air quality. A team of scientists in London are modeling emissions and measuring whether there is a benefit from these schemes for an air quality point of view.

So far, the answer has been difficult to determine. PM10 modeling for the two years before and two years after implementation indicates that pollution has decreased. But 2003 was a very dry, hot year, so that year pollution was worse despite the program. Moreover, modeling predicted an increase in NO2 due to the increased penetration of particle traps on buses and taxis.

Monitoring within the central zone was limited prior to the CCS and was deemed inadequate for a rigorous examination of the issue. However, changes in the zone during the 2 years after introduction of the scheme were compared to changes outside of London, which led them to believe that there was no detectable change of roadside NOx, NO, NO2 or background NOx. However, the comparison was based on only one monitoring station so Kelly advised us to take these results with a grain of salt.

In conclusion, the changes in air quality that can be documented are very small, and it's hard to associate them with the CCS program. Any scheme like this is a complex scenario to interpret with many ongoing changes, and analysis will be limited by relying on available data. The clear lesson from this work is that if similar assessments are to be undertaken in other areas, it will be important to have good monitoring data in place a few years before the program to have to compare with data after the program. Improved data and modeling approached have has led the London team to be better prepared to assess other programs.

Kelly stressed that the fee program was not designed to improve air quality. It wasn't justified on a health basis, because individual awareness of air quality and health would not have supported such a tax in 2003. The program was instead designed to decrease congestion and benefit business.

Livingston, the mayor who was responsible for the original scheme wanted to increase the charge for high emitting vehicles, making it an emissions-based charge. The new mayor will not however introduce this policy. The question is now whether the CCS will continue in its present form, since congestion has increased again. Kelly pointed out however that it may have been worse without the program. The new mayor has promised a referendum on the westerly extension in October, but the central CCS is expected to continue.

There are other difficulties in implementation of such schemes. For example, U.S. diplomats refused to pay the congestion price because they interpret it as a tax from which diplomats are exempt. Unfortunately, many other consulates followed suit.

Discussion

One participant asked whether there was a show of accountability, including the promise of certain benchmarks and measurement of the achievement of those goals. Kelly responded that the promise was the decrease in congestion, which is disappearing now. Kelly believed that the political agenda was to make London more and more car unfriendly. To this end there has been a rephasing of traffic lights which has contributed to increased congestion times. There is a parallel to NYC, where there is a lot of road digging going on to replace drains leading to problems. The number of cars entering London was already dropping was probably due to parking pricing and difficulty of coming into London. Still, overnight, following the introduction of the charge the number of cars coming in dropped by 30,000-40,000.

Questions were also asked regarding the mechanism for collecting the fees, and Kelly briefly described an online system where people pay in advance. If they do not do so, cameras detect license plates and bills are sent to the addresses registered to vehicles.

Bruce Schaller, NYC Dept. of Transportation
New York's Congestion Relief

Congestion Pricing was one element of Mayor Bloomberg's PlaNYC, a 2030 sustainability plan. The objectives of this plan were to help decrease the city's contribution to global warming by 30% by 2030, while at the same time accommodating 1 million more residents and improving quality of life and economic and environmental factors. In terms of transportation, congestion was recognized as a problem with peak period speeds averaging less than 12 miles per hour in much of the city. Transit lines were projected to be at or over capacity by 2030. The plan contained a proposal to apply congestion pricing in Manhattan below 86th street and use the revenue to improve transit and thus service the expected increase in ridership.

USDOT awarded the City and MTA $354M contingent on implementing the Congestion Pricing Scheme. The State Legislature created a Congestion Mitigation Commission to study the Mayor's plan and various alternatives. The Commission made recommendations in January, the City Council approved the Commission's plan in March, but the state legislature failed to approve the program by the April deadline for receiving the DOT grant. The governor then appointed a new Commission to study MTA funding needs.

The Congestion Mitigation Commission considered a wide range of alternatives, including tolls on bridges. Its final recommendation, after receiving extensive feedback from the public, was an $8 fee for all inbound traffic below 60th Street, for the period 6 am to 6 pm. The fee for intra zonal trips was eliminated and replaced by parking and taxi fees for parking and trips below 60 Street. The goal was 6.8% VMT reduction.

Even though the scheme was not adopted this spring, Schaller recognized important outcomes. A tremendous amount of public support for the proposal was generated but contingent upon the reinvestment of revenue in public transit. Two governors and the City Council endorsed the proposal. The public supported it IF the revenue would be used to support public transit. Schaller argued that politics prevented approval in Albany, involving issues such as equity amongst individual drivers and regionally, and MTA credibility for use of the funds. NYCDOT and its partner agencies such as the MTA will continue to work on these issues.

This process helped those involved understand the bigger transportation picture. Growth was a powerful argument and has a big impact on public perceptions. The fact that the plan was modified in response to public concerns helped build support. Alliances were created and the level of support leads to the expectation that the overall agenda will continue to be pursued, but there is a continued need for effort and coordination both from the governmental and nongovernmental sides. There is also support now for the broader agenda of improved public transit.

The NYCDOT Strategic Plan provides a comprehensive approach—issues addressed include traffic congestion, promoting non motorized transport, transportation demand management, operations, aligning prices with policy objectives, and enhancing streets as public spaces. Some next steps include: painting wide red lanes for buses only, providing sidewalks to get to bus stops, extending bike lanes separated from traffic (including signals), piloting variable rate parking, creating Saturday no traffic day on Park Avenue in Manhattan, and building plazas throughout the city.

Schaller argued that if you change how you handle traffic there are many other good uses for the public space. The changes are being well received, and they relate to the larger goals of the strategic plan, which he hopes will bring them back to congestion pricing.

Discussion

One participant asked what could be learned from London's experience, where benefits were hard to measure or not sustained, a hard value proposition to put forward. Schaller's response was that much was learned from London. London congestion levels were largely due to street work and things would have been much worse without congestion pricing. From a NYC perspective they would expect to have a large reduction in congestion and an increase in reliability of travel time. Congestion pricing is a litmus test whether to move forward in that direction. In the NYC case, they were careful not to oversell the air quality benefits, particularly on asthma reduction. Congestion arguments are more straightforward than the air quality connection.

Another participant pointed out that these strategies are modeled more after the Bogota, which is trying to take back the city for the people. Schaller responded that NYC is taking pieces from many cities to follow the "NYC model," which is learning from a number of different cities and taking what is applicable.

Another participant raised the issue that driving also has positive externalities in terms of economics. Schaller responded that studies in NYC do not project a negative economic impact. For example, the large majority of people arrive by means other than cars for shopping. Retailers are more concerned of how it will affect their ability to arrive to work rather than their customers. The point is to reduce auto traffic, not eliminate it, by encouraging people to think twice before they decide to drive. The average person who drives into Manhattan drives in some days of the week rather than every day, so this is encouraging them to drive a day or so less.

Another question was raised regarding whether these drivers are simply moved into taxis and transit, moving people to another system and then jamming up that system. Schaller responded that they were simply trying to encourage people coming to the CBD to take transit rather than drive.

The same participant asked about how they had considered truck traffic. Schaller expects a smaller reduction in trucks than other vehicles. There are some efficiency opportunities like night delivery (though maybe limited).

Finally, one participant raise the connection of cycling and health impacts, suggesting that reducing obesity might be a more effective health argument than air quality. NYC has seen a 70% increase recently in cycling, and they are adding hundreds of miles of bike lanes and paths over the next several years. A notable interaction to the various initiatives is that greatly reduced bus emissions makes cycling more attractive.

Session 4: International Urban Transportation

Moderator: Praveen Amar

Amar gave a brief history and introduction of people involved in the NESCAUM symposium, which has been organized annually since 1993. There is a focus on the science and policy of climate change. Amar emphasized that every city will be different and solutions should fit the context.

