Megacities:
Sustainability, Transport, and Economic Development

By

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Abstract

The connections between sustainability, transport, and economic development are and will remain essential in the governance of cities. Sustainability concepts include valuing and preserving the earth's resources so that future generations can enjoy their benefits. It requires changing human behavior and practices to be more efficient and less damaging to the environment, especially with the current rates of population growth and urban concentration. In addition, there is the element of social equity in which investments should secure benefits for all classes of society, not just the affluent. These concepts are particularly applicable in transportation systems, because they have been neglected in the traditional quantitative approaches to planning and investment. Of course, policies defining transportation and those enacted for sustainability impact economic development, which is a chief priority of governments. Therefore, future success in urban areas lies in balancing an array of interests and adopting the most comprehensively advantageous policies.

This study will demonstrate the need for rethinking traditional urban transportation development strategies. It will detail the problems associated with urban transport that infringe on environmental conditions and human quality of life. This paper will explain approaches to transportation that can lead to improvements in the negative corollaries currently experienced. It will also present policy measures and tools that can be implemented.

This research paper will provide information for city officials and planners to better understand the implications of transportation policies and the options available for governance. These decisions are becoming more critical as urban growth leads to large metropolitan regions with incredible transportation demands. More optimistically, the challenges facing society from transport can be overcome through commitment to better policies and the strengthening of institutions that oversee them.

Thesis Supervisor: Fred Moavenzadeh

Title: James Mason Craft Professor of Civil and Environmental Engineering

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I must acknowledge the research of Fred Moavenzadeh, Brantley Liddle, Benjamin Cheatham, Satish Lion, and Sandi Lin whose research and thesis papers composed at MIT provided information necessary for the development of this paper. The second chapter of this thesis on sustainability draws from the research paper "Sustainability and Development" by Brantley Liddle and Fred Moavenzadeh. The text of this chapter has been excerpted and edited entirely from this work. Similarly, the fifth chapter outlining transportation policies and tools has been extracted from masters thesis papers. The first five subsections on demand and supply tools are derived from Benjamin Cheatham's "Sustainable Urban Transportation in Developing Megacities: A Review of Policies, Regulations, and Technologies." The remaining two subsections on land use planning and intelligent transportation systems come from Satish Lion's "Transit Oriented Development Strategy: Guangzhou Case Study" and Sandi Lin's "An Institutional Framework for Deployment of Intelligent Transportation Services" respectively. These materials allow a more comprehensive presentation of the elements of urban transportation systems that need to be considered concurrently.

I would like to thank my thesis advisor Professor Fred Moavenzadeh for his direction and guidance during my research. I am grateful for the time he dedicated to share his knowledge.

I have been enriched by my endeavors in the Construction and Engineering Management Program and am grateful to the professors that made the course rewarding. In addition, my classmates in this program have broadened my perspective and development through our interaction.

I would like to thank the staff of the Civil and Environmental Engineering Department including Patricia Vargas and Cynthia Stewart for their kindness. In particular, I would like to thank Danielle Severino for her assistance and friendship.

My parents and brother are cornerstones of my life, and I dedicate this thesis to them.

Justin Charles Tobias
14 February 2005

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1 *Introduction and Organization*

This study examines urban transportation for large cities from a development context that considers the economic, social, and environmental aspects of these systems. In order to do this, it presents the concepts of sustainability and identifies transportation policy practices in conjunction with an analysis of growth, environmental, and institutional challenges.

Economic development remains a principle concern for governments around the world, but there is growing support for consideration of other factors in urban management. This support stems from problems that have been caused by policies enacted and ascribed to over extended periods of time. In transportation, there has been a neglect of environmental, social, and other sustainability concerns that would better serve the short and long-term interests of society, from a qualitative perspective. At present, transportation poses a tremendous threat environmentally, and if unaltered it could lead to breakdowns in mobility, economic disruptions, and severe repercussions for the natural world. Simultaneously, social discrepancies in terms of access to mobility are getting worse for urban inhabitants at lower income levels. These two consequences of transport policy are detrimental to societal well being, and they can have negative economic impacts, which is ironic because they are typically neglected initially for financial reasons. Thus, integrating more comprehensive analysis into transportation planning is essential, but it requires transitioning from traditional views of governance and policy development to less familiar and customary concepts.

The research herein covers critical methods for mitigating problems associated with transportation to ensure that future megacities will exist in more sustainable conditions. In this discussion of urban transport, a broad approach is taken at times given the geographically specific nature of transport that makes generalizations impractical if not taken from a more universal perspective.[1] For the sake of specificity, the last chapter outlines possible policy and strategy options in urban transportation agendas that vary in their applicability based on geography. An introduction to the thesis chapters follows.

[1] Black, William R. (2003). Transportation: A Geographical Analysis. The Guilford Press, New York.

Chapter 2: Economic Development and Urban Infrastructure

This chapter sets the stage for development by detailing the existence of and the projections for megacities, while discussing urbanization and motorization. Infrastructure is critical for development, and in many regions it can act as a limiting factor that stalls growth. Transportation infrastructure shapes the characteristics of cities, and its supply shapes economic behavior along with social and environmental conditions.

Chapter 3: The Environment and Transportation

The pollution and byproducts caused by human activity pose a threat to environmental integrity and terrestrial life. Transportation is a growing source of this waste including air pollution, accidental death and injury, noise pollution, and ecological destruction. Evaluating the barriers to change and the potential reactions to specific technologies and infrastructure possibilities are critical in selecting methods for reducing pollution created by vehicles. This chapter describes the technology of fuels and vehicles based on petroleum and other cleaner sources of energy. It concludes with a summary of the environmental challenges and policy struggles of Mexico City.

Chapter 4: Sustainability

This chapter presents a background on the development of sustainability as a topic of increasingly recognized importance. It describes the essential elements of this ideology and explains their impacts. In addition, the chapter details the unresolved debates that exist within this community of thought on the best manner of achieving sustainability and the extent to which those efforts should be pursued. The differences between incentives and regulation for governing in sustainable ways are stated, and this distinction is used later in classifying policies. Again, this section has been drawn from Brantley Liddle and Fred Moavenzadeh.

Chapter 5: Transportation Policy and Sustainability

The inherent tradeoffs in development are defined at the beginning of Chapter 5, as they must be considered in policy evaluation. Automobile dependence characterizes too many developed megacities, and it results in congestion and takes a heavy toll on government

budgets. Alternatively, non-motorized transport and public transportation are insufficiently emphasized in planning and managed by governments in urban areas. The final sections of this chapter outline some critical considerations for sustainable transport and discuss better governance.

Chapter 6: Demand and Supply Management, Land Use, and Technologies

A comprehensive understanding of the policy practices and their possible effects is vital for government officials to select optimal courses of action. The first four subsections of this chapter lay out demand and supply side management divided again into market based incentives and command and control regulations. This presentation of policies and examples of their use was formulated by Benjamin Cheatham. The subject of land use planning then identifies government policies available for this arena that are essential considerations given their impact on mobility behavior; this section comes from Satish Lion's research. Lastly, intelligent transportation systems are outlined, because of their importance not in solving urban transport challenges but in playing a key role in the process if utilized.

