Sustainable Transportation Networks: An Introduction

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Introduction

The physical movement of humans and commodities over space and time is essential to the functioning of societies and economies.

Fundamental to the movement is the existence of infrastructure networks, in particular, transportation networks, which allow for the physical movement to take place.

Indeed, the very organization of societies and economies themselves is increasingly taking on the structure of networks with both transportation and telecommunication networks forming the underlying foundations.

The transportation of humans and commodities cannot be realized without vehicles and their production comprises the biggest manufacturing industry in the world today.

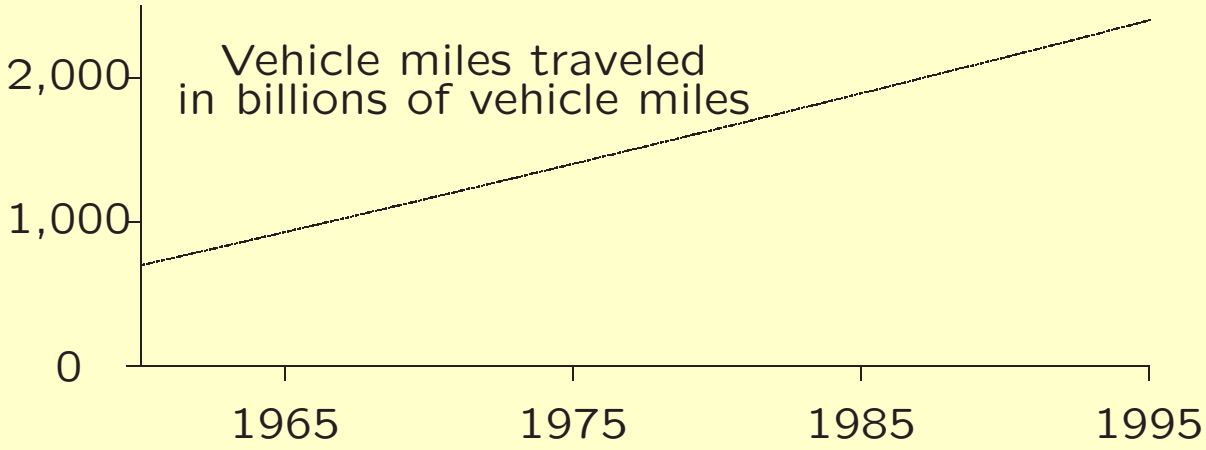
Historical Background

In the middle of the twentieth century there were 2.6 billion people on the earth and 50 million cars. Half a century later, the number of people has risen to 6 billion and the total number of cars to 500 million with the total number of vehicles including trucks and motorcycles being 777 million. The tenfold increase in the number of cars has occurred in only a couple of generations.

Vehicles and, in particular, cars have provided the medium for enhanced mobility and freedom for individuals and access to cars has been pivotal in shaping modern urban forms.

Indeed, there are few aspects of today's modern life that have been untouched by the car, and the production of cars, as well as their usage, has revolutionized modern industry and has led to the evolution of the spatial structure of cities and regions as we know them today.

Ground transportation alone, as a sector of the United States economy, provided $277 billion contribution to the 1992 gross domestic product (GDP) and in 1994 this figure, which measures all expenditures for moving goods and passengers, was in excess of $900 billion.



Trend for vehicle miles traveled in the United States

Source: Oak Ridge National Laboratories (1993)

Some Facts

In 1995, it was estimated that the United States had 30% of the world's motor vehicles and yet only 4.5% of the world's population. Furthermore, the total number of passenger miles traveled annually in the United States alone was estimated to be 3.7 trillion passenger miles over 4 million miles of roads and highways (see Dower, et al. 1997).

In the Figure, the trend in vehicle miles traveled in the United States is presented.

Nevertheless, despite the positives of vehicle ownership and use, the negative effects, notably, traffic congestion and pollution associated with vehicular travel and with increasing vehicular use, are now well-recognized.