Joseph Sussman, Professor of Civil and Environmental Engineering and Engineering Systems, MIT,
The MIT Portugal Transportation Systems Program: Towards Sustainable Transportation

MIT is implementing a five-year program in Portugal and Boston (the MIT Portugal Program (MPP)) that began in Sept. 2006. It is funded by the Portugal Ministry of Science, Technology, and Higher Education at about $8 million per year. The intent is to support research and education in five areas: bio-engineering, engineering design/advanced manufacturing, sustainable energy systems, transportation systems, and cross-cutting engineering programs. The focus of this talk was transportation, to which about 20% of those funds are dedicated. The program operates within the Engineering Systems Division (ESD) at MIT which includes people from engineering, management,

and social science. This enables each of these areas to be integral to the approach in each of the applications areas of MPP.

The purpose of the program's transportation focus is to design integrated intermodal transportation systems that permit sustainable development. Sussman defines sustainable development as development that allows for economic growth in an environmentally suitable way combining that with social equity. MIT faculty work with faculty Lisbon (IST), U. of Porto, and U. of Coimbra, Portugal to develop new graduate programs in transportation systems at the master's and PhD levels. Graduate students at both MIT and the Portuguese universities work on related topics aimed ultimately at designing a sustainable, regional, intermodal transportation system.

In addition, a transportation industrial council was established to build relationships between the universities in Portugal and private industry,

This program adopts a regional approach, which in Portugal's case is defined as the national level. The approach also views transportation as a complex, large-scale system. Sussman expressed an interest in advancing methods in transportation systems that will help other areas: real options analysis, design structure matrices, enterprise architecting, etc. The structure of the program is designed around three elements (ITS, airports, high speed rail), and one cross-cutting focus on regional transportation needs. Sussman argues that it is important to consider the interconnection with the various levels of transportation, from the urban system to the larger regional system, from city to city and national to international scales.

The educational component of this program currently consists of a Master's program taught primarily by Portuguese faculty with participation by MIT faculty and using MIT content from the OpenCourseWare website at MIT. The program is composed of a two semester curriculum, which his presentation described in more detail, and a thesis. PhD programs in transportation current exist on the three Portuguese campus; these are being redesigned to take advantage of the new intellectual content being developed by MPP.

Sussman discussed various transportation eras, and believes the current era in transportation is characterized by an expanded role for stakeholders and a broader definition of stakeholders—in defining the system, defining performance metrics, considering strategies, making decisions. Also a characteristic of the current era is a focus on sustainability (economics, environment, & social equity) as a performance consideration.

Sussman described the thesis work of one graduate student, Travis Dunn, on the link between technology and strategic planning. He explained that our capacity for using technology for operations and tactical decisions has improved; however, it is not being used well for strategic purposes. Strategy does not only come from planning, but also can come from a pattern of decisions and the notion of the economic and non-economic contributions an organization can make. Dunn is looking at a step-by-step method of how to revise processes and designs using various technological inputs.

Discussion

One participant raised the question of the role of politics in this work. Sussman responded that the political concerns are being accounted by considering the institutional framework within which decisions are made. The level of strategic intervention, whether it is the federal, state, or other level, will be a key component of Dunn's work.

Students engaging in research have met with various authorities in Portugal at multiple levels indicating cooperation from the appropriate government agencies.

Walter Hook, Institute for Transportation and Development Policy
Urban Transport in India

Most traffic in India is pedestrian (39% mode share in 2002), but motor vehicle traffic is exploding with the growth of the economy. There is huge variation from city to city, including different rates of sprawl and expansion. One problem in dealing with these issues is that manuals, guidelines, and designs are being taken from western sources and then applied in the Indian context where mode share is different. Motorcycles are much of the motor vehicle population. Particulate matter from motor vehicles is a significant problem. Overpasses (flyovers) are being constructed to help ease street crossings, but cost millions of dollars. Safety is a big problem and pedestrian and two-wheelers tend to be the most frequent victims of accidents. Pedestrians often walk in the road because there is no room on the sidewalk. Most accident victims are pedestrians or bicycle riders. Many accidents are occurring at the curbs where buses competing for passengers let them disembark into traffic.

Shared three-wheelers are inexpensive popular alternatives to busses. There is much debate about what sort of mass transit system to build. Many (smaller) cities are planning bus rapid transit systems, though there are also plans for metros, light rail, monorail, and commuter rail.

Urban settlements have complex streets complicated by various encroachments (mosques, graveyards, etc.) that constrain the width of any proposed right-of-way relatively arbitrarily. This can complicate the design for a BRT.

Some cities ban cycle rickshaws. In Old Delhi they were banned by the Supreme Court in 2006. Many decisions in India are pushed up to the Supreme Court which makes unilateral decisions, which is not always the most appropriate solution. ITDP and other activists challenged the ban because rickshaws cannot be blamed for congestion. Demonstrations were organized. ITDP also developed modern designs for cycle rickshaws. Modern cycle rickshaws are lighter in weight and more comfortable for the passengers, and they are an important source of income. They cost the same as the old rickshaws and more than 250,000 have been sold so far.

Hook then described the typical characteristics of BRT, including: newer, cleaner high capacity buses, enclosed and secure stations, pre-board payment and free transfer,

pedestrian and bicycle access, and segregated lanes. Central lane bus configuration is normal and critical to increasing speeds by preventing interference of turning vehicles, taxis, and bicycles. The use of central bus stops requires doors on the correct side of the bus, requiring the purchase of new buses. Ideally, a regulatory agency should properly design the BRT facility and set and enforce operating procedures. The operation of the busses can then be public or private.

In some cities in India, due to poor design, the whole concept of BRT can be threatened because, in the case of Delhi, the design unnecessarily reduced mixed traffic speeds significantly. Hook described the system in Pune, which opened in 2006 in a narrow political window. Hook argued that there was a poor design standard, poor operations, and that this effort brought modest benefits but its image was not good enough to secure political support for BRT.

Delhi's system, which opened in Spring of 2008, has a good bus design (including CNG buses), complimentary separated bicycle facilities (to reduce accidents with buses and encourage cycling), good pedestrians crossings, with buses operating in the central median (a good standard). However, there are numerous problems. For example, any buses (not just BRT buses) can use the dedicated bus lanes. Some of these buses are old and cause backups due to breakdowns. Stations, which are not very comfortable, are also built at intersections, which cause congestion. Stations must be back from the intersection to make it possible for busses to move after loading/unloading passengers without waiting for the light to change. If buses turn from inside the bus way at many of the signals, then additional signal phases are needed to allow the turns, slowing down both mixed traffic and bus speeds. Bus routes should be changed so that the number of turns are restricted; passengers should be required to change busses rather than accommodating all existing turning bus movements.

The problems with the Delhi BRT are undermining the credibility of BRT throughout India. The problems seem largely due to a poor understanding of the best operational and technical design features and a lack of cooperation with foreign experts. No one had tried BRT in India before 2002. The recurring problem is that the physical system was designed without considering how it will operate.

Hook briefly drew upon the TransJakarta example outside of India. After the BRT system the old buses stopping at the curbside were also allowed to operate, which contributed to congestion and competed with the BRT.

Finally, Hook discussed the BRT in Ahmadabad in India. In this example, designers are trying to avoid the problems that exist in Delhi with better station design and better operations. In addition, they are going to try to make the BRT a product of both the public and private sectors, following the Curitiba and Bogotá examples. As a contrast, Delhi's system is almost entirely public sector.

Discussion

One participant asked what challenges are raised by the public/private issues. Hook responded that the Indian government supports special purpose vehicles (SPV) for developing public-private partnerships (PPPs). Delhi created a SPV but its powers are not clear. He argues that it is key to have a regulatory body in power to regulate the BRT system and its proper use. Then, he said, it is good to contract out the operations.

Another participant returned to the Supreme Court issue of making decisions regarding transportation. He stated that the Indian Supreme Court has made some good progress with emissions related issues. He argued that the fundamental problem is institutional in nature, and asked whether Hook saw the government solving the institutional problems. Hook answered that the SPV had a chance to do this, as the SPV for the Delhi Metro works well, but he was skeptical because he is unsure whether the BRT SPV will be given enough power to solve the problems.

Two-wheelers were mentioned by two respondents as critical in the Indian situation, as well as in other countries where they are spreading rapidly. Other developing countries, especially those in Latin America, can learn from Indian experience with two wheelers, which is an important environmental problem.

Finally, a responded asked if there was a "light at the end of the tunnel" with regards to national transportation. Hook responded that India is learning how to do BRT, but the problem is that the operations are not being thought of until the infrastructure is built. The national government is now requiring an operations plan in advance, which is very positive and gives hope for the successful use of BRT in India.

Jiawen Yang, Georgia Institute of Technology
Urban Transportation in China – Challenges and Hopes

China experiences many urban transportation problems, including severe congestion and pollution. The national government has its own measurement system and doesn't record smog days, though some cities have started to do so. In Shenzhen in 2007 there were 231 smog days. Mixed traffic and behavior adds to congestion problems: cars park on sidewalks, cyclists use the sidewalks, buses cannot maneuver in and out of traffic, and intersections become snarled because people don't follow the signals.

Yang asked the question how China, once the kingdom of bicycles, has come to today's situation. As in many developing countries, economic and income growth contributes to an increasing demand for mobility and a greater ability to purchase automobiles, leading to rapid motorization and accompanying congestion. Car owners are much less likely to walk, bike, or use transit. China's particular situation is exacerbated by China's specific situation of limited space and fertile land. The government, unprepared to deal with the issues associated with the constraints and rapid motorization, attempted to build out of congestion.

China has undergone a unique transformation of urban space. China was a market based economy, switched to a planning based economy, then in the late 1980s switched back to

a market based economy. In the 1950s-80s, when China was a planning based economy, urban areas expanded while people remained concentrated in work compounds with the full set of self-contained activities. Because of this phenomenon, travel demand did not increase with the expansion of urban areas. However, once China returned to market based economy, developers started building new communities without a guarantee that people's trips would be contained in these communities. People's homes became separate from their work places. These factors contributed to longer trips that are less amenable to walking or biking. In addition, activities in the pre-existing work-unit compounds were resorted according to the market mechanism. In these conditions, the increase in travel demand and automobile mode share grew much faster compared to benchmarks in typical market economies.

As a way to deal with these challenges, at the national level China is now prioritizing public transit. At the same time, the national government is promoting an "environment friendly and resource saving society" through controls on air quality and energy prices and limiting land development through a national standard for compact city development. Local level government is prioritizing BRT and rail projects, tying land revenues to infrastructure, and consolidating metropolitan planning and land ownership to promote compact development. Although high household incomes are driving demand for single family housing, there is also demand for higher density in the cities. Because local governments rely on the money from land leasing to build infrastructure, Yang believes they will see the economic benefit of compact development. Their control of all land use in the city area allows them to pursue this strategy.

Yang then described some changes that are occurring in China that might reflect certain trends. For example, he showed that the annual rate of urban land increase is 6.26% but the floor area increase is faster (10%). This may indicate that cities are already pursuing density. He also pointed out that although cycling has decreased, walking has increased. Finally, he described a 2006 household survey in Beijing at the community level, which looked at characteristics such as household income, commuting time, car ownership, and mode split. This survey demonstrated that in China there is not the typical division between the poor living in the central city taking transit, and the rich living in the suburbs and driving. In China the situation is more mixed, with a weak relationship between household income and car ownership.

Yang concluded that the international climate is currently more favorable to make changes that are currently prioritized by the government in China. The visit of many scholars to China shortens the learning curve. The International Association for China Planning and China Planning Network are two groups that are involved in bringing international expertise to China. Finally, the centralized political power in China offers tremendous institutional capacity, which he hopes will be used to deal with these transportation issues.

Discussion

One participant asked whether there are plans to use the centralized power in China to encourage the use of transit through pricing and tax structures on vehicles, vehicle use, and fuels, or by subsidizing transit. Yang answered that transit is subsidized in Beijing but China is keeping the price of gasoline low. Yang is unsure whether it is beneficial to penalize people for driving rather than building the capacity for public transit. He cited the success of the Beijing transit system as an indication that people will use transit if it is there.

Another participant questions what role freight plays in congestion issues and transit planning in China. Yang answered that China is building more highways for freight and rail transportation in China. China regulates the time of use of urban streets for freight.

Adrian Fernandez, National Institute of Ecology
Urban Transportation in Mexico City

The National Institute of Ecology (INE) is part of the Mexican ministry of the environment.

Most Mexican cities have severe air quality problems. The Mexico City Metropolitan Area (MCMA) exceeded the standard for ozone on 222 days in 2007, and 17 days for PM10 (and this is an improvement).

The number of cars sold in Mexico has declined in the last few years to about one million new cars per year. However, this number is matched by the number of used cars coming in from the US, mostly in poor repair. Mexico imports about 40% of its gasoline. There is a huge subsidy of the price of gasoline and diesel, and many people cross the border from the U.S. just to fill up their tanks. Gasoline demand increased 50% between 1996 and 2007.

82% of the vehicles in Mexico City Metropolitan Area (MCMA) are private cars. Heavy duty trucks emit most PM. Cars emit most CO and SO_2, and about 40% of NOx. About 13% of the Mexican GHG emissions come from the MCMA.

Three motor vehicle emissions control measures were investigated by INE in terms of estimating cost savings from reduced pollution: renovation of the taxi fleet, expansion of the metro system to replace micro busses, and the replacement of 1000 diesel buses with hybrids. Replacing the taxis has huge net benefits, but very large capital costs.

One lane of BRT began operation in 2005 in Mexico City, called Metrobus. It seems to be working well, with buses traveling faster than the private cars. Nine or ten additional corridors are planned. There was a lot of opposition initially, and some mistakes were made. High capacity busses are now transporting 250,000 passengers per day. Emission reductions were estimated, as were health benefits and time savings. Significant reductions in commuters' personal exposure to pollutants were documented by comparing exposure in minibuses before construction to exposure in BRT buses after

construction. Travel time reductions (therefore shorter exposures) as well as well as reduced concentrations contributed to the benefits.

Remote sensing devices were used to discover that in Mexican border cities, vehicle emission rates are higher. Many vehicles do not have catalytic converters. 80% of the vehicles were initially purchased new in the U.S. and were imported used into Mexico. Fernandez is advocating an inspection/maintenance (I/M) program for these areas. He argued that the solution is to require vehicles to meet the federal standards rather than asking the U.S. to stop the flow of vehicles across the border. As an interesting point, subcompact Mexican cars are actually producing less NOx emissions than imported cars.

INE studies showed the Treasury that the benefits of low sulfur gasoline and diesel are greater than the cost, so Mexican government gave PEMEX, a national gas company, funding to convert. Unfortunately, Pemex have so far not met deadlines; it is taking more years than expected to fully make the transition to low sulfur fuels.

In Mexico City, the local government is providing incentives to have low emission vehicles (using NOx as a surrogate) and fuel efficient vehicles by giving vehicle owners waivers on required twice-yearly vehicle inspections. The obligatory standard in Mexico is Tier 1. Many people have said that they are complying with these standards, so INE expects the government to increase the standards to Tier 2, and then they will require much higher fuel efficiency. Very clean and efficient vehicles can have up to a 6-year waiver on testing.

Several transportation initiatives are part of the Mexico City Climate Action Plan, issued a few weeks ago, including minibus fleet renewal, BRT corridors, taxi fleet renewal, expansion of the metro, and mandatory school transportation system. All 32 states in Mexico are developing Climate Action Plans, GHG inventories, impacts, and mitigation opportunities. Some manufacturers are being encouraged to bring the smaller engine options of cars to Mexico because they have higher fuel efficiency.

In a few weeks INE plans to release a web site comparing vehicle model performance on energy efficiency and emissions. INE is working with different sectors to talk about how climate change is going to impact their sector and how they can adapt to what is going to happen.

Discussion

One participant asked what level of activity there is in the states in Mexico in terms of air pollution control agencies. Fernandez responded that 23 states have monitor networks and inventories, but only eight to 10 are working on equivalents to the state plans. Most plans are conceptual, don't aim to meet the standards so much as make some improvements.

Another participant asked how certain it was that the low sulfur fuel program would be implemented next year. Fernandez responded that if it doesn't happen, Pemex will be in non-compliance and there will be another target that Pemex will have to meet. In a few weeks we will know how bad the delay is and what mitigations will have to be made. Pemex requires urgent reform.

Frank Kelly, Kings College, London
Policies to improve transportation in London – London's Low Emission Zone

In 1956 the UK Clean Air Act moved coal burning out of London and banned it for home heating. Black smoke and sulfur dioxide levels fell dramatically, and now smog is due largely to traffic emissions. The Low Emission Zone (LEZ), which aims to decrease emissions from individual vehicles by dealing with the most polluting vehicles, was introduced in February 2008. Unlike the congestion pricing zone it was justified on the basis of health effects from air pollution.

Poor air quality reduces life expectancy by 8 months (on average in Europe—London is probably worse). About 1000 premature deaths are thought to occur annually in London from PM10 pollution. Air pollution in London is also causing the UK to breach European health based standards, and, as a consequence, they will be taken to court and fined if air quality does not improve by 2010.

The EU limits on PM will be dropping significantly in 2010, from 40 to 20 ug/m3. Central London roadside sites frequently exceed the lower level applicable in 2010.

The LEZ encompasses the greater London urban area, which is most of the area inside the main ring freeway (M25). The program targets fleets with diesel engines, Heavy Goods Vehicles (over 12 tons), buses, and coaches. In 2010 it will be broadened to include smaller trucks, heavier vans, and minibuses. Pollutants addressed include PM, NOx,/NO2, and CO2. Cameras are used to check license plates to assess whether the vehicle is within the permitted classes in terms of emissions (currently Euro III). If not, a penalty notice is issued to heavy vehicle fleet operators for about $350, which doubles in two weeks if not paid and smaller penalties for lighter vehicle fleet operators. This is not considered a tax because it is a disincentive, a penalty.

Fleet operators were given about two years notice and much advice on how to meet the requirement. Large fleets upgraded their vehicles and/or sent older vehicles elsewhere. It has been harder for smaller fleet operators to meet the requirements, but some support has been available to help them. Because many of these operators are based outside of the city, the benefits of requiring the cleaner vehicles were expected to extend to a wider area.

A team of researchers has been working to set up a system to assess the impacts of the LEZ. Based on emission modeling they have designed a monitoring network to detect air pollution signals, produced model predictions, and developed methods to study health care data of those residents most likely to benefit from the LEZ scheme.

On major routes, the team identified high traffic areas and predicted differences in pollutant concentrations for various pollutants. This information was used to upgrade the monitoring network. Each site has automatic traffic counters, periodic manual classified traffic counts, and camera sampling of Euro Class profiles, as well as monitors for pollutants and meteorology.

The first stage of their plan is to compare data for two years before and two years after the program is implemented. They will compare modeled and measured air quality differences. Health effects will be checked for prevalence and incidence, stratification by pre-existing disease, and interactions with smoking in health care data.

Discussion

There were a variety of questions regarding the methodology for measuring the impacts of the LEZ. One participant argued that it is important to first predict the amount of expected change and then compare that to the results. Kelly responded that they have done this: expected benefits have been modeled. Some areas are not expected to see much benefit, so those will be control areas. Some sites will include particle number measurements and this is expected to be quite variable. A participant asked why there were only ultrafine PM measurements on some sites. Kelly explained that they would be at the key sites, and they only became operational in 2007. Kelly also responded to a concern regarding baseline analysis by stating that they will run a number of models taking into account meteorology, policy changes, etc. Finally, there was concern over the short period of time for the study. Kelly explained that the scheme will be tightened up as they assess the measurements. Two years is simply an interim point.

Finally, a participant asked who pays fines if the vehicle is publicly owned. Kelly responded that government vehicles are now above Euro 3 except for some military vehicles. He thinks these are exempt, although part of the agreement is that the government bring on plans to make them compliant in due course.

Session 5: Oil Price Forecast

Guy Caruso, Energy Information Administration (leaving in Sep 2008)
The Future of Transportation Fuels in the Annual Energy Outlook (AEO) 2008

World oil prices are expected to decline, and then rise again. For the last 6 years, EIA's oil price forecast has been too low. Prices have been following their High Price scenario rather than their Reference case. It is very difficult to predict what will actually happen.

However, factors other than fuel prices also affect transportation in the U.S. The increase in the CAFE standards last year was a big change, as was the introduction of the renewable fuel standard (RFS) that mandates a very high level use of ethanol and biofuels beginning in 2012. Both are due to the federal energy act. Another important current

policy affecting their forecasts is that there is no program to reduce greenhouse gas (GHG) emissions. This may change in the future.

The future outlook on fuels is that high fuel prices will reduce the expectation of growth in liquid fuel demand, although liquid fuels will continue to dominate primary energy consumption in the US. Demand for liquid fuel is expected to peak and decline for the first time. Recent levels exceed those in the late 1970s and early 1980s, which were the previous high levels.

Coal is the sector that has grown the most in BTUs since 1960. The EIA model assumes that there will be no CO2 emission restrictions, hence the anticipated growth of coal use.

Renewable fuels are projected to be the fastest growing segment (though still a small percent of the total). CAFE standards and RFS will promote the use of ethanol. Today, only 7% of fuel used is from corn-based ethanol. The energy bill mandates a certain percent of fuel be based on cellulosic ethanol. It may be difficult to reach the target in the bill, but there will be a large increase compared to current levels. In order to meet the Energy Act requirements, it will be necessary to shift to E85 fuel by 2020. The Act allows the EPA Administrator to allow waivers if the targets cannot be met, and EIA believes this will be needed by 2020.

Residual oil use is projected to be constant. Distillate is projected to continue to increase, as with jet fuel. EIA also expects there will be more diesel vehicles in the US market, though not as great a percent as in Europe. Gasoline use is expected to decrease. In their 2030 forecast, price seems to have a greater impact on decreasing the amount of gasoline used than on increasing diesel or biofuel use, probably because they are predicting slower economic growth.

VMT is also down for the first time in 2008 since EIA began tracking it—mainly because of the increased price of gasoline. Behavioral change due to high fuel prices will lead to flattening out of light-duty vehicle (LDV) energy use.

Overall, with lower expectations on U.S. GDP and productivity growth, EIA expects lower energy demand. Transportation continues to be the largest consumer of energy, though its growth has been slowing. Transportation dominates liquid fuel consumption. Growth has been pretty steady since 1970.

They expect lower sales of SUVs and light duty trucks to cause a slower growth in the demand for light duty vehicle fuel. Hybrids, diesels, and flex fuel vehicles will increase substantially by 2030. About 45% of new car sales will be of these vehicles (which is now about 10%). It will be hard to meet the new CAFE standards without some movement toward diesel or a greater use of plug-in hybrids. Heavy duty vehicles are expected to continue to grow in use of fuel relatively steadily.

Annual Energy Outlook (AEO) 2008 projections are lower than the projections made in 2007 for the years 2010, 2020, and 2030. EIA have lowered their projections of GDP

growth, which reduces energy demand growth. The policy changes mentioned above (renewable portfolio) also contributed to the change.

Currently 60% of oil is imported. Even in the high price scenario, 45% would continue to be imported in 2030 (vs. 54% in reference case). Caruso's view is that energy independence is virtually impossible.

He recommends visiting their web site, www.eia.doe.gov for various periodic and special reports. One recent report is an analysis of the Lieberman-Warner Climate bill and the fuels and energy implications. The report concludes that the bill can be effective with relatively little impact on the economy. Opponents project this small change over many years and argue that it is a larger effect. [1]

Discussion

Will we see different outcomes from the 1970s, when energy use bounced back after the oil embargo was lifted? There was more elasticity in the market then, because there was more industrial and power use of oil at that time, and these could shift to other fuel alternatives.

What is the effect of off-shore drilling? EIA models show that it will take a long time (over 10 years) to develop those resources and therefore they will not have a very big impact on price.

What about the effect of the differential between diesel and gasoline prices? Gasoline has been more expensive than diesel for over 40 years. In the last few years that has flipped, largely because the strong demand for diesel in Europe and Asia has grown before the international refineries have been able to meet the demand. That is not expected to change until about 2010/2011, when the gap will narrow and gasoline may again be more expensive. This projection affects their expectations of future increases in demand for diesel in the US.

Independent oil companies have discovered a lot of natural gas in the last few years. This is expected to increase natural gas production in the US more than even their recent projections indicate. There is no infrastructure for CNG vehicles, so this may not affect vehicles as much as the rest of the economy.

Importing ethanol from Brazil is reduced by the tariff that is currently in place. If that is allowed to expire, we will see a large increase in importation of sugar-based ethanol. Most politicians aren't betting on that expiring, since the farm lobby continues to be very effective.

There is some expectation of "coal to liquid" conversion in their outlook. "Gas-to-liquid" seems to have more technological problems and be more expensive, so there are no gas-

[1] Remarks on cost and technology refer to US applications

to-liquid plants in their projections. There is a different price structure in Europe, which is why they are moving toward this technology. There is not a world-wide natural gas market yet—prices vary widely from place to place.

Fuel cell vehicles and plug-in hybrids did not follow current technology trends, and were hence excluded from the AEO. But Caruso believes that technology breakthroughs like these would be required to make a difference. Another potential technology "game changer" is carbon capture and sequestration.

Session 6: Future Transportation & Sustainability

Moderator: Alan Lloyd, International Council on Clean Transportation

Lloyd opened the session by commenting that political will is essential to solve many future transportation problems. However, he regrets that there is a lack of sense of urgency for climate change. Reiterating ICCT's stand, he believes there should be no tradeoff between GHG and air pollutants. The fueling infrastructure must also be considered in conjunction with planning future vehicles, and we need to look at this fuel/vehicle system as a whole.

Dario Hidalgo, EMBARQ: The World Resources Institute for Sustainable Transport
Bus Rapid Transit (BRT): Case Studies from Developing Cities

Hidalgo began his presentation by saying BRT is not new in concept, but is new in terms of delivering bus services. The most impressive systems are in Latin America, and they are spreading around the world. Around 50 cities have BRT systems now, versus about 100 cities having metro systems.

Physical components of world class BRT systems include dedicated lanes, intersection priority, stations with level access and pre-payment, large buses with multiple doors and low emissions, differentiated services (local, accelerated, express long distance), links with feeder services, fares affordable and integrated with rest of transport system, and advanced technologies (using ITS as a core element).

World-class BRT systems also include user information, good access for pedestrians and cyclists, full accessibility (for elderly, very young, people with disabilities), adequate financial management, land use management, excellence in user service, and marketing (branding—not just the same old ugly, polluting bus).

BRTs are cost effective. Their capacity can exceed light rail and be similar to most metros, with high speed and at a fraction of the capital cost of fixed rail systems. For instance, up to 45,000 passengers/hour in each direction use the BRT system in Bogota. This goes beyond textbook traditional limits to bus based transit systems, and it is done at a fraction of the cost of rail alternatives. BRT also shows greater cost effectiveness over a 20-year period than other transit options. BRT can also be implemented in a short time. Hidalgo notes that implementing *any* mass transit option is better than doing nothing.

Hidalgo then went on to describe some examples of existing BRT. Current systems in operation are located in Pittsburgh, Cleveland, Boston (Silver Line), New York, and others. He provided examples from South America and Mexico, indicating some achievements and issues.

Curitiba, Brazil has a dedicated lane system that moves over 1 million passengers per day. Initial corridors have been in place for 30 years. However, buses are overcrowded and high fares price out the poor.

Quito, Ecuador has an electric trolley system and two additional corridors moving about 440,000 passengers per day (as compared to 600,000 in DC). The system is aging and fares are too low to support it adequately (USD 0.25 per rider).

Bogota, Colombia has a large, high capacity system, with two dedicated lanes in each direction (at least at stations). The system has 84 km and it serves about 1.4 million passengers per day (20% of the city's transit demand). There were early implementation problems with pavement structures and the fare collection system. It is usually very crowded. Traditional bus services in Bogota are chaotic, and the current administration is supporting construction of a metro to complement the BRT system.

Mexico City's small BRT system serves about 315,000 passengers per day, and there are plans to expand it in the future. In Mexico, it is interesting to note that female passengers have the option of riding separately from male passengers.

As a whole, BRT systems can reduce travel time and enhance safety and reliability. Energy consumptions and emissions can also be improved. Problems have included hasty construction (usually due to upcoming end of term of officials), financial support, and integration with other parts of the transit system. BRT has proven a cost effective alternative even for very high demand levels.

Discussion

Three thousand passengers per hour on a route is the minimum needed for a successful BRT system.

Kent Hoekman, Desert Research Institute
Biofuels: Optimism and Concerns

Current use of energy from every source is greater now than at any previous time in U.S. history. Introducing new sources of energy may slow growth in the use of oil or other fuels, but in general, new sources can only supplement and not replace existing fuels.

Renewables are the only source that is expected to grow. Hydro is the largest contributor today, but its contribution in the future will remain the same. Combustion of biomass is the second largest and expected to grow the most. Ethanol is also expected to grow by

2030. As a benchmark, the current annual gasoline consumption in the U.S. is 140 billion gallons, over 17 quads.

Drivers for the increased use of biofuels are public policies aimed at reducing the use of imported oil, reducing greenhouse gases, stabilizing energy prices, promoting rural development, and improving energy security.

Hoekman then introduced some common terminology for biofuels (see slide #8). Biodiesel is methyl esters produced from fats and oils. Renewable diesel is a non-fossil hydrocarbon fuel produced via hydroprocessing of fats and oils.

Biofuels are currently dominated by corn-based ethanol, requiring 15% of the U.S. corn crop, and supplying 4% of U.S. gasoline demand. Soy and waste oils are the main feed stocks for biodiesel. In 2007, biodiesel production was much smaller than ethanol—biodiesel supplied about 1% of U.S. diesel demand. Ethanol production today is about 6 billion gal/year.

The 2007 Energy Act substantially expanded the requirements for renewable fuels production over goals set by the 2005 Energy Act. The target is to produce 36 billion gal/year of renewable fuels by 2022, which will be a big challenge to meet. Both forest and field crops are potential feed stocks for these fuels. Hoekman referred the audience to DOE/USDA's "billion-ton" study (2005) on feed stocks. The most optimistic scenario projects one billion tons per annum of feedstock available in the future, which can provide 30-40% of today's gasoline use.

There are a number of biofuels production pathways – feed stocks and processes that will lead to different fuel products. Examples of processes include fermentation, thermo-chemical treatment or various combinations of them.

There are many environmental concerns about the production of biofuels and their feed stocks, including water quality and quantity concerns, runoff, long-term impacts of crop residue removal, disruption of habitat , effects on biodiversity, and overall sustainability of agricultural and forestry systems. Different life cycle analyses (LCA) have been carried out, yielding different results, so this topic is highly controversial. Results depend on assumptions on allocation to co-products (heat, power, GHGs), agricultural practices, type of fossil energy used, and land use changes. LCA are also affected by assumptions regarding indirect land use effects.

In general, LCA results are highly scenario-specific and are difficult to generalize. But studies have concluded that there can be small benefits in GHG emissions using corn ethanol, and larger benefits using cellulosic ethanol.

Alex Farrell published an article in Science in 2006 in an attempt to harmonize various life cycle analyses for ethanol from corn. The results show that much depends on how it is done. There's general agreement that "second generation" fuels are better, i.e. not

using the corn, for example, but using the residue or other non-food feed stocks. First generation fuels may be considered a transition to the next generation.

To promote responsible growth of biofuels, he recommends optimizing the advantages that characterize the locality. There is no single approach that is best for all areas. We need to avoid a "one-size-fits-all" approach. We also need to emphasize sustainability—carry out a life cycle assessment and include environmental impacts. Finally, products must be affordable and available so consumers are willing to purchase them. The entire supply chain must be economically sustainable—feedstock, logistics, production, distribution, and end use.

Discussion

In answer to a question, Hoekman indicated that the use of food stocks for fuel should be minimized but has not been the major reason for food price increases. It has contributed but not been the major cause. Biofuels has had an impact, but there are other factors including food shortages and increases in energy prices. He recommends not focusing on this tradeoff, but rather focusing on second generation biofuels that don't depend on food feed stocks.

When asked about the tailpipe emissions from engines using biodiesel, Hoekman replied that if produced to high quality, emissions will not be too much of an issue. In older engines, using biodiesel is known to reduce CO, HC, PM, but NOx might stay the same or go up.

Microalgae is one of the potential feed stocks which can be grown without vast amount of land (30x better than seed oils), however, the practical applications are not there yet. NREL is currently restarting an algae program.

On biofuel processing, he believes that thermochemical routes are more likely to succeed, because they have more history and we have more experience with them. Biochemical routes, e.g. using enzymes, are still new. The scale and timeframe of these developments will matter.

John German, Honda
Future of Urban Vehicles in the U.S.

German started his presentation by posing a question: given recent spikes in fuel prices, will the shift to smaller vehicles be a long term effect, or will the market revert once prices stabilize? Historically, the proportion of sales that are cars (instead of light trucks) tends to track fuel prices (in both directions).

Today, the real price of gas is higher than the spikes of the 1980s but if we include the mileage and compute cost in terms of cents per mile, it is not higher than the 1970s. As a percent of per capita disposable income, the price of gasoline is still below levels before 1985. So we are not revisiting historical highs. Gasoline prices would have to go to $5

per gallon to be at levels of 1970-85. It is the rapidity of the rise that has spooked people and caused the change in behavior—it makes them uncertain about the future.

When making vehicle purchases, fuel economy is an important characteristic but not one of the top ones that drive decisions. Reliability and drivability are more likely reasons given by those purchasing vehicles.

German cites David Greene's work on customer uncertainty and loss aversion – the more uncertain you are about the outcome of a bet, the less likely you are to make it. This applies to fuel prices, which are very uncertain. So to the customer, the MPG on the sticker label is not real, and s/he remains unsure how long the car will last, what gasoline will cost, etc. So other vehicle features, like performance, quiet drive, leather seats, etc., appeal more because they are more certain. This causes the market to produce less fuel economy than is economically efficient, because the uncertainty drives people to use other factors as a basis for their decisions when selecting vehicles. Innovators and early adopters may be willing to pay for technology, but most people are more risk averse and want a shorter payback period.

Compact car sales are most sensitive to fuel prices. Higher fuel prices will almost certainly create a larger market for these cars long term, and a shift from truck-based to car-based utility vehicles (large SUVs to crossovers). However, once fuel prices stabilize, there will be a shift back, even though compact car sales will stabilize at higher levels.\

The new CAFE standard is a game changer. It is aggressive and will be challenging to meet. It is an attribute-based standard, so every manufacturer will have to meet a unique standard based on their vehicle fleet. Larger vehicles have to meet a lower mpg standard. If the market shifts to smaller cars, the standard requires higher mpg. Therefore, cars must be more efficient. This will drive development of technology to improve vehicle efficiency.

There will be multiple technology developments that can reduce fuel consumption. The market is very competitive. Customer expectations for performance and reliability must be met. Honda's power train roadmap includes hybrids (HEV), diesels, and fuel cell vehicles (FCV). All are necessary to meet the standards. There are too many technologies, and it is difficult to tell which ones will win. This forces automakers to work on everything in order to remain competitive.

The lead time for developing new technologies is the real barrier. It is not a matter of how to do it, but when it can be done. Costs and risks increase dramatically if development is rushed. Lead time consists of 2-3 years of product development followed by 2-3 years for a low-volume pilot introduction. After this initial 5 year or so period, it takes an additional 5 years to spread the technology across the fleet - so about 10 years total lead time to introduce a new technology into the fleet.

National fuel efficiency requirements are essential. Separate state requirements would divert carmaker's development resources and increase costs and lead time. To meet

GHG standards, the entire car must be modified. There are limited engineering resources to develop advanced vehicles.

Hybrids are ideal for urban areas. Regenerative braking energy is a huge part of the benefit, which can lead to 30-50% increase in urban driving fuel economy (5-20% highway driving). Engine downsizing and shut off during idle are also beneficial to economy. Early next year there will be a new Honda "dedicated" hybrid (body design not available except as hybrid). The goal is to bring down the incremental cost of a hybrid to $2,000. Another hybrid (Honda CRZ) will be made available in 2010.

Regarding plug-in hybrids, a breakthrough in energy storage or oil shortages would be needed for mass market acceptance. The cost and battery capacity are the biggest issues today. Plug-in hybrids would reduce petroleum consumption, but offer potentially little benefit in GHG emissions. The effect on GHG emissions will depend on how the electricity is generated. He referenced a 2007 MIT study by Kromer and Heywood (Electric power trains: opportunities and challenges in the US light-duty vehicle fleet).

Conventional hybrids need high power batteries, but do not need to store much energy. Plug-in hybrids need to store a lot of energy, but don't need to charge or discharge quickly (power). The new Li-ion batteries currently in development can deliver much higher amounts of power, but do not hold more energy than current Li-ion batteries. This will reduce the cost of conventional hybrid batteries and will make it harder for plug-ins to compete with conventional hybrids.

Electricity or hydrogen will not replace gasoline internal combustion for a long time, although these are perceived to be the "ultimate solutions" in the long run. Numerous technology improvements are needed for either, and it is uncertain which will win out. Honda is bullish on fuel cell vehicles, and is launching a model this year – the new FCX Clarity. They are also working on a home generation system to develop hydrogen for the vehicle and to generate both heat and electricity for the home.

Future conventional internal combustion engine developments will extend the fossil fuel era. The government needs to set performance objectives, and he concludes that there is no silver bullet, we have to make progress on many fronts.

Discussion

Alan Lloyd stressed the importance of consistent policies, as auto manufacturers need consistent signals to plan their vehicles.

When asked about his vision for an automobile for urban applications, German replied that there will be more small vehicles, but this shift will not be sustained when prices go down. Consumers are likely to upgrade to maybe not bigger, but more luxurious cars.

Mike Walsh suggested that California functions as a laboratory and the state's unique regulations are not slowing things down. The reason why the recent Energy legislation

was adopted was that EPA was on the verge of issuing a waiver to CA and issuing its own GHG car rules. German responded that California is indeed a leader ahead of the federal government. Their strategy has worked well and has spurred the federal government to action, but he prefers a national program to a California program. Both Congress and the Administration are aggressively moving forward now. It is great to get the federal government moving but not to continue to play one-upmanship. They need to let auto makers focus on meeting the new standards, and not distract the mission.

On CNG or dual-fuel CNG vehicles, German replied that you lose 10% efficiency if you have a gasoline engine that can also run on CNG. You can have a much higher compression ratio with dedicated CNG vehicles. The sales of their CNG Civic have been disappointing. Sales have increased due to the increase in the price of gasoline.

Wayne Eckerle, Cummins, Inc.
Diesel Vehicle Future Technology

Cummins is the last independent diesel engine manufacturer in this country. Their largest customers make diesel engines but also buy Cummins engines. For example, the Dodge Ram pickup uses a Cummins engine. Most others are in commercial applications.

One of the macro trends he sees is the rise in diesel fuel prices to $5/gal in the U.S. As a result, sales of engines for the Dodge Ram pickup dropped dramatically in a year He sees an increased emphasis on fuel economy.

About 90% of the goods transported in the U.S. are moved using diesel fuel. Diesel accounts for 30% of petroleum usage in the US, and trucks and buses use about 20-30% of the total. There is a considerable impact on energy security. There is an increased urgency of sustainable development, concern about GHG emissions, and emphasis on energy independence.

Commodity prices are of interest to Cummins, especially precious metals, steel, and nickel. Their prices have increased greatly.

Globalization is here: over half of Cummins' revenue comes from sales outside the U.S. They produce products overseas for overseas markets. There is a wide range of emission standards. Cummins cannot compete by selling older technology in markets that have less restrictive emissions. Cummins is developing engine technology that can be adapted to the wide range of emissions standards while providing very good total cost of ownership to all consumers.

Cummins is committed to sustainability: they are interested in fuels derived from biomass, clean and efficient diesel engines, nuclear energy with sustainable processing of waste (opportunity to produce hydrogen, which their engines can burn), renewable energy, and more efficient use of energy. Eckerle's talk focused on biomass fuels and cleaner engines, but there are other aspects, including regulatory environment, that have

to come together. Other aspects include fuels, lubricants, end user driving habits, and the power train.

NOx and PM emissions from diesel engines have come down tremendously. Their focus now is on improving the engine's brake thermal efficiency to reduce CO2 emissions. They will improve brake thermal efficiency from 39% to 42% between 1998 and 2010 and then want to achieve much higher numbers by 2025.

The top 5 strategies for reducing a diesel engine's CO2 footprint: High efficiency clean combustion, low temperature after treatment, idle reduction, waste heat recovery, and hybrids. Onboard diagnostics for engine maintenance can also improve in-use emissions performance.

A heavy duty engine tank-to-wheel energy balance chart was shown – fuel energy starts at 100%, then subtract heat transfer 26%, and exhaust 24%, which leaves 50% indicated power. Then subtract gas exchange 4%, friction 1.5%, and accessories 2.5%, which leaves brake power at 42% of the fuel energy content. This means, for every unit of energy in the tank, they get about 42% to get the vehicle down the road. Cummins want to increase this with technologies to 50%.

Advanced combustion is the top strategy for improving combustion efficiency. There are many other strategies as well, including the fuel system, controls, air exchange in valves, EGR loop, and many more. An 8% increase to 50% brake power seems feasible. This is about a 20% increase and would save a lot of fuel.

Regarding fuels, Cummins' main concern is consistent fuel quality. It is difficult to develop a cost-effective engine technology if the future of fuels is uncertain. It is hard to provide cost-effective options for small pockets of different fuels. The calibration of the engine and its duty cycle have major effects on how an engine handles mixtures. Their engines can currently handle 20% biofuel blends. NOx increases with 100% biodiesel, and this is unregulated. They are only regulated on standard diesel fuel. They'd like to see a uniform blend nation-wide.

With higher fuel prices, their customers can afford new efficient technology—the rule of thumb is to offer improvements that are able to breakeven in 18 months. They will only buy it if it pays.

There still exists a tradeoff between reducing NOx emissions vs. fuel consumption. NOx after treatment will play an important role.

Waste energy recovery and use of hybrid engines to recover brake energy are both beneficial. Hybrids perform better if the driving cycle involves more start/stop. Waste heat recovery is more beneficial for long hauls with less stop and go. Cummins is working on both hybrids and electric vehicles. Regulations are not set up yet to certify diesel hybrids. There is a lot to be gained from working on this.

Discussion

Do you have evidence that customers have a narrow economic view when it comes to more fuel efficient vehicles? Cummins nearly went out of business in 2002. In the 1990s, Cummins made diesel engines that were more efficient, but customers were not willing to pay for it.

When asked about the penetration of light-duty diesel vehicles in the U.S., Eckerle replied that diesels tends to be about 25% better on a fuel consumption basis than gasoline engines, but with diesel fuel costing 25% more than gasoline vehicles, the market for diesel automobiles is very small. Cummins has engines for LT and SUV applications, but sales never took off. Their marketing will need to emphasize other customer attributes like the "fun to drive" aspect.

Session 7: Health Effects

Moderator: Maria Constantini, Health Effects Institute (HEI)

Maria thanked the Mickey Leland National Urban Air Toxics Research Center for help in organizing this session and supporting the conference.

Many factors affect traffic health impacts – vehicles, fuels and traffic congestion which affect emissions, atmospheric chemistry, and human exposure. We need knowledge from these disciplines to assess the health effects and the risk, in order to better influence policy. This session will look into the exposure link.

She mentioned that HEI's draft document on the health effects from traffic related air pollution will be available for peer review this year.

Bart Croes, California Air Resources Board (CARB)
Assessing Exposure to Traffic in California

PM2.5 has become the major focus of CARB's air pollution control efforts due to the larger impacts on premature death and other health effects as compared to ozone and known air toxics. The diesel PM fraction also has been associated with health and other effects, including cancer, decreased lung function, chronic bronchitis, increasing hospitalizations, aggravated asthma, increased respiratory symptoms, lost work days, reduction in visibility, and global warming.

The majority of ozone-forming emissions in California still comes from both on- and off-road vehicles.

California has reduced PM2.5 statewide by 50% over the last two decades and, over the past 40 years, achieved an 18 times reduction in diesel soot emissions per unit of fuel consumed, though the amount of fuel consumed has increased six-fold. Looking ahead, a target of 85% less diesel PM by 2020 (compared to 2000) has been set for on- and off-

road vehicles and stationary engines by means of new vehicle standards, retrofits, cleaner fuels, and anti-idling measures. California wants to replace, or put an after treatment device on every diesel engine. Idling is limited to 15 minutes.

The University of Southern California (USC) Children's Health Study looked at longitudinal changes in lung function associated with traffic. There is a 6.5% decrease in lung function for 18 year olds that lived within 500 meters of a freeway. Most young adults will not detect this change, but as they age it can become apparent.

Exposure to traffic pollutants can be estimated through direct measurements on roadways or in-vehicle, models, or the use or surrogates (e.g., daily truck counts). CARB investigated low-cost passive monitoring methods that can be sited near roads (too difficult and costly to use federal reference method [FRM] samplers), These methods are low cost and do not require power. However, they are time-integrated (vs. instantaneous) samples, and can only provide 7-day averages.

A Desert Research Institute (DRI) study compared passive monitor measurements to lab or FRM concentrations. Good results were obtained for NOx, some toxics, and fairly good results for other pollutants.

The Harbor Communities Monitoring Study compared concentrations near the Ports of Los Angeles and Long Beach and nearby freeways to concentrations in other areas of Los Angles in 2007. The community helped provide sites for the monitors. CARB wanted to identify potential hot spots and establish a baseline for comparison to concentrations after port trucks are upgraded. They found that concentrations of secondary pollutants in the area near the ports were not higher than the rest of the air basin. They sampled for one month in each season and reconstructed an annual average for comparison to FRMs. San Bernadino and Riverside concentrations were higher (downwind far enough to get photochemical pollutants). NOx was high compared to the rest of the Los Angeles Air Basin, and diesel concentrations were elevated for near-source sites.

CARB investigated how far from roadways elevated concentrations persisted. Short-term studies conducted by UCLA and USC showed an exponential drop-off after about 200 to 250 meters. CARB found that annual average concentrations did not show as much difference as did short-term concentrations. Legislation now prohibits new school construction within 500 feet of a freeway.

Diesel PM, benzene, and 1,3-butadiene exposures tend to be much higher inside vehicles on freeways than at sites near the freeway. Concentrations on local streets are lower. Time on the road matters in terms of exposure.

To reduce exposure, it's 2 to 5 times more effective to control on-road emissions of diesel PM than to control off-road sources. When one vehicle drives behind another, exhaust high and at the front of leading vehicle produces 5 times less in-vehicle impacts in the second vehicle than exhaust low and at rear of the leading vehicle. A 90-minute commute represents 60% of the average person's exposure to diesel PM.

In a diesel bus, exhaust recirculates into the cabin, so school buses are self-polluting. Children on diesel school buses are highly exposed unless the bus uses after treatment and is well-maintained, or the exhaust pipe is raised at the rear of the bus. It is worse for older buses and closed windows. The bus in front has twice the effect of the bus that the kids are riding in, so CARB is carrying out an outreach program to discourage bus caravanning in schools.

In summary, air pollution is elevated near freeways, especially diesel PM, NOx, and motor vehicle toxics. Short-term near-roadway diesel PM and other air toxic concentrations are 35 times higher than other areas. Annual concentrations near roadways are about 2-3 times higher than other areas. A 500 ft buffer is effective at reducing exposure to roadway sources. In-vehicle exposure is very important.

Discussion

Synopses of completed research projects sponsored by CARB are available on their web site. Progress reports of ongoing sponsored studies can also be made available, and in-house research projects are targeted for journal articles.

CARB is continuing to study other aspects of exposure to motor vehicle sources, such as assessing differences between roads dominated by gasoline vs. diesel, effects on the lung function of bicyclists, effects of sound walls and tree lines, and effectiveness of in-vehicle filters.

CARB has set limits on the amount of NOx that can be in the form of NO2 from retrofit diesels. The limit is based on modeling that shows high NO2/NOx fractions lead to enhanced ozone and PM2.5 nitrate formation in Los Angeles.

Michael Jerrett, University of California, Berkeley
Spatial Models for Predicting Traffic-related Air Pollution Exposure

Economic development and sprawling land use has led to a greater amount of traffic, which has an effect on human health. Increasingly, studies show that near-by traffic sources are implicated in major health effects. The location within cities near large populations influences exposure and possibly increases the intake of pollutants compared to more regional sources.

In dense cities, it is difficult to avoid exposure from major roads. Exposure to roadway pollution is much broader than exposure to individual point sources due to the wide extent of the transportation system. Zhow & Levy study did a meta-analysis of studies of gradient around roadways, and recommended a 500m buffer. 45% of Toronto's population lives within 500m of freeways or 100 m of major roads. The fraction for LA is about 44% (about the same). These people will have higher exposure to traffic related pollutants.

In the mid-1980's, work by Pope concentrated on using central city monitors to characterize exposures. Other efforts have looked at distance from sources. However, interpolation between monitors is difficult, so little is known about in-city variation.

More sophisticated models for near source exposure assessment are needed for basing policy-making decision. Biomarkers and direct personal monitoring are too expensive or infeasible for large population studies. Spatial concentration models for large populations (2,000-500,000) are needed, and Jerrett uses a land use linear regression model for this end.

The modeling method uses regression on land use. In 2005 in Journal of Exposure Analysis he published a study of various methods, although he said none are theoretically very elegant.

The existing monitoring network is inadequate for small-scale modeling for NO2 or ultrafine particles. Passive monitoring can help fill in the gaps. Monitors should be located to identify changes in pollution and to get information about where people are located.

Existing monitoring networks are often insufficient for capturing effects on all affected communities because they are too dispersed. He has developed an optimization method to best deploy/allocate limited number of monitors.

They used 200 passive NOx monitors in LA to operate for 2 two-week periods and were able to develop annual averages from that and used that to estimate exposure for subjects living in the LA area. Statistical analysis included use of the "semi-variance" to assess geographic variability.

When estimating cancer risk with EPA's NATA, they found that the ports of LA and Long Beach (and the nearby refineries) are the major sources of risk in LA, due to the heavy logistics traffic. 70% of cancer risk are due to diesel PM.

Mobility makes exposure and dose difficult to determine. Truck routes are very high sources of in-vehicle exposures. This may be about 33 to 45% of a person's total exposure to ultrafine particles.

Discussion

The studies have focused on the spatial resolution of exposure – how about temporal resolution? There is less variation in exposure in fixed space over time, except for ozone, which fluctuates over the year.

A small GPS biosensor can monitor a subject's location, movement, and certain biological characteristics. This can help provide information on where the subject experiences exposure to air pollution.

Monitors of ultrafine particles are very expensive. There is variation in the mixture of pollutants to which people are exposed.

Jerrett concluded that a re-orientation to personal monitoring, mobile monitoring platforms, and personal movement monitoring will inform future work on exposure analysis.

Mark Frampton, University of Rochester Medical Center
How Can Air Pollution Cause Health Effects

Frampton looks into the health effects of PM exposure, in particular exposure to ultrafine particles (UFP), which are nanoparticles measuring 28-30nm. He shared results from his epidemiological studies, which show increased pulmonary and cardiac deaths, although there are no respiratory symptoms, no decrements in lung function, and minimal airway inflammation were seen due to lab exposures of various types of particles. Asthmatics only experience lower lung capacity (FEV) with certain types of particles. He did not have an explanation for this other than that epidemiological studies always see the impacts of a mixture of pollutants.

He cites McCreanor's (2007) study examining diesel exposure in two locations within London – Oxford Street heavy with diesel traffic vs. Hyde Park away from diesel traffic. Lung function was found to be lower for subjects exposed to diesel in Oxford Street, which has higher PM and ultrafines. FEV declined more on the polluted street as did forced vital capacity (both are measures of lung capacity). Lung capacity recovered after the exposure ended, but even 5 hours later it was still lower than the capacity when people walked in the park. The effect was more demonstrable for ultrafine particles than for PM2.5.

He then showed the locations of inhaled particles in human respiratory system by particle size – in upper airway, tracheobronchial and alveolar. Particles larger than 0.1 micron in diameter tend to deposit in the nose and upper airway. Most traceobronchial deposition is the ultra fine particles smaller than 0.1 micron. Most ultrafines end up in the alveolar part of the lung, near blood vessels where gas exchange to oxygenate blood takes place. During exercise, or if subject has asthma, particle deposition in respiratory system is higher.

Ultrafine particles can migrate into the blood stream and affect the heart. Inhaled ultrafines can also be deposited, enter nerve cells and the frontal lobe. Exposure to ultrafines caused drop in monocytes, an adhesive molecule (a pulmonary vascular effect). This is also seen to lower forearm blood flow rate, and delayed increases in heart rate of diabetics. In summary, inhaling UFP has effects on the lung, maybe the central nervous system, and contributes to cardiac and vascular effects.

Discussion

For the next stage in this investigation to explore UFP, Frampton plans to move beyond studying mild asthmatics to a larger group of people with asthma.

Patrick Ryan, University of Cincinnati Medical Center
Traffic Related Air Pollution and Children's Respiratory Health

Children are particularly at risk to air pollution because they are more active, spend more time outdoors, are more likely to breathe through their mouths, and breathe in a larger of volume of air in comparison to their body weight. Girls are about 18 years old, boys about 20 when their lungs fully develop. Their immune system is also developing after birth.

Proximity models assume that if you live near roadways you have a greater exposure to air pollution. Ryan's studies look into, "will living near roadways affect children's health?"

He then summarized various studies that examined this question:

- Among asthmatics, road density is associated with air inflammation and reduced lung function
- Children living < 75m from road have lower occurrence of asthma and wheezing
- NO2 measurement and distance to freeway correlated
- Another study exploring wheezing in infants age less than one year near stop-go, moving traffic and who are unexposed. Wheezing was found to correlate with exposure to traffic.

About a third of schools are located less than 400m from major roads, and 12% are within 100m. This is an environmental justice issue, and it is important to consider where to locate schools, care facilities, as well truck routes.

Discussion

Are socio-economic differences in these studies accounted for/corrected? There is control for race and income in their models. Ryan agrees that this is an important factor to consider. They plan to continue testing on older children (7 year olds) involved in the study, and continue looking at persistence of wheezing as the children grow older.

What about the effect of using new technologies in cleaner diesel engines? UFP should go down with the use of particulate traps.

Do you look at how much time children spend in vehicles? Yes, this information is captured, for different types of vehicles.

Murray Mittleman, Beth Israel Deaconess Medical Center, Harvard University
Air Pollution and Cardiovascular Events

Mittleman is an epidemiologist, who looks at the cardiovascular effects of exposure to air pollution. The number of publications on this topic has been increasing rapidly since 2000. Our understanding is rapidly evolving.

About 2.5 years ago the American Heart Association convened a "writing group" to prepare a statement of the state of the science, summarizing key findings of the field. Another panel is starting to update this now.

There are concerns about both chronic (long-term exposure) and acute (transient exposure) effects. There are varying degrees of evidence for different effects.

Mittleman cites several studies carried out on chronic effects:

- Chronic exposure to PM2.5 is associated with greater risk of mortality, cardiovascular events in women
- Proximity to roadway increases risk of acute myocardial infraction (MI). Socioeconomic data taken from census.
- Rabbits exposed to PM10 for 4 weeks suffered coronary atherosclerosis, had more lesions in their arteries.
- Subjects living in areas with chronic exposure to PM2.5 displayed higher risk of cardiovascular events.
- Residential exposure to traffic (proximity to roadway) associated with coronary atherosclerosis

There are many studies on acute effects as well:

- Higher mortality rates are related to exposure to PM10
- Higher hospitalization with increase in PM2.5 exposure
- Short-term PM exposure studies (time series, etc.)
- Risk of MI increases following PM2.5 exposure
- Higher probably of being in traffic in the hours prior to MI
- Driving and VT/VF – risk of ICD shocks high after 30min of driving
- PM associated with increased heart rate, defibrillator discharge
- Myocardial ischemia lower when exposed to diesel exhaust

Overall, the findings have been consistent, but further study is still needed to examine pathways, etc.

Discussion

The reasons for the low impact on respiratory symptoms are still largely unknown.