Chapter 7: Conclusions

Chapter 7 briefly summarizes the material covered within this thesis and ties together the diverse subjects; a grouping that must be made to address the tremendous challenges faced in megacities and rapidly urbanizing cities around the world.

2 *Economic Development and Infrastructure*

2.1 **Infrastructure and Development**

Economic growth and prosperity has laid the foundation for societal advancement throughout history, and it is a chief concern among all nations. Economic progress occurs in stages or levels composing building blocks that serve as a foundation for future growth. This process cannot occur without the provision of services, transport among them, that are critical to satisfying basic needs of communities. The demands of providing these services impose extremely versatile challenges on governments, which must effectively manage resources and growth. Governments are heavily involved infrastructure provision and preservation because of their traditional role in funding projects.[2] Success in achieving infrastructure goals varies in correlation to development around the world, and yet these demands seem never ending with population growth and changing global trends.

The ability to provide basic services eludes governments of poorer nations that cannot supply the water, housing, sanitation, power, transport, and telecommunications infrastructure necessary. Many nations in the developing world, particularly in Africa, fall into this category. Aside from Egypt, Libya, Tunisia, Algeria, Morocco, and Sudan, the African continent has the lowest development percentages for adequately providing basic services. The percentage of its people with housing access to electricity, water, and sewage averages 53.9, 48.4, and 30.9 percents respectively.[3] Meanwhile, the rest of the world holds averages above 90 percent for electricity access, a huge discrepancy. Sewage treatment and water infrastructure access varies to a greater degree whereby the Asia-Pacific region falls a distant second to the above figures for Africa. These statistics show deficiencies in development around the world that many industrialized countries take for granted. Despite economic development, however, even the more prosperous of nations struggle with the supply and management of infrastructure.

[2] Black, William R. (2003). Transportation: A Geographical Analysis. The Guilford Press, New York.
[3] United Nations Center for Human Settlements. (2001). The State of the World's Cities Report 2001. Oxford, Oxford University Press.

The provision of infrastructure supports economic growth, but its allocation is limited by financial and technological capability. The shortage of these services in Africa and the Asia-Pacific region arise from the inability to fund improvements under current strategies and budget limitations. Insufficient industry strength and technological sophistication create barriers for many countries. For example, water infrastructure was limited worldwide before the invention of cast iron pipes and steam driven pumps in the 1850's.[4] In contrast, the developing countries of today have the benefit of turning to industrialized nations for advancements, but they typically struggle in trying to create their own industries or in paying for importation. The failure of governments to provide basic infrastructure services not only infringes on growth potential, but it also creates discrepancies in social welfare levels, especially in less developed regions where access is limited. The percentage of the population excluded from using services or inadequately provided for as described in the preceding global averages represent the lowest level income earners. When these individuals are denied, they are victims of circumstance with a handicap that puts them at a disadvantage for participating in societal activities and economy productivity.

Nations around the world, including those with higher income levels, suffer under the complexity of managing infrastructure. Part of this challenge occurs through the difficulty of allocating resources and selecting projects for development. Infrastructure investments usually occur in stages since initial and expansion projects must be large enough to have an impact and must satisfy connectivity requirements of existing systems. Thus, the irregular investments over time must match dynamic levels of demand, which history often difficult to accurately estimate. In addition to initial investment costs, established cities and nations continually struggle with the maintenance requirements of infrastructure. Too often, this preservation work is forgone to pay for other expenditures like new infrastructure projects, which are more exciting and visible. Maintenance neglect causes faster deterioration leading to greater capital expenses necessary to rebuild failing infrastructure. Roadways, for example, erode more rapidly in the absence of

[4] World Bank. (1994). World Development Report 1994: Infrastructure for Development. New York: Oxford University Press.

proper upkeep. It is estimated that in Latin America every dollar not spent on road maintenance costs three to four dollars in premature rebuilding needs.[5]

The challenges of infrastructure and its role in economic development have existed for a long time, but the nature of this relationship continues to evolve. As the world changes, the failures of mismanaging resources and authority will become clearer. The growth of major cities around the world makes supplying infrastructure more difficult and mistakes more costly, particularly as government jurisdictions overlap. Rising concentrations of people in city centers is redefining activity within urban space and creating problems, particularly for transportation. Nevertheless, solutions exist for sustainable approaches with economic objectives in mind, and they can be reached through broader decision making by governments and increased awareness of good policies and practices. The rise of megacities makes this transition imperative.

[5] World Bank. (1994). World Development Report 1994: Infrastructure for Development. New York: Oxford University Press.

2.2 **Mega-Cities**

The trend over the past century has been the movement of people into cities, transforming the distribution between rural and urban concentrations. This rearrangement has occurred due to migration into city centers in combination with global population increases. Many metropolitan areas have amassed populations exceeding ten million people, which is the current classification for status as a megacity. Unfortunately, these agglomerations are creating challenges for industrialized countries and especially developing ones. Figure 1, below, lists the current data for cities over ten million inhabitants and the projections for the year 2015. The twenty cities listed for 2003 are a significant rise from only four cities over ten million in 1975.

Figure 1: Megacities List

Population Agglomerations with 10 Million Inhabitants or More (Millions)			
2003		Projections for 2015	
Urban Agglomeration	Population	Urban Agglomeration	Population
Tokyo, Japan	35.0	Tokyo, Japan	36.2
Mexico City, Mexico	18.7	Mumbai (Bombay), India	22.6
New York, USA	18.3	Delhi, India	20.9
São Paulo, Brazil	17.9	Mexico City, Mexico	20.6
Mumbai (Bombay), India	17.4	São Paulo, Brazil	20.0
Delhi, India	14.1	New York, USA	19.7
Calcutta, India	13.8	Dhaka, Bangladesh	17.9
Buenos Aires, Argentina	13.0	Jakarta, Indonesia	17.5
Shanghai, China	12.8	Lagos, Nigeria	17.0
Jakarta, Indonesia	12.3	Calcutta, India	16.8
Los Angeles, USA	12.0	Karachi, Pakistan	16.2
Dhaka, Bangladesh	11.6	Buenos Aires, Argentina	14.6
Osaka-Kobe, Japan	11.2	Cairo, Egypt	13.1
Rio de Janeiro, Brazil	11.2	Los Angeles, USA	12.9
Karachi, Pakistan	11.1	Shanghai, China	12.7
Beijing, China	10.8	Metro Manila, Philippines	12.6
Cairo, Egypt	10.8	Rio de Janeiro, Brazil	12.4
Moscow, Russian Federation	10.5	Osaka-Kobe, Japan	11.4
Metro Manila, Philippines	10.4	Istanbul, Turkey	11.3
Lagos, Nigeria	10.1	Beijing, China	11.1
		Moscow, Russian Federation	10.9
		Paris, France	10.0

[Source: UN WUP][6]

[6] United Nations. (2003). World Urbanization Prospects: The 2003 Revision.