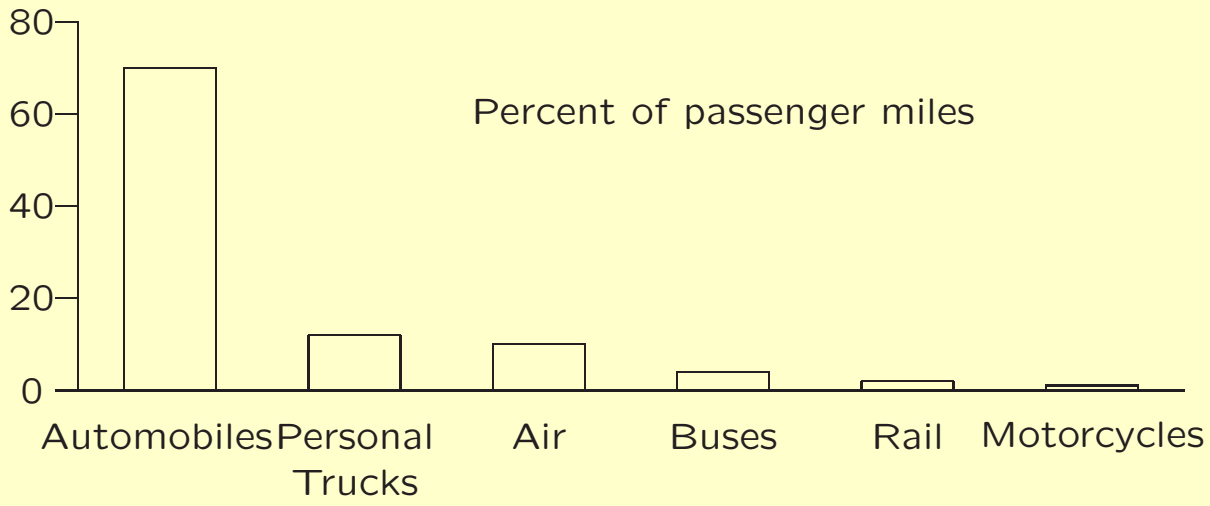
Negative Externalities

In the United States alone, congestion results in $100 billion in lost productivity annually, whereas the figure in Europe is estimated to be $150 billion.

The average American car driver travels approximately 12,000 miles annually, with a typical trip being of average length about 8.4 miles, whereas the European driver travels only about 8,400 miles annually.

In the United States, buses and trains account for only about 3% of the travel mileage, whereas in Europe the percentage exceeds 15% (*The Economist* 1996).

In the next Figure, the percentage of passenger travel by different modes of travel in the United States is given.



Passenger travel in the United States

Source: American Automobile Manufacturers Association (1996)

In addition, in the United States, the increasing suburban sprawl results in greater distances between residences and places of work as well as stores, schools, and other amenities. Furthermore, the traffic and congestion in many metropolitan areas in both the United States and abroad are growing annually with conditions expected to only worsen in the future.

Moreover, environmental pollution is one of the most pressing public policy problems faced by our societies today and the degradation of the environment due to adverse environmental effects such as air pollution from vehicular exhaust emissions is well-documented.

More Environmental Issues

The average car during its lifetime travels 100,000 miles, uses over 3,000 gallons of gas and over 50 gallons of oil.

It discharges through its exhaust more than 35 tons of carbon, with the world's 500 million cars producing 10 trillion cubic meters of exhaust fumes annually (*The Economist* 1996).

Despite 25 years of engineering progress and efforts and substantial reductions in transportation-related emissions, motor vehicles remain important sources of emissions of carbon monoxide, organic compounds, nitrogen oxides, and other forms of air pollution, mainly due to the growth of vehicular fleets.

Presently, about 15% of the world's emissions of carbon dioxide, the principal global warming gas, is generated by motor vehicles. Furthermore, transportation is responsible for approximately 50% of the nitrogen oxide emissions, which, in combination with other pollutants, form nitric acid which then falls to earth as acid rain.

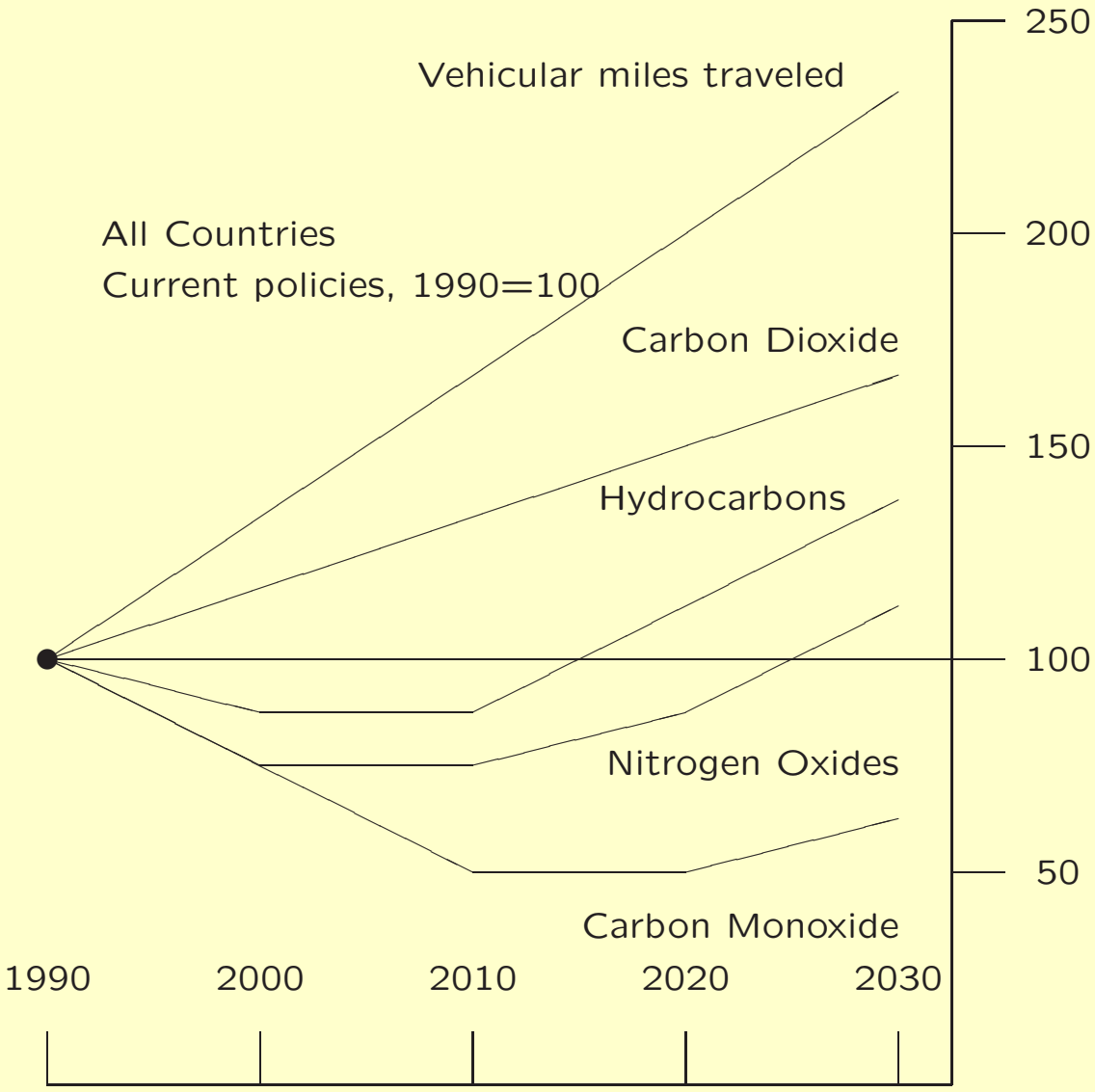
Finally, 90% of the carbon monoxide generated comes from emissions from the transportation sector (Button 1990). Cars and other motor vehicles are responsible for at least 50% of the air pollution in urban areas (*The Economist* 1996, 1997).

The number of cars is expected to rise by 50% by the year 2010 and to double by the year 2030.

The next Figure illustrates the travel and emission forecasts for all countries through the year 2030, given current 1990 policies. Indeed, even with potential reductions in vehicular emissions due, for example, to engineering innovations, without intervention congestion will not be reduced.

The World Health Organization (WHO) has conducted studies which reveal that only about 20% of the town dwellers on our earth enjoy good enough air quality as measured by the levels of emissions, such as nitrogen oxides.

Indeed, the United Nations has estimated that people residing in approximately one half of the world's cities are breathing more carbon monoxide than is good for them (*The Economist* 1996).



Travel and emission forecasts for all countries through the year 2030, given current 1990 policies

Source: Adapted from *The Economist* (1996) obtained from OECD

Sustainability Issues

In light of the above figures, and the recognition of the negative effects of the dual problems of congestion and pollution by both individuals as well as their governments, one may ask the question whether or not the existing transportation networks are *sustainable*, that is, *can they last*?

Indeed, with the seemingly conflicting forces of demand for transportation resources on the one hand and pressures to attain environmental quality standards on the other, as increasingly mandated by governmental legislation, and to also reduce congestion, one wonders whether there even exists a viable solution.

Course Objectives

In this course, a framework for the formulation, study, analysis, and design of sustainable transportation networks is developed. The subsequent Figure presents a depiction of the major theme of this course, which is the achievement of sustainability of transportation networks through appropriate policies.

The topic of sustainability, which explicitly considers the integration of economic, environmental, and social goals, has been the subject of increasing attention, as well as debate, since the 1987 Brundtland Commission Report (World Commission on Environment and Development 1987) defined *sustainable development* as development that meets the needs of the present without compromising the ability of future generations to meet their needs.

This course focuses on sustainable transportation from a network perspective and to demonstrate – in a rigorous manner – how a spectrum of policy interventions, ranging from pricing policies to tradable pollution permits, and, finally, network design and technology can be applied in order to attain environmental goals. The topic is especially timely due to increasing interest in the subject on local, regional, national, as well as global levels.

Furthermore, with the advances in both analytical techniques, as well as the availability of computer technology, the theoretical results established in this book can be implemented in practice. Indeed, a recent report by the World Bank (1996) contends that "A policy for sustainable transport is one that identifies and implements the win–win policy instruments and explicitly confronts the tradeoffs so that the balance is chosen rather than accidentally arrived at. It is a policy of informed, conscious choices."

The course is presented against the backdrop of increasing activity in the transportation field as regards environmental issues and, in particular, the notion of sustainability, as evidenced from recent conferences, papers, and studies that have addressed such issues (see, for example, Replogle 1991; Roseland 1992; Whitelegg 1993; OECD 1995; Sperling and Shaheen 1995; World Bank 1996; President's Council on Sustainable Development 1996a, b; Nijkamp, Rienstra, and Vleugel 1998).

A recent report by the Transportation Research Board (1997) addressed the nature of long-term threats to the environment due to transportation infrastructure development and operation in the United States.

Sustainability – Historical Roots

The notion of sustainability has roots at least as early as the work of the eighteenth-century economist and philosopher Thomas R. Malthus, who, however, focused on growth limits (see also Meadows et al. 1974). As regards transportation, sustainability has evolved, according to a recent World Bank report (see also Transportation Research Board 1997), to include such principal components as:

• the economic and financial component, which concerns the adequacy of the transportation infrastructure;

• the environmental as well as the ecological component, which concerns issues of how investments in transportation and mode choice options affect transportation and land use patterns and how these, in turn, affect, for example, emissions, air and water quality, and energy consumption; and

• the social component, which focuses on adequate access to transportation services by all members of society.

The course aims to develop a rigorous theoretical framework for the study of sustainable transportation networks, which encompasses various facets of the above components. It is by no means, however, meant to be all-encompassing, but, rather, to set the foundations for further research, discussion, and policy analysis and implementation.

References

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