



INITIATIVES IN
ENVIRONMENT and
SUSTAINABILITY

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The Automobile and the Environment:

MIT conference addresses the costs of congestion and looks for solutions

"Traffic Congestion: A Global Perspective" brought over 150 scholars, planners, government officials, and business representatives to MIT's Tang Center on June 8th and 9th. The conference, sponsored by MIT's Cooperative Mobility Program, addressed the nature and extent of the world's traffic congestion problem, the trends influencing its development, and a range of possible technical and social solutions.

Congestion has local as well as regional and global dimensions. It is intimately bound up with basic issues of mobility, economic development, and access to crucial goods and services. Transportation's share of the world's energy resources is growing faster than any other end-use sector. Planners interested in resource conservation and the reduction of harmful greenhouse gas emissions must therefore concern themselves with efficient, unconstricted mobility systems.

Neil Ressler, Vice President and Chief Technical Officer at Ford Motor Company (an important sponsor of the Cooperative Mobility Program and this conference) gave the opening address. In an observation echoed several times over the next two days, Mr. Ressler pointed out that congestion is a natural if unwelcome consequence of the modern mobility systems it stifles. Cities with good transportation systems attract development and grow. If they grow too much or too fast, their road networks clog up. He used Atlanta and Denver as examples of cities that have outgrown their infrastructure and have had to cope with serious congestion problems.

Mr. Ressler discussed several new methods of reducing traffic congestion including lightweight electric cars like Ford's THINK, a two seater

ENVIRONMENT AND
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SEMINARS *

september 15

"AGS 2000: The new Request for Proposals process and the January Meeting," Prof. David Marks and Dr. Joanne Kauffman, Center for Environmental Initiatives.

september 22

To Be Announced

september 30

"Corporate Strategies for Climate Change," Prof. David Levy, University of Massachusetts and Faculty Research Fellow, John F. Kennedy School of Government.

october 6

"Catalysts of Sustainable Consensus," Saleem H. Ali, Doctoral Candidate and Martin Sustainability Fellow.

october 13

"Green Campus Initiatives" Dr. Matthew T. Gardner, Coordinator of the Program on Environmental Education and Research.

* The seminars are held at MIT from 12:00 to 1:30 pm in E40-496. For the most current listings, see the CEI website: <http://curricula.mit.edu/CEI>

Please send MIT sponsored event listings to Dr. Richard St. Clair, stclair@mit.edu, fax 617-258-6590, phone 617-253-9871.

Green Chemistry *workshop* held in China

A key goal of sustainable development is economic growth that creates jobs while preserving the environment. In recent years, the "Green Science and Technology" movement has been promoted by the US Environmental Protection Agency and other agencies and NGOs as a strategy for reaching this goal. This approach seeks to avoid "end-of-pipe" pollution controls by developing cleaner and less wasteful manufacturing and processing technologies. Industrial ecology and Life-Cycle Analysis are key tools for accomplishing these aims. Through the application of these tools to chemical technology, "Green Chemistry" has become an important research area, with support from an NSF/EPA Partnership on "Technology for a Sustainable Environment" and a coordinating body, the Green Chemistry Institute, which promotes cooperation, exchanges information, and develops educational materials.

The Green Chemistry movement is international in scope. At a workshop in May 1998 at the University of Science and Technology of China the Chinese branch of the Green Chemistry Institute was established. A second workshop took place in May 1999 at Sichuan University in Chengdu. Foreign participants included Prof. Jeffrey Steinfeld (MIT.), Dr. Dennis Hjeresen (Los Alamos National Laboratory), and Prof. Kenneth Seddon (Queen's University, Belfast, Northern Ireland). Several others could not attend because of political tensions between the US and China at the time of the workshop. Following the workshop, participants were taken to see a number of environmental projects in the area, including the Chengdu Research Base of Giant Panda Breeding and the Wolong Nature Reserve (home of one of the last remaining populations of wild pandas).