In the past century, the one hundred largest cities in the world have been more concentrated in industrialized countries, but this dominance has and continues to reverse. By 1995, sixty-four of these one hundred were located in developing countries, up from forty-one in 1950, and population projections show that this trend will continue until three-quarters of the largest one-hundred cities belong to developing nations by 2015.[7] These statistics forecast increased challenges to national and city governments of the developing world already struggling under the heavy burdens imposed on them by massive metropolitan concentrations. This urban growth stems from population growth and urbanization that overburdens infrastructure and can lead to environmental deterioration.

2.2.1 Urbanization

As countries develop, their cities grow in economic importance. In fact, most developing countries receive half of their Gross National Product from the urban districts.[8] The economic strength of urban areas is responsible for the influx of people into city centers, known as urbanization. This concept differs from population growth, which is the increase in overall numbers in equal proportions over rural and urban areas. During the past century, people have migrated into city centers to benefit from the economies of scale and agglomeration. This activity called urbanization can occur in an environment without population growth as evident in China where numerous city centers have formed rapidly urban influx. Worldwide, the percentage of the population living in urban areas climbed from 38% to 47% between 1975 and 2000 and by 2025 the anticipated urban share should reach 59%.[9] Some countries have tried to oppose urbanization through controls on movement, but efforts in China, Vietnam, and the Soviet Union failed. These tactics proved costly to both the nations and their citizens, as in Indonesia, where the practice of evicting migrants proved unsuccessful and was discarded.[10] Therefore, it should observed that attempts to redirect urbanization driven by economic incentives are

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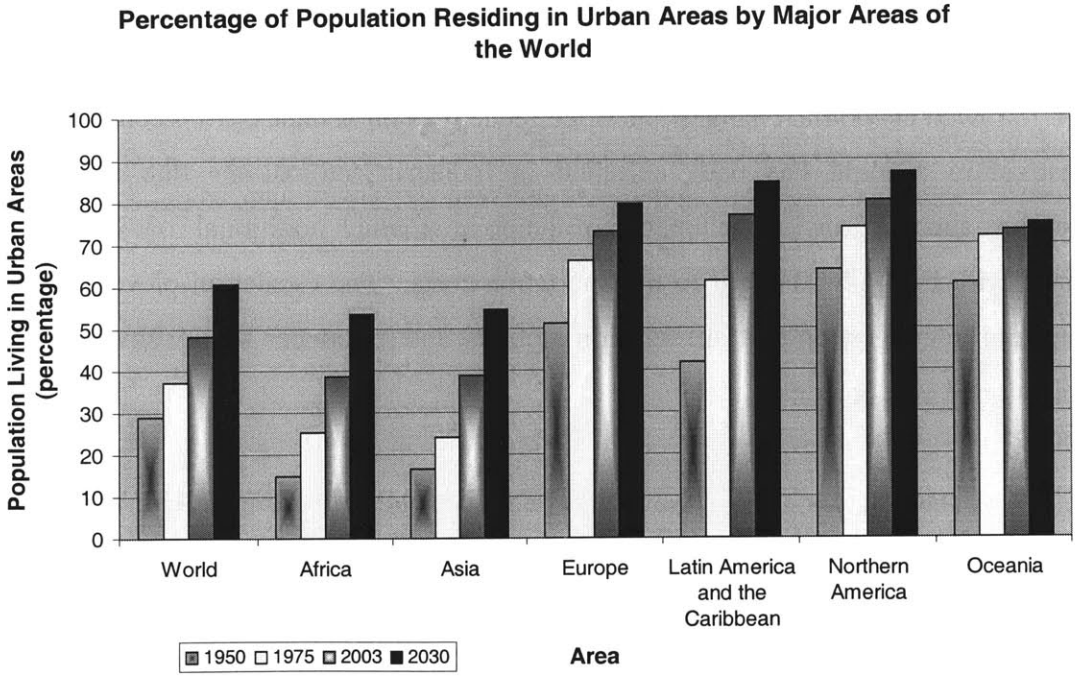
[7] United Nations. (2003). World Urbanization Prospects: The 2003 Revision.
[8] Gwilliam, Ken. (2002). Cities on the Move: A World Bank Urban Strategy Review. The World Bank, Washington D.C.
[9] United Nations. (2003). World Urbanization Prospects: The 2003 Revision.
[10] World Development Report 1999/2000: Entering the 21st Century. (1999) World Bank, Oxford University Press.

dangerous and likely futile. Cities must then find means of dealing with the pressures of urbanization and population growth in combination. Population growth is far from negligible with a 46% increase in the developed world during the second half of the twentieth century and four times that rate estimated for the remaining nations.[11]

In order to illustrate the trend of urbanization, Figure 2 depicts the observed transition from rural to urban areas by percentage of total population for the past fifty years more specifically identified by major regions of the earth, along with forecast values for 2030. The trend toward cities has been strongest in Latin American and the Caribbean since 1950, but this appears to be slowing there. Meanwhile, Asia and Africa will continue to experience strong migration of inhabitants to urban areas.

Figure 2: Urban Population Percentages



[Source: UN WUP][12]

[11] World Business Council for Sustainable Development. (2001). Mobility 2001: World Mobility at the End of the Twentieth Century and its Sustainability.
[12] United Nations. (2003). World Urbanization Prospects: The 2003 Revision.