Workshop topics included new reaction media such as ionic liquids and supercritical fluids; new catalytic systems including supramolecular assemblies, biomass-based processes; and their applications in the tannery and paper industries. Follow-up activities were planned, including a visit to MIT by a Green Chemistry delegation from Chinese universities and research institutes in November 1999, and an IUPAC sponsored CHEMRAWN (Chemistry Research Applied to World Needs) Conference in July 2001. Numerous opportunities exist for collaboration between MIT and Chinese laboratories in this area. For further information, contact Professor Jeffrey Steinfeld, MIT Dept. of Chemistry, 617-253-4525 (jsteinf@mit.edu). ☺

*Jeffrey Steinfeld and panda at the
Chengdu Research Base of Giant
Panda Breeding.*



New web tool, *DOME*, being applied to *Green Product Design*

Researchers at MIT, the University of Tokyo, and the Swiss Federal Institute of Technology are working on a product development framework that fosters collaboration between experts working on discrete aspects of a larger design problem, and integrates environmental concerns into their decision-making. The framework is called DOME (Distributed Object-based Modeling and Evaluation), and it allows teams of designers to dynamically share information over computer networks. The Alliance for Global Sustainability is excited about DOME's potential to advance good environmental design practices.

DOME grew out of graduate research Professor David Wallace did at MIT on environmentally sound product design. Professor Wallace discovered that fixed sets of techniques or rules of thumb to minimize the environmental impact of product design didn't always lead to the expected outcome. Connections between independent factors are complex and sometimes counter-intuitive. An appreciation of the subtle interactions among independent elements is at the root of DOME.

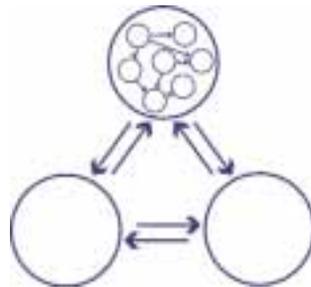
The high cost of complexity

Product design frequently involves complicated problems that overlap several engineering and design disciplines. When environmental consequences are considered, the issue becomes acute. One approach is to delegate parts of the overall design to specialists and allow them to concentrate on specific sub-problems. One group concentrates on selecting the right materials for a new engine while a second develops a fuel system and a third concerns itself with overall mass. An environmental expert may be consulted or the designers may refer to a simplified set of environmental guidelines. This isn't always satisfactory and doesn't lead to the best decisions. The design goals and decisions of the separate teams may conflict with their colleagues' efforts. A method is needed that allows timely communication between groups and resolves conflicts.

DOME is a design methodology that focuses on interactions between the elements of a complex design problem. The overall problem is broken down into manageable sub-



Above: A DOME module is a mathematical simulation of one element of a complex design, in this case the engine of a vehicle. The smaller circles linked by arrows are interdependent engine components and processes. The enclosing circle represents the DOME "wrapper" which facilitates communication with other modules.



Above: Separate DOME modules communicate via the internet using standard communication protocols and languages. Each module reacts to design changes made by the others. In this example the engine dynamically exchanges information with the fuel system and environmental assessment modules.

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problems called modules. Modules are clusters of software models or simulations that represent a particular aspect of the larger design, like materials, fuel, cost, or environmental impact. The modules communicate with each other via the Internet. The product is designed through the interacting.

DOME offers many advantages for designers

DOME offers several advantages. First of all, complexity is reduced. Experts can concentrate on familiar issues, using familiar tools. Responsibility and information are shared non-hierarchically. Experts collaborate with other experts working on different sub-problems in separate departments, companies, or even different countries. And DOME leverages experience. Once built, modules can be reused. Working with Motorola, MIT's CADLAB developed a DOME system to account for unexpected heat gain in computer cases. The knowledge developed on the efficiency of fan designs, the insulating properties of different materials, and their interaction with other processes and materials could be applied to other designs where component overheating is an issue.

A module's software simulations may take several weeks to build, but connecting them together can be done very quickly. Defining the interactions between models is crucial. For example, an automobile's acceleration, maximum speed, and cargo capacity all affect each other with implications, separately and combined, for the environment. One module's design choice influences the others. The output of one module determining the car's size, acts as an input into the acceleration module, which in turn can pass information on to modules concerned with fuel efficiency, vehicle performance.

Building a web-based design environment

Making the information available to each module in a form it can use is a fundamental DOME strength. Because the different modules use unique software tools they cannot communicate directly. The DOME system wraps or encapsulates each module in an interface that translates the data being exchanged into intelligible formats for each module. The cost of a material specified in a drafting program is made available to a business spreadsheet stripped of unneeded and irrelevant software codes. The process is entirely transparent to the users. The encapsulating shell also protects proprietary information and trade secrets.

Like the Internet, the DOME system architecture is decentralized and non-hierarchical. However, instead of users following hyperlinks between related web sites,

information follows the network connections. Experts building their simulations receive pertinent data as inputs into their modules, and their own design decisions are communicated to other modules. Once the connections are established, data ripples through the system's connections nearly instantaneously. Each module is made concurrently aware of the design decisions that affect its specific design goals and adapts accordingly. Links to specialized environmental impact modules allow product designers who lack environmental training to consider multiple alternatives and receive information about each one before making decisions. Conflicts between design goals can be adjudicated by algorithms that manipulate design parameters until an acceptable balance is reached.

Life Cycle Assessment modules supply designers important information on environmental consequences

In a DOME system the environmental implications of design decisions are typically supplied to designers by a Life Cycle Assessment module (LCA). LCAs measure the environmental impact of a product throughout its entire

Like its economic cost, the environmental impact of a product is substantially determined during the early stages of product design.

existence, beginning with the acquisition of the raw materials needed to manufacture it and proceeding through its working lifespan to its eventual disposal. Once constructed and connected, LCAs deliver environmental assessments several seconds after being notified of design changes through their links to other system modules. Specialists working on other design issues learn the environmental consequences of their choices and can consider alternatives.

Creating LCAs, however, is a time consuming and demanding task. Like its economic cost, the environmental impact of a product is substantially determined during the early stages of product design. Traditional LCAs are not effective during the beginning design stages because they cannot accommodate the rapid conceptual changes that typically occur. Researchers at MIT's CADLAB are developing a new kind of LCA model that extrapolates environmental consequences from databases of previously constructed LCAs. Supported in part by the Alliance for Global Sustainability (AGS) and the National Science

Foundation (NSF), researchers are exploring the use of Artificial Neural Networks to create *Surrogate LCAs*—that is, LCA models which can generalize from the experience of other design projects.

Learning from experience

Surrogate LCAs can be built relatively quickly, in days instead of months. They can estimate the environmental impact of a change in one design parameter, even

Finding a balance between the material demands of our industrial culture and the natural environment's carrying capacity is key to a sustainable future.

before other parameters are decided on. A Surrogate LCA derives its analytic capability from the collective experience of traditional LCAs. Surrogate LCAs can extract reliable results from incomplete, tentative, and 'noisy' data because they are trained to generalize from aggregate experience of existing LCAs.

Artificial Neural Network (ANN) learning algorithms accept the known inputs from multiple LCAs and, in effect, train the Surrogate to weight each factor appropriately. Preliminary research suggests that surrogates can be nearly as accurate as detailed LCAs and, because they 'learn', they benefit as the database is added to and the connections between design attributes and environmental impacts are refined.

Sustainability is a design issue

Finding a balance between the material demands of our industrial culture and the natural environment's carrying capacity is key to a sustainable future. DOME is a practical, holistic approach to mediating between design goals and environmental limits. Environmental values can be embedded in the design process so that the consequences of design decisions are actively measured and considered, rather than noticed and regretted at a later stage of product manufacture or use. According to Professor Wallace, "sustainability is a design issue." If we want to build environmentally sound products, it makes sense to build environmental analysis into the design process.

Further information about DOME can be found on the web at <http://cadlab.mit.edu/publications>.

"I approach green design from the perspective of a product designer, and one of the challenges product designers face is balancing environmental impacts. How much soot is equivalent to how much CO2? DOME allows designers to build mathematically weighted environmental values into their design models."

—Professor David Wallace
MIT CADLAB and
Department of Mechanical Engineering

The Tokyo Half Project:

Using DOME to solve complex environmental issues

The objective of the Tokyo Half Project (THP) is to discover ecologically effective and economically rational techniques to reduce Tokyo's emissions of carbon dioxide by 50%

To achieve this, the Tokyo Half Project has three basic goals:

To evaluate how new and existing technologies might be integrated to reduce greenhouse gas emissions;

To identify the analytical tools needed to assess energy, transportation, infrastructure, and policy alternatives; and

To develop a dynamic, holistic modeling system that allows specialized models of technological and policy alternatives to receive information reflecting their impact on the overall system.

Researchers from MIT, the University of Tokyo, and the Swiss Federal Institute of Technology are using a DOME model to investigate the most effective blend of technical and social innovations to reduce greenhouse gas levels in the city of Tokyo by the year 2020.

Specialists from several laboratories at these three universities will explore the development of new technologies, better uses of existing ones, and social and development policies. THP grew out of research at the Global Engineering Laboratory at the University of Tokyo and has expanded to become an Alliance for Global Sustainability project.

Burning fossil fuels like oil and coal produces carbon dioxide and other greenhouse gases. The accumulation of greenhouse gases in the atmosphere is implicated in global warming. Modern industry and society in general are deeply dependent on the use of fossil fuels that threaten our long-term survival. THP will study how various elements in urban life contribute to this problem and what changes they need to make to ameliorate it.

DOME (Distributed Object-based Modeling and Evaluation; discussed in a related story on page 3) will act as a common platform linking the various approaches. The DOME framework will coordinate the efforts and measure the effects of each approach. Nothing will be considered in isolation; the best options will be arranged in reasonable combinations to achieve the overall goal.

DOME's strength as a collaborative framework for designing new products extends to troubleshooting existing ones

If a product is not meeting expected standards, or if environmental or other costs fall outside of the range of acceptability, a DOME system model can show why and where the design failed. The separate product elements are represented as software models, and the models are linked together to represent the complex interactions that occur in the real world. Weaknesses are revealed that would not be apparent to the specialist concentrating on a single design function. The DOME system is a way to understand com-

plex systems as well as a technique for designing complex products.

Unintended consequences and good intentions gone awry

The Alliance for Global Sustainability is interested in DOME's ability to analyze and understand whole systems because environmental sustainability cannot be achieved by addressing single factors. Well-intentioned policies that mandated higher smokestacks to relieve air pollution led to acid rain. Gasoline additives that reduce harmful emissions from cars and trucks are polluting lakes and streams. Aside from these examples of harmful side effects, effective environmental policy imposes serious costs, both economic and social, on society. Trade-offs and sacrifices are often necessary. It makes sense to identify the technologies and policies that return the best results and impose the minimum costs. Environmental sustainability requires coordinated efforts informed by whole system understanding.

The first step is to quantify the impact each element of urban society has on the production of carbon dioxide in both relative and absolute terms. A clear definition of the problem and identification of its sources is crucial. Experts in many fields including civil engineering, mechanical engineering, chemical engineering, environmental science, political science, public health, computer aided design, and other fields will design models representing the components of a large city and their energy consumption. The models will include transportation, construction, industry, and energy. They will be linked to each other via computer networks so that changes in one will be reflected appropriately in each of the others. A comprehensive understanding of a city's energy use depends on a cross-sector viewpoint that recognizes the dynamic interactions between models.

Next, models will be developed to assess the economic, environmental, and GHG implications of existing and proposed technologies and social policies. Models of new GHG reducing technologies will be linked to models representing the industries they will affect and be affected by. In the past, attempts to deal with GHGs have been piecemeal, inefficient, and sometimes outright damaging because the dynamics of the entire system weren't clearly understood.

The University of Tokyo created a DOME model of a shoreline ecosystem that illustrates the interdependence of component factors in complex systems. Scientists connected software simulations of tidal basins to simulations of the natural forces influencing them. The salinity of a given tidal basin, for instance, depended on tangled interactions between evaporation rates, water temperature, and precipitation. These, in turn, shared many reciprocal connections.

Influence, in the form of data, flowed both ways. The behavior of the system model was produced through interactions among simpler factors.

The THP team has determined that in Tokyo direct carbon dioxide emissions from tailpipes and smokestacks account for only 30% of the total. Most emissions are indirectly induced by urban life and activities. Both direct and induced emissions must be addressed if Tokyo is to achieve the targeted 50% reduction. THP is exploring improvements in electricity generation, hybrid fuel-electric automobiles, and efficient HVAC, lighting, and appliance technologies.

Technology advances will be linked to recycling policies, new manufacturing processes, intelligent transport systems, and urban planning and land use scenarios. Increased efficiency in heating and air conditioning may depend upon land use policies encouraging centralization. High building density could also lessen personal automobile use. By using an integrated DOME design framework, various alternatives can be explored separately, and optimization algorithms can be applied to identify and test promising combinations.

Future Applications

The trend towards larger cities is expected to continue well into the twenty-first century. The specialized technology, environmental, and social models developed for the Tokyo Half Project are being built with the expectation that they will be reused. When the project concludes, recommendations will be made for applications of similar models in the US, China, or Switzerland. The DOME platform developed for Tokyo can assist other cities facing decisions about how to reduce greenhouse gas emissions. Naturally, the inputs and many of the limitations and tolerances would be different in other cities. A third world megacity faces a different set of challenges than Tokyo. But THP should establish a basic, widely applicable framework for constructing an energy use inventory, for describing technological and social options with software models, and for making informed choices. Lack of integrated understanding precludes a coordinated and economically rational way of tackling global environmental problems. DOME supplies a consistent and rigorous yet flexible way to understand problems and try to solve them.

Beyond the contributions the Tokyo Half Project may be expected to make to Tokyo, or even to controlling greenhouse gases generally, it may serve as a comprehensive and coherent approach to other complex environmental problems. 🍌

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designed in Norway for city driving, and the use of Intelligent Transportation Systems (ITS) to monitor traffic and direct drivers to uncongested routes. However, he noted, vehicle “intelligence” cannot always compensate for infrastructure inadequacies. Four million of Tokyo’s fleet of cars and trucks are equipped with advanced navigation systems, but gridlock still occurs when the number of vehicles overwhelms the available road capacity. Mr. Ressler saw no single solution to congestion. Rather, in his view, the most effective strategies will involve coalitions of public and private institutions applying integrated technological and public policy solutions.

*“By subsidizing parking and
the automobile in the US,
we’ve undermined our ability
to fund transportation systems
that need high demand,
like buses and railways.”*

—Michael Repogle,
Federal Transportation Director
at the Environmental Defense Fund

The conference was organized around seven panels addressing different aspects of congestion and mobility. Each panel had between three and six speakers who made presentations and took questions from the audience. Some of the points raised provoked extended questions and comments from the audience, and on several occasions moderators had to cut the question period short when it threatened to spill over into the following session. Discussion was taken up again during breaks, meals, and the reception held for conference participants on the evening of June 8th.

The first two panels following Neil Ressler’s speech described mobility conditions in the developed and developing world. Together, with the third panel “Urban Growth and Sustainability,” they delineated the range and severity of congestion problems today and looked at general solutions. Subsequent panels focussed in depth on specific solutions including public transportation, infrastructure development, and capacity management. After these sessions Mortimer L. Downey, Deputy Secretary of the US Department of Transportation gave a speech on DOT-sponsored initiatives to reduce traffic congestion. The final panel turned to emerging future issues, in particular the impact modern communications technology and aging populations will have on shaping transportation demand. At the close of the second day, MIT Professor Daniel Roos, Director of the Cooperative Mobility Program, summarized the conference proceedings.

Lax emissions standards in the developing world the cause of proportionately much higher air pollution

A sobering picture was painted by the sessions focussing on the pervasiveness of motor vehicles and the severity of the congestion problems they create. Western Europe has about 450 automobiles per thousand population and in the United States the ratio is higher. The developing

world has proportionally fewer cars, between 10 and 100 automobiles per thousand, but endures environmental and social consequences that frequently exceed those in Europe and North America. Air quality suffers due to lax emission standards and older vehicles. Cars, motorcycles, and buses share the same limited road space with bicycles, pedestrians, and animal-drawn carts, leading to high traffic fatality rates.

In both Western Europe and Japan the economic costs of congestion are estimated at two percent of the Gross Domestic Product. Zmarak Shalizi of the World Bank stated that the economic penalty in developing countries is even higher. Commuting times, which average around twenty-three minutes in the United States and over half an hour in Japan, can be much higher in the third world. According to Professor Ralph Gackenheimer of MIT, the average commute in Bogota Columbia is 90 minutes each way.

Public transportation accounts for three quarters of travel in the developing world. In the United States that figure is less than 2%. Europe's public transportation sector is more robust than America's, but road use has still doubled since 1970. Dr. Andreas Schafer, an MIT researcher, presented data on global trends in vehicle use and the consequent emissions of green house gases. He demonstrated that distance travelled rises with income level, but time spent travelling remains remarkably steady from the poorest societies to the richest. Citizens of wealthy countries travel more miles than their poorer counterparts because they rely heavily on energy-intensive transport modes like automobiles.

Today almost three quarters of the 600+ million motor vehicles on the road world-wide are driven in North America, Europe, and Japan but the balance will shift. Mr. Ashvin Chotai of Standard & Poors DRI showed slides of population and economic growth rates in Asia to illustrate the likelihood that another billion vehicles will be added to the roads of the developing world over

the next several decades. In the near term, the number of motor vehicles in the world is expected to double by 2025.

In addition to passenger vehicles, the number of trucks on the road will increase. Mr. Greg Brashears of United Parcel Service talked about the growth of freight shipping in developed countries. In Western Europe shipping by truck has grown from 49% in 1970 to 73% today, with the balance is handled by rail, pipeline, and inland waterway. In the United States, which relies on railroads to move over 40% of freight, the growth is less dramatic but still substantial. In 1970 trucks accounted for 22% of freight shipping. Today the figure is 30% and Internet-based commerce is expected to push the percentage higher as businesses and consumers buy goods online and receive their orders by truck. Projections of the growth of E-commerce have driven the stock valuations of truck manufacturers to record highs according to Professor Yossi Sheffi, Director of MIT's Center for Transportation Studies.

The Internet's total impact on mobility is difficult to imagine, much less calculate. Advanced communications permit businesses to decentralize their operations, allowing some employees to work at home rather than commute to central offices. On the other hand, computerized inventory systems and supply chain management facilitate production outsourcing and Just-In-Time delivery schedules. Production and warehousing efficiencies lead to more vehicles on the road carrying smaller loads and making more frequent deliveries. Professor Sheffi predicted that reductions in existing travel patterns due to the Internet will probably be more than counterbalanced by new travel demands.

Joseph Coughlin shared the Future Issues panel with Prof. Sheffi and spoke about the impact aging populations will have on congestion. In the United States, Sweden, and Japan the fastest growing demographic segment of the population is seniors over eighty-five

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To Left: Panel on Congestion and Mobility in Developed Countries, from L. to R.: MIT Prof. Daniel Roos, Director of the Cooperative Mobility Program (conference sponsor); Alan Pisarski, transportation consultant; Greg Brashears, Corporate IE Manager for UPS Freight Movement in Urban Cities; Prof. Masao Kuwahara, Univ. of Tokyo Institute of Industrial Science; and Harvard Prof. Alan Altshuler, Professor of Urban Planning and Policy.

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years old. Characterized by improved health, greater incomes, and higher education levels than earlier generations of elders, this age group will demand high levels of personal mobility.

Most of the conference speakers approached congestion from either of two very different directions. Some of the speakers treated congestion as chiefly a challenge to travel efficiency. Professor Remy Prud'homme of the University of Paris argued that congestion concerns are sometimes overstated. Professor Prud'homme could not attend the conference but sent a videotape pointing out that commuting times in Europe and North America have held steady over the past fifty years and that average traffic speeds are up. While congestion certainly exists, according to Prof. Prud'homme its costs are not enormous and it can be relieved by improving infrastructure.

Other speakers treated congestion as essentially an environmental problem. Mr. Michael Replogle of the Environmental Defense Fund argued that from an environmental point of view, reducing traffic congestion can be counterproductive. He compared expanding highways to relieve congestion to loosening one's belt to cure obesity. Road building can release pent-up travel demand that cancels out the added road capacity. In instances where construction does successfully ease traffic flow, longer commuting distances become acceptable, contributing to sprawl and more tailpipe pollution.

Sometimes, adding infrastructure makes sense from both an environmental and a strictly defined mobility perspective. Alan Pisarski, author of *Commuting in America*, explained how congested conditions can actually increase automobile use. For example, an individual facing a slow bus ride may switch to travelling by car. The choice may improve his or her personal commute, but it adds to the burden the overall mobility system is struggling with and further degrades the environment. Effective solutions to congestion frequently have to balance diverse and sometimes contradictory values.

*"The data show that
the richer we become,
the further we travel.
But time spent travelling
doesn't increase, so we
choose faster, more
energy intensive travel modes."*

—Andreas Schafer,
Research Associate at
MIT Center for Technology, Policy,
and Industrial Development



"Congestion is important to Ford because it is important to our customers."

—Neil Ressler, Vice
President and Chief
Technical Officer at Ford
Motor Company

Dr. Mario Carrara, the General Manager of Centro Studi sui Sistemi di Trasporto, spoke about the sophisticated transport policy known as Telematic Technologies for Traffic and Transport in Turin, Italy, or 5T for short. Turin combines urban traffic control with public transportation management. 5T monitors travel conditions and citizens can access information on the web or at special kiosks to select appropriate routes and modes of transport. Variable Message Signs (VMS) keep travellers informed about changing conditions. The bus system is efficient, accessible, and well integrated with the city's rail lines. Total travel in the section of central Turin where 5T is operational has declined by almost a quarter, but a substantial part of the reduction is in ridership on buses and trains. As 5T expands, the challenge is to shift capacity gain towards public transportation options and away from private vehicles

Properly managed, efficient public transit systems can reduce automobile use. David Bayliss, former Director of Planning of London Transport, talked about the factors that contribute to effective public transit systems. Though he mentioned technical innovations like buses running on physical tracks and high speed intercity rail service, Mr. Bayliss focussed on service rather than technology. The key features of successful public transportation include integration with other transit modes, intensified services, increased capacity, and cost-saving management techniques borrowed from the private sector. Mr. Bayliss also emphasized that public transportation is an issue of land use as well as mobility.

One city that has successfully combined transit and development policy is Ottawa, Canada, which was the subject of a presentation by John Bonsall, who worked on planning and managing their model bus system. 90% of the city population is within 400 meters of a bus stop and commercial development is concentrated along transit lines. Curitiba, Brazil is another city with an efficient bus system and a focussed development policy. Express and local buses travel along five radial arms on dedicated roadways from the center of the city. The tallest



*“The challenge is to look ahead and develop safer and more efficient systems...
...A sustainable multimodal transportation system is the measure of our success.”
—Mortimer Downey,
US Department of
Transportation*

buildings run alongside the bus routes with progressively less dense land use further out. Despite fairly high vehicle ownership, Curitiba has avoided many of the congestion problems that plague other Brazilian cities.

One way to encourage public transportation while discouraging personal automobile use is to reserve specific road lanes for buses or carpools. High Occupancy Vehicle lanes aren't always popular. Drivers stuck in traffic resent seeing lightly traveled HOV lanes on their right. Some communities compromise and allow ordinary passenger vehicles to travel the reserved lanes if they pay a toll. Other cities, most notably Singapore, take tolls a step further and use them to dynamically manage traffic flow. Tolls increase during peak hours on heavily traveled highways prompting drivers to find other routes, other transport modes, or quieter (and less expensive) times to travel.

Managing Congestion Through the Pocketbook: Road Pricing

Drivers in Singapore have tolls deducted electronically from debit cards as they travel the highway system. Road Pricing, as it is called, is an effective but politically controversial way to manage congestion. The tolls vary with the time of day which helps spread traffic around the clock, since Singapore, a crowded city on a small island, cannot disperse itself spatially. Prof. Sheffi speculated on future scenarios where tolls could fluctuate dynamically in response to weather and traffic conditions as well as the time of day. Mr. C. Kenneth Orski, whose International Mobility Observatory collects, collates, and publishes transportation innovations from around the world, envisioned a dual road system emerging in the 21st Century. The old highway system would be supplemented by high speed toll roads offering better service for a fee. Discussing the political implications of Road Pricing, Mr. Orski stated that most drivers are receptive to the idea of paying extra for a faster commute with less stress. However, they resist Road Pricing when they perceive it as a means to discourage driving during certain hours.

Singapore supplements its electronic toll network with an advanced Intelligent Transportation System. ITS monitors driving conditions and quickly dispatches help to the scene of accidents and other traffic snarl-ups. Variable Message System signs inform drivers of developing conditions up ahead, reroute them, and even close off lanes.

Innovations in highway capacity management have been matched by innovations in the ways roads are built, and

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even paid for. Peter Zuk, who managed Boston's Central Artery Project for eight years, compared the challenge of building new roads and tunnels while the city goes about its daily business to performing open heart surgery while the patient plays tennis. Large infrastructure projects have to satisfy environmental, social, and economic concerns that lie beyond narrowly conceived transportation issues. Transportation policy is negotiated among stakeholders as much as it is planned by experts.

At the close, Professor Roos noted, the number of practical "success stories" is not very large. This is partly because congestion is not a single problem, but a constellation of problems intertwined with basic issues of independence, access, economic well-being and mobility. The exact mix of these factors varies from place to place and so do appropriate solutions. Policies that succeed in one dimension by easing traffic flow, may fail to address critical environmental concerns, or dampen economic development. "If congestion were the only problem that we faced," one speaker commented, "it would be a lot easier to solve."

Further information on the conference proceedings can be downloaded from the web at http://ilp.mit.edu/ilp/non_member/conferences/TrafficAgenda.html.

The Cooperative Mobility Program's website is <http://web.mit.edu/ctpid/cmp/index.html>.

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