2.2.2 *Motorization*

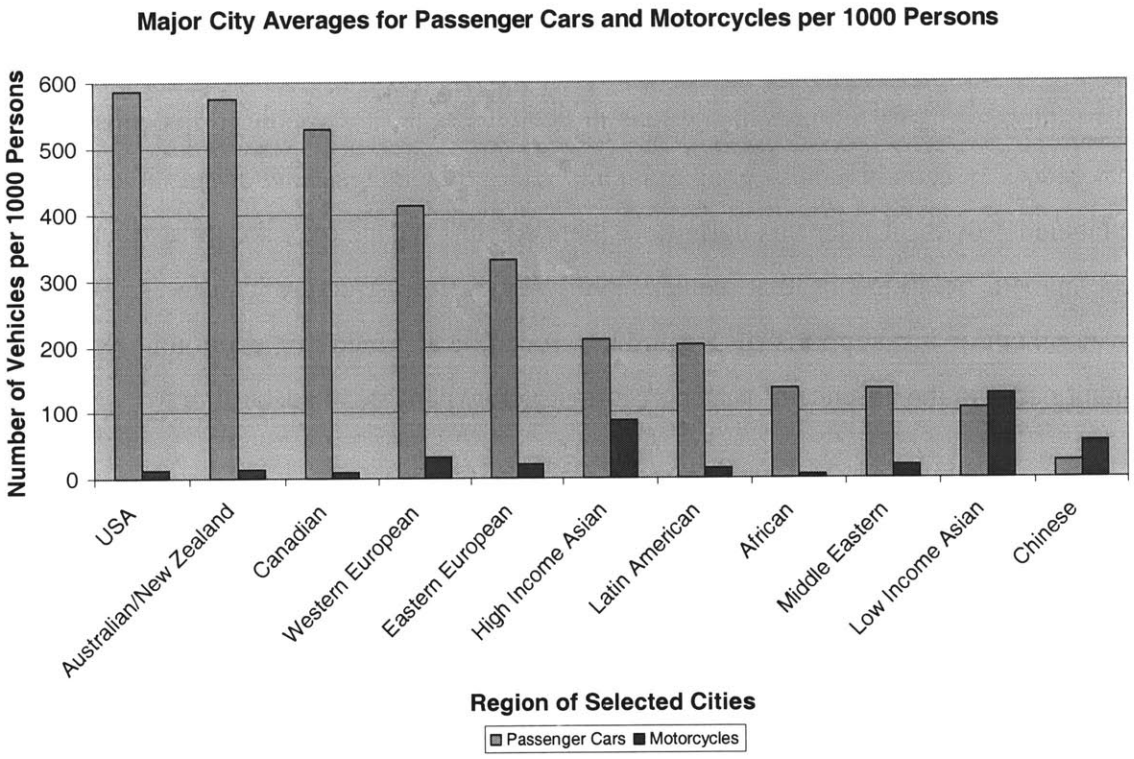
Another major trend is motorization, which pertains to transportation but affects many conditions. The ownership of motorized vehicles has been a trademark of industrialized nations, but developing countries are increasing adopting this behavior. The provision of road infrastructure allows the growth of vehicle fleets, and the correlation between its supply and the demand for road space is indisputable, provided people can afford the expenses. Typically, the government funds infrastructure projects or subsidizes fuel costs, as many countries do, which reduces the costs of private vehicles making them more attractive to consumers. This conceptually mistaken practice has been implemented to a large degree and deserves responsibility in recent motorization surges. In developing countries, even those with traditional emphases on public transport as in Asia, private vehicle ownership is increasing due to the convenience, purchasing power of rising incomes, and changing cultural values. In Delhi, the motor vehicle fleet reached 3.3 million in 2000 from 2.4 million just five years prior.[13] Of course, this movement in Delhi followed economic changes and price reductions on vehicles. In recent years road infrastructure funding has been curtailed in industrialized nations due to financial constraints and the growing acceptance of the point at which additional roadways induce demand with negligible benefit to transportation costs. The escalation of vehicle fleets creates traffic congestion that infringes on mobility and introduces social, environmental, and economic costs on cities.

Figure 3 on the following page shows the rates of ownership for cars and motorcycles, specifically from major cities around the world, as selected by Kenworthy and Laube. The variance represents the differences in both income levels, which make ownership possible, and transport mode patterns as influenced by governments. It shows the potential growth for ownership around the world, which is particularly troublesome considering the environmental and social problems associated. Rapid motorization will most likely continue to increase in the developing world.[14] The motorcycle figures show

[13] Economic and Social Commission for Asia and the Pacific. (2001). Review of Developments in Transport and Communications in the ESCAP Region 1996-2001. United Nations, New York.
[14] Alcântara de Vasconcellos, Eduardo. (2004) Urban Transport and Tensions in Developing Countries. In: Benería, Lourdes and Savitri Bisnath (eds) Global Tensions. Routledge, New York.

the prevalence of this mode, which is most common in Asia and a possible stepping stone to more expensive automobiles.

Figure 3: Major City Vehicles Per 1000 Persons Averages



[Data Source: Kenworthy and Laube][15]

In addition, the number of kilometers traveled on average by drivers has also risen, which correlates to the increasing desire for personal mobility with income gains. With more economic power, people find greater need for travel whether driven by longer work commutes due to suburbanization or by retail and entertainment trips. Nevertheless, the rising ownership levels and commissioning of new roads escalates transportation crisis as city planners battle to provide more sustainable transportation networks.

[15] Kenworthy, Jeff and Felix Laube. (1999). An International Sourcebook of Automobile Dependence in Cities, 1960-1990. Boulder, Colorado, University Press of Colorado.

2.3 Transport Infrastructure

Economies can be stimulated by different events but principally from population expansion, new business introduction or innovation, productivity gains that can come from various sources, and transportation investment that reduces cost structure. The latter of these is particularly controversial in terms of whether investments into transport can spur growth as distinct from relocation.[16] The addition of infrastructure, a new road for example, is likely to evoke development along its right of way, but if this construction only causes an economic shift geographically rather than increased economy it should not be labeled growth. Under this definition, there is still a debate over the infrastructure and development relationship that centers on whether infrastructure causes growth and development or just supports it. Regardless, it can be affirmed that economic expansion cannot occur in the absence of transport infrastructure capable of sustaining it.

The establishment of urban transport supports economic activity by mobilizing goods and people to take part in manufacturing, trade, and service activities. Therefore, the quality of networks is responsible in part for prosperity or lack thereof. All countries but especially those in the earlier stages of development face difficult choices in the allocation of funds for public transportation and roadways, in which endeavors they typically spend between 15 and 25 percent of annual expenses.[17] Ideally, investment in transportation infrastructure should create savings in time expense, fuel consumption, and pollution emission.[18] Beyond these direct impacts, transportation ties into the general conditions of a region.

With great challenges remaining in the provision of infrastructure, transportation concerns have been improperly addressed and overlooked for their interdependencies with other development issues. With the effect of transportation on economic development and its impact on the quality of life for poor people, attention to and efforts for this urban concern cannot be under appreciated with respect to more basic needs.

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[16] Black, William R. (2003). Transportation: A Geographical Analysis. The Guilford Press, New York.
[17] Gwilliam, Ken. (2002). Cities on the Move: A World Bank Urban Strategy Review The World Bank, Washington D.C.
[18] Black, William R. (2003). Transportation: A Geographical Analysis. The Guilford Press, New York.

This understanding has increasingly become part of developing government ideologies, but courses of action remain unclear. Different regions and cities approach these problems with completely disparate mechanisms and philosophies in some cases. This reality makes city governance in rapidly growing cities, particularly the megacities and future megacities of the developing world, a huge challenge.

2.3.1 Transport Planning

Planning for megacity transportation needs differs from smaller cities in that the sheer volume of traffic can overwhelm the type of networks that are successful in medium to small sized metropolises. Light rail, for example, can be very successful in medium sized cities, particularly when instituted with good supporting networks and facilities, as is the case with the Metropolitan Area Express Light Rail system in Portland, Oregon.[19] In megacities, heavy rail is more practical given the quantity of people that must be moved within these large city centers. Networks should be designed with main trunk and feeder lines that funnel public transport travelers to heavily traveled corridors with sufficient capacity to move large volumes of people. Transportation systems must also be designed to accommodate growth and development potential, whereby city governments must not only plan for short-term solutions but also define and account for future extensions and enhancements.

Transportation planning is changing as a whole. The failures of past planning can be stereotyped by the focus on capacity with pointed concern over forecasts and identifying where to expand in order to placate rising demand. Instead, transportation planners are now moving away from these quantitative questions to better evaluate more qualitative aspects such as social impacts, the environment, and safety.[20] This redirection will help lead to a balance between economic growth and its costs or byproducts. Transportation planners have long been conscious of environmental costs of transport, but with little more than acknowledgement, which is changing. Moreover, the distinction between growth and development is becoming clear, as evidenced by large cities where the full

[19] Trimet. (2004) http://www.trimet.org/newsandinfo.htm.
[20] Banister, David. (2002) Transport Planning. Spon Press, New York.

repercussions of planning reveal themselves. While cost-benefit analysis of the past has been instrumental in transportation strategies, socio-economic interests are taking a foothold, so that broader impacts can be understood and accounted for.[21]

2.3.2 Social Considerations

In discussing urban tensions, Edward Soja highlights the rising urban poverty and socioeconomic polarization as a chief concern for the future. He believes cities that will continue to inadequately provide for the lower classes, thereby depriving them of mobility and economic opportunities.[22] Soja calls this challenge a socially divisive issue with potential catastrophic consequences. It is perfectly reasonable for lower classes to expect governments to fully account for their interests in planning urban networks. Public transportation provision is essential to economic development and must be treated appropriately in budget allocations for transportation. It is important to not deprive people of affordable public transit with satisfactory levels of service. Too often, these systems are insufficient, and governments choose to cater to automobiles by funding extensive roadways projects that encourage personal vehicles and allow poor land use management, as demonstrated by cities like Los Angeles. Governments must provide sufficient road infrastructure to prevent economic hindrances and seek to maintain public transport services that sustain high demand levels. Accessibility of all classes must be paramount, which coincides with economic goals in allowing the lower class mobility for pursuing occupations and purchasing consumer goods.

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[21] Banister, David. (2002) Transport Planning. Spon Press, New York.

[22] Soja, Edward W. (2004) Urban Tensions: Globalization, Economic Restructuring, and the Postmetropolitan Transition. In: Benería, Lourdes and Savitri Bisnath (eds) Global Tensions. Routledge, New York.

3 *The Environment and Transportation*

3.1 Environmental Degradation

The transportation of goods and people is fundamental to the conduct of society, but its importance in this capacity does not supersede the need for environmental preservation. Unfortunately, this notion was largely ignored through most of the twentieth century, leading to high pollution levels and undesirable conditions in most major cities. There can be no doubts as to the benefits achieved through the advancement of technology that allows for the conveyance of materials and persons over increasing distances at faster speeds for purposes such as economic productivity, cultural development, and recreation. This progress, however, has occurred in conjunction with a host of detrimental impacts that continue to plague the environment and human wellbeing. It was the adoption of motor vehicles powered by petroleum products for personal travel that began the tremendous consumption of natural resources and the production of harmful pollution that exists today.

In fact, transport is the major sector that continues to follow negative environmental trends while other areas have secured improvements that stem or reverse the growth of environmental externalities. Negative externalities encompass the unfavorable byproducts of systems, or as William Black defines them they are "events that result in significant disbenefits for persons who had little or no role in the decision making that led to the events."[23] For transportation, this term refers to the air pollution, accident rates, noise, and general environmental decay. These offshoots of transport negatively impact society, and it is important to note as described by Black that these side-effects result from transportation policies and agendas enacted by governments that determine living conditions for all citizens.

In transportation, policies addressing environmental pollution did not begin until after environmental issues rose to prominence in other industries during the 1970's, which

[23] Black, William R. (2003). Transportation: A Geographical Analysis. The Guilford Press, New York.

then opened the door for measures in transport.[24] This progression in part explains why transportation continues to pose environmental problems, but there are far more substantial reasons than the delay in policy efforts. They consist of the geographical restrictions on transport activities and the rising demand for travel. Pollution from sources among the power and manufacturing industries can be mitigated from its effects on urban conditions through relocation. Power plants, for example, can be removed geographically from city centers decreasing their impact on local conditions, but this reduction technique is impossible for transportation.[25] By nature, transport activities must occur within cities to serve their function of mobility in and around development. This fact makes controlling air pollution from this sector particularly difficult. The urban repercussions of this limitation are furthered by the growing demand for mobility in terms of total distances traveled. Unfortunately, the volume of movement of passengers and goods is rising, even in developed nations, due to the requirements of globalization and other pressures. These two conditions of geographical permanence and demand escalation are principal reasons for swift changes in transport to protect the environment. While early government action towards these goals has targeted specific and pointed concerns, the growing problems have encouraged broader interest in environmental sustainability. More current emphasis revolves around finding practical and agreeable actions that can effectively reduce transportation externalities with minimal constraints on mobility.[26] The justification for such efforts lies in the impacts of transport byproducts.

Air pollution has a variety of consequences for the environment. Air pollution harms animals, plants, global ecological balance, and even the built environment through material decomposition. The emission of harmful materials in high quantities exposes living animals to deleterious elements and disrupts the chemical and physical properties

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[24] Feitelson, Eran and Verhoef Erik. (2001) Transport and Environment: From Policy Measures to Sustainability and Back. In: Transport and Environment, Feitelson, Eran and Verhoef Erik (eds.). Edward Elgar Publishing, UK.

[25] Bickel, Peter and Rainer Friedrich. (2001) Environmental External Costs of Transport. Springer-Verlag. Berlin, Germany.

[26] Feitelson, Eran and Verhoef Erik. (2001) Transport and Environment: From Policy Measures to Sustainability and Back. In: Transport and Environment, Feitelson, Eran and Verhoef Erik (eds.). Edward Elgar Publishing, UK.

of the earth. Evidence from science proves that the toxins released from vehicles with internal combustion engines deteriorate the health of living organizations. Studies of emissions have shown that they hinder plant growth and general health in urban areas and along major roadways.[27] In addition, materials, whether metal or non-metal, are affected by pollutants, principally sulfur and nitrous oxides, released into the atmosphere by motor vehicles.[28] These contaminants speed the decay of materials used in manmade structures. The overall damage caused by air pollution from transport is pervasive, and yet the costs of it are often not incorporated into the planning of systems or pricing of goods.

The value of environmental deterioration has been excluded from economic pricing and policy decision making, in part due to the difficulty of quantifying it monetarily but also out of disregard for long term consequences. In the past, environmental concerns have been undervalued by industries and policy makers concentrated on capital. This mindset still plagues the balance between the environment and economy, whereby it is extremely difficult to overcome past bias. The price of oil, for example, should not only include the cost paid by companies or traders for excavation and refinement; it should also incorporate the expense of the destruction to flora and fauna. With historical discounting and subsidies, however, imposing more accurate pricing is extremely difficult and unpopular.

Motor vehicles with internal combustion engines are largely responsible for the environmental externalities associated with transport that plague urban areas in both the industrialized and developing world. The more advanced nations of the world support the ownership and operation of large vehicle fleets through investments and subsidies. The result of favoring automobile travel is environmental problems and often inadequate infrastructure to support demands, which furthers pollution emissions. Alternatively, in developing countries the vehicle fleets are smaller, but these urban areas can still suffer due to fleet characteristics that tend to include insufficient maintenance and older

[27] Ashenden et al. (2003) Impacts of Vehicle Emissions on Vegetation. In: Brebbia, CA and LJ Sucharov (Eds) Urban Transport IX: Urban Transport and the Environment in the 21st Century. WIT Press, UK.
[28] Bickel, Peter and Rainer Friedrich. (2001) Environmental External Costs of Transport. Springer-Verlag. Berlin, Germany.

vehicles with lower environmental standards, which offset the fewer numbers.[29] The environmental conditions in developing countries are particularly alarming when considering the relatively low levels of ownership and the upward trends of motorization.

While planning in urban transport for wealthier nations typically has revolved around private vehicles, the environmental repercussions of this course make competitive transit alternatives necessary.[30] Public modes such as buses and rail carry passengers more efficiently in terms of space occupancy and energy consumption. Unfortunately, the convenience and comfort of private vehicles has captured dominant market share in many metropolitan areas, initiating a path of lopsided investment in expansive road infrastructure, which is often accompanied by continued demand for travel. The result of course is ineffective urban transportation systems that fail to function properly due to congestion, further damaging and in some cases destroying the ecology and life on this planet.[31] Therefore, change in urban mobility practices must occur, whether it is a restructuring of transport mode preferences, instituting pricing that reflects true costs, altering urban organization and travel needs, or an undiscovered alternative, because the irresponsible acceptance of environmental costs cannot continue. In the next sections, three principal negative byproducts of transportation are detailed to reinforce the need for management of environmental externalities from urban transport. The three aspects are air pollution, vehicle accidents, and noise pollution. While safety and noise problems affect communities around the globe, they are more geographically concentrated. Meanwhile, air pollution acts on a global level in addition to locally, and this distinction makes it especially challenging.

3.1.1 Air Pollution

Urban transportation exists in many different forms around the world, but in most places it results in the production damaging chemicals, albeit in varying degrees. Although it is difficult to estimate the effect of contaminants on health due to the complexity of

[29] Hensher, DA and KJ Button (eds.) (2003) Handbook of Transport and the Environment. Amsterdam.
[30] Vuchic, Vukan R. (1999) Transportation for Livable Cities. Center for Urban Policy Research.
[31] Baarbé, HI. (2002) Emissions at Different Conditions of Traffic Flow. In: Benitez, F., CA Brebbia and LJ Sucharov (Eds) Urban Transport VIII: Urban Transport and the Environment in the 21st Century. WIT Press, UK.

isolating specific contributors, the World Health Organization believes approximately 800,000 people die prematurely from lung cancer, cardiovascular and respiratory disease each year as a result of air pollution.[32] Remarkably, this statistic does not include other illnesses induced or furthered by pollutant exposure. The reduction in quality of life and deterioration of lifestyle based on exposure to pollution in the air is more difficult to assess, but their emissions have a severe detrimental impact on human health and the environment, one that creates an economic toll through the consumption of every nation's resources. The World Bank estimates the loss of 2-3% of Gross Domestic Product in India and China resulting from mortality and morbidity caused by urban air pollution. [33]

The air pollution released by motor vehicles consists of a handful of byproducts that have specific damaging effects, whether direct or indirect. These products include nitrogen oxides, volatile organic compounds, carbon monoxide, and particulates. Nitrogen oxides are harmful to animal respiratory systems. These reactive gasses have two additional and substantial effects, including the ability to transform into nitric acid to create acid rain. They can also form ground level ozone and smog, other respiratory hazards, through reactions with sunlight and hydrocarbons, a volatile organic compound. VOC's include any organic chemicals prone to photochemical reactions in the atmosphere. Another substance, carbon monoxide is a toxic chemical that blocks oxygen carriage of blood in animals and is lethal in high concentrations. This gas typically oxidizes after a month in the atmosphere to form carbon dioxide, which is a greenhouse gas responsible for the effect known as global warming.

The most dangerous air pollutant to human health is particulate matter, which refers to various solid particles in the air that can be inhaled into the lungs.[34] These little elements vary in size from visible as cloudiness down to a size that is imperceptible to the human

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[32] Cohen et al., (2003). Mortality Impacts of Particulate Air Pollution in the Urban Environment, World Health Organization, Geneva.

[33] Pandey, K. D., Bolt, K., Deichmann, U., Hamilton, K., Ostro, B., Wheeler, D., (2004) (forthcoming), The Human Cost of Air Pollution: New Estimates for Developing Countries, World Bank Development Research Group Working Paper, Washington, DC.

[34] Cohen et al., (2003). Mortality Impacts of Particulate Air Pollution in the Urban Environment, World Health Organization, Geneva.

eye. The smallest of these, classified as ultrafine, comes from industrial fuel burning and vehicle exhaust and is the most dangerous. Despite composing a smaller percentage of total particulate matter, this group has higher potency that comes from the depth of penetration that these smaller particles can achieve and their greater surface area exposure to the respiratory system.[35] As yet particulate matter cannot be identified by contributing sources and defined in terms of isolated impacts, but there is agreement on its harmful effects and the value of reducing its release into the environment. In order to show conditions around the world the Figure 4 is below detailing levels of total suspended particulates in urban air with levels of nitrogen dioxide and sulfur dioxide also given. The WHO guidelines are the annual mean guidelines recommended.

Figure 4: Air Quality Measures in Select Megacities

Megacity	Total Suspended Particulate	Sulfur Dioxide	Nitrogen Dioxide
(Listed According to 2003 Size)	1995*	1998**	1998**
World Health Organization Standards	90	50	50
Tokyo, Japan	49	18	68
Mexico City, Mexico	279	74	130
New York, USA	-	26	79
São Paulo, Brazil	86	43	83
Mumbai (Bombay), India	240	33	39
Delhi, India	415	24	41
Calcutta, India	375	49	34
Shanghai, China	246	53	73
Jakarta, Indonesia	271	-	-
Los Angeles, USA	-	9	74
Osaka-Kobe, Japan	43	19	63
Rio de Janeiro, Brazil	139	129	-
Beijing, China	377	90	122
Cairo, Egypt	-	69	-
Moscow, Russian Federation	100	109	-
Metro Manila, Philippines	200	33	-
*Data is for the most recent year 1990 - 1995, Most 1995.			
**Data is for the most recent year 1990 - 1998, Most 1995.			
All figures are listed in micrograms per cubic meter			

[35] World Health Organization. (2004). Health Aspects of Pollution: Results from the WHO Project "Systematic Review of Health Aspects of Air Pollution in Europe. June.

[Source: World Bank][36]

Additionally, there are other air pollutants derived from transport that vary depending on the region of the world and existing regulatory restrictions. Lead, for example, is an additive in fuels. Many countries exclusively use lead free gasoline, because of the known repercussions of lead, particularly in causing learning and behavior impairment in children. Still, many countries use leaded fuels as their sole or a primary vehicle power source. This practice permits the emission of a substance in urban environments, where as high as 80 to 90% of total concentrations of lead levels can be attributed to motorists.[37] This additive, like others, must be controlled because of the implications for the environment and the impact on humans.

3.1.1.1 Greenhouse Gases

Greenhouse gases, such as carbon dioxide, methane, and nitrous oxides, trap heat in the earth's atmosphere by absorbing radiation reflected from the planet's surface. This process occurs naturally and normally, but man made byproducts from industries that use petroleum fuels for power have raised global levels, particularly where carbon dioxide is concerned. Transportation is increasing faster than any other sector in the discharge of greenhouse gasses and contributes over twenty-two percent of carbon produced by fossil fuels globally.[38] Of this contribution to the carbon dioxide output, eighty percent comes from road traffic.[39] Continuing the production of carbon oxides furthers the process of global warming, which poses uncertain dangers in its potential long term effects on climates, weather patterns, and ocean water levels. In the year 1999, road transportation was responsible for 4,064,730,000 metric tons of carbon dioxide released into the atmosphere, an increase of 26.3% from 1990; 1,167,480,000 metric tons were attributable to developing nations, a 59.4% increase since 1990.[40] While the overall rise is bad, the rising production in the developing world is particularly disconcerting.

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[36] World Bank. (2001) World Development Indicators.
[37] Kojima, Masami and Magda Lovei. (2001) Urban Air Quality Management. Technical Paper No 508. World Bank, DC.
[38] Intergovernmental Panel on Climate Change. (2000). Methodology and Technological Issues in Technology Transfer, Cambridge University Press, Cambridge.
[39] Root, Amanda. (2003) Developing Sustainable Transport, Pergamon, Amsterdam.
[40] World Resources Institute. (2003) EarthTrends Data Tables: Climate and Atmosphere.

The release of greenhouse gasses constitutes a global threat as distinct from a local one. There are numerous problems presented by air pollution, and in order to understand the impacts and develop a context for confronting them it is necessary to classify pollution by its physical effects in terms of local or global contexts; both must be considered. The next subsections divide these two areas in an effort to examine how they are distinct and should be approached.

3.1.1.2 Global Pollution

Rising levels of air pollution, including carbon dioxide, ozone, and sulfate particles that affect the environment as a whole, constitute global threats. These problems are the product of combined emissions from all nations. Thus, they must be approached through cooperative action among the nations of the world to prevent global degradation. When isolated countries acknowledge their contribution to global pollution and commit to change environmental standards, the result is beneficial. Unfortunately, individual efforts are insufficient without the support of others in united coalitions that can seriously alter the deadly levels of air pollution produced by transportation activities. Thus, the overwhelming challenge posed by the current environmental situation becomes no easier with the difficulty of achieving widespread participation. Convincing nations that their priorities should include genuine preservation of the environment and its resources appears simple superficially, but it can require drastic changes in existing infrastructure and in upgrading technologies. Such undertakings can impair economies and create strong political opposition; a risk government officials fear.

The central problem, which chapter four will develop more fully, is the difficulty valuing environmental health quantitatively and the traditional absence of it as a consideration in financial evaluations. As scientific forecasts now predict the implications of global pollution such as greenhouse gas involvement in global warming and its potential impacts, debates and support are translating into actions to limit global pollution. This progress should continue, but it will not be simple. Complex decisions will arise, such as industrialized countries examining whether to invest in new technologies or finance projects in developing countries that may offer far better financial returns toward the goal

of curbing global pollution.[41] While this progression will be difficult and the choices crucial in shaping the quality of the environment, taking the steps to face these global conflicts will be a success given the immense obstacle it represents in terms of collaboration and consensus.

3.1.1.3 Local Pollution

Local pollution acts more directly than global with impacts that are more visible, making them concerns of the public and subsequently political and economic issues. When high concentrations of pollution develop, residents of major cities turn to governments for action. This cause and effect pressure makes local pollution issues more dominant than global ones given the greater attention given them based on their effects. In addition to causing political pressure, local pollution burdens urban economies by creating hostile environments for attracting companies and investment. Thus, governments have responded to local issues much more readily than global concerns. In many cases, they install measures and policies to deal with the negative repercussions, but experience has shown their energies can be insufficient and misdirected.

For local conditions, the location and concentration of air pollution is particularly important. As mentioned, urban transportation cannot be removed from city centers, but it also takes places primarily at the ground level, which causes greater local impacts than emissions at higher altitudes. Dispersal is more difficult at low altitudes, and chemicals can be trapped by atmospheric forces in the phenomenon of thermal inversions that prevents the diffusion of pollutants. Unfortunately, the negative consequences of pollutant concentrations on humans are multiplicative and not additive at higher levels, so problems compound. Additionally, the release of byproducts into populated cities is more detrimental than in rural areas, because more people are exposed. The damage potential is also higher given the chemical interaction of pollutants with toxins already emitted into the air to form secondary pollutants.[42] More concisely, transportation air

[41] Kojima, Masami and Magda Lovei. (2001) Urban Air Quality Management. Technical Paper No 508. World Bank, DC.
[42] Bickel, Peter and Rainer Friedrich. (2001) Environmental External Costs of Transport. Springer-Verlag. Berlin, Germany.

pollutants play a major role in the troubling local pollution that afflicts most megacities in the world. There are, however, other serious dangers to the human population from transportation, namely vehicular accidents.

3.1.2 Safety

A terrible consequence of transportation networks is the number of crashes and accidents that occur. These incidences continue to directly harm increasing numbers of people. In fact, vehicular accidents kill an estimated 1.2 million people and injure or disable over 20 million more all over the world each year, according to the World Health Organization.[43] The mortality figure rose from half a million deaths per year estimated less than one decade ago. This proliferation can be attributed to growing passenger travel and motorization, principally in the developing world. There is a disproportionate distribution of accident frequency between countries of different economic status; what is more, 70% of fatalities occur in developing countries.[44] This discrepancy stems from the caliber of infrastructure and supporting services governments are able to provide and the safety standards of vehicles manufactured. A major component of all this is the interaction between non-motorized travelers and drivers. In industrialized nations, vehicles are combined with cyclist and pedestrians less often and under more formal controls than in lower income nations, where pedestrian and cyclist involvement in fatal accidents with vehicles is more frequent. This circumstance is unfortunate given that many lower income wage earners walk or ride a bicycle due to an inability to afford alternate means of travel. Thus, their safety is jeopardized because of infrastructure provision and network decisions beyond their control.

Accommodating non-motorized traffic safely is a critical component of sustainable transport. Factors such as road layout, vehicle safety standards, and traffic regulation determine the safety of a network. These measures are easier for more developed nations to finance, but comparing economically similar nations still shows accident rates vary significantly. This truth exposes the influence that governments have in organizing and

[43] Peden M. et al., (2004) The World Report on Road Traffic Injury Prevention, World Heath Organization, Geneva.
[44] Ibid

legislating safer networks and vehicles. Too often, road planning focuses on motorized vehicles and ignores other valid modes of transport creating a higher likelihood of accidents, especially in cities where densities are high. The provision of safe paths for non-motorized travelers and increased public transportation options to reduce the potential for deaths and injuries is necessary to prevent unsafe modal combinations. With current forecasts, the World Bank predicts that thirty-five high income countries will continue to reduce fatalities at a rate of 27% between 2000 and 2020 while one-hundred twenty one less developed countries will suffer a total 83% increase in fatalities led by an alarming 144% increase by seven nations in South Asia.[45] These predictions are positive for developed countries, but ominous for others, where adjustments must be pursued for the common good. Transport accidents are a major source of physical impairment and premature death, so safety considerations must be better incorporated into network goals and planning, particularly where the design of infrastructure and vehicles are concerned.

3.1.3 Noise Pollution

Noise pollution is another negative product of transport. Motor vehicles, aircraft, and railways are responsible for creating it, but road traffic is the most dominant source in urban settings of industrialized nations.[46] While noise had been dismissed as an irritation for a long time, it has been deemed a serious problem based on observations of its impacts. Noise reduces personal health by inducing stress, disrupting behavior, and disturbing rest. Economically speaking, it can lower land values, as evidenced by reduced property values adjacent to major highways for example, and therefore can be translated quantitatively and valued unlike many other externalities of transportation. Unfortunately, this assessment, as defined by market property value, does not effectively value the health impacts, which are more difficult to quantify. Still, it does show the correlation between the existence of concentrated noise pollution and reduced attractiveness of land.

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[45] Kopits E, Cropper M. (2003) Traffic Fatalities and Economic Growth, World BankPress, Washington, DC.

[46] Garcia, Amando (Ed.) (2004). Environmental Urban Noise. WIT Press, UK.

Despite this financial recognition of noise as a form of pollution, this subject remains relatively undefined and poses complexity in terms of general recognition and consensus on valuation. The key to addressing noise in the future will be to determine and manage an allowable capacity for noise, as described by David Gillen in "The Economics of Noise". He points out the major obstacles in this endeavor to be determining a value for quiet and creating a market device for controlling it.[47] These two steps will require significant cooperation for the treatment of quiet as a commodity and then the decision of how to allocate it under a certain threshold.

Alternately, there are more targeted means for reducing levels of noise pollution in urban areas. There are in fact three ways of dealing with noise: attacking the source by changing traffic patterns or reducing engine noise, reducing transmission by erecting barriers along roads or placing pavements that are less conducive to noise transfer, or limiting the reception of sound by installing acoustic installation into buildings.[48] These techniques are more likely to be implemented successfully in the near future than comprehensive plans for noise capacity and allocation. Investigations into the science of engine tribology will potentially allow reductions in the noise created by engines. These studies that examine the sources of noise and vibration from internal combustion engines, for which the piston slap is the most significant, have the potential to allow reductions that will not only make quieter engines but also raise efficiency and therefore lower energy consumption.[49] Regardless whether techniques are implemented to lessen and combat noise or a system of regulation is installed, noise pollution must be recognized as negative externality of transport that must be managed in the urban environment.

3.1.4 Summary of Conditions

Transportation activities cause the release of damaging contaminants into the environment, but mobility is essential to society and cannot be renounced for the sake of

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[47] Gillen, David. (2003) The Economics of Noise. In: Handbook of Transport and the Environment, Hensher, DA and KJ Button (eds.), Amsterdam.
[48] Garcia, Amando (Ed.) (2004). Environmental Urban Noise. WIT Press, UK.
[49] Ruggiero, A. and A Senatore. (2003) On the role of engine tribology in the reduction of noise and emissions. In: Brebbia, CA and LJ Sucharov (Eds) Urban Transport IX: Urban Transport and the Environment in the 21st Century. WIT Press, UK.

these repercussions. Thus, there must be compromise between these interests, but given the historical imbalance adjustments are necessary in the methods of transport to better protect and conserve the earth's resources. Air pollution must be minimized within reasonable constraints or else abated through innovations. While the earth has the ability to absorb particular levels of pollution without damage, human activity has exceeded those bounds, and action must be taken to reestablish balance with the environment.[50] Fortunately, if corrections can be made the natural systems in existence will improve conditions by breaking down and distributing pollutant concentrations.[51]

Despite studies and reports of the hazards of environmental negligence, societal dependence on vehicles and road infrastructure remains unwavering; in fact it is growing. This threatens to make this planet far less inhabitable for reasons beyond air pollution including premature death by vehicular accidents and detrimental effects of noise. With the geographical inflexibility of transport activities, urban transportation must be changed. Vehicle prioritization must be forsaken for better integration that helps make mobility more efficient. This can also aid economic interests in reducing flow failure in the form of congestion that environmentally can increase local pollution from road traffic by as much as 50%.[52] More broadly, it is critical that efforts for environmentally conscious plans address different time frames as described by Eran Feitelson in his book on transport and the environment. Environmental policies require different gestation periods before they are felt, which means long term measures must be implemented with medium and short term.[53] Since private vehicles are so deeply ingrained in societal operation a pragmatic view of the many possible solutions to transport environmental externalities lies in technological improvements of internal combustion engines and eventually alternative power sources for vehicles.

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[50] Root, Amanda. (2003) Developing Sustainable Transport, Pergamon, Amsterdam.
[51] Molina, Luisa and Mario Molina (eds). (2002) Air Quality in the Mexico Megacity. Kluwer Academic Publishers, Boston.
[52] Baarbé, HI. (2002) Emissions at Different Conditions of Traffic Flow. In: Benitez, F., Brebbia, CA and LJ Sucharov (Eds) Urban Transport VIII: Urban Transport and the Environment in the 21st Century. WIT Press, UK.
[53] Feitelson, Eran et al. (2001) From policy measures to policy packages: a spatially, temporally and institutionally differentiated approach. In: Transport and Environment, Feitelson, Eran and Verhoef Erik (eds.). Edward Elgar Publishing, UK.

3.2 The Barriers to Change

The challenge of altering transport practices in the interest of the environment consists of a series of complex developments and restructuring. The sheer magnitude of these pollution problems in terms of established and accepted methodologies makes inhibiting the detrimental effects daunting. While the technical challenges of altering pollution production are imposing, they actually can be superseded by an inability to create support to pursue change. Substantial investment is necessary for research and implementation of new technologies and policies. Additionally, inducing a willingness to commit to these activities does not happen easily, but fortunately it can develop from sources including principled initiative, consumer demand, social pressure, market benefits, or through government legislation with either regulations or economic incentives. These driving forces are tough to mobilize, because they require broad efforts and cooperation with a true appreciation for environmental responsibility. Recognition of the value of environmental protection is critical for acceptance of the costs of adopting new practices and technologies.

The primary driver behind most growth in pollution control comes from regulations imposed by governments, or else tax credits and subsidies. These measures provide the medium for moving transportation towards more sustainable practices. Typically, political and social resistance to changes in transport exists, and it is important to review them before examining technologies. Section 3.2 of this chapter will discuss barriers as they relate to improving transportation practices with a strong focus on air pollution and related technologies, but on a broad scale there is certainly carryover with traffic accidents and noise pollution.

Two problems with advances in transport to combat air pollution are overcoming the opposition based in industry and the indecision caused by uncertain technologies. The manufacture of vehicles occurs in an industry with significant employment and economic influence. Government policies for action in the realm of pollution standards, alternative fuels, and technologies can have a great impact on these industries through the introduction of uncertainty, making it dangerous for politicians. Regulations affecting

these businesses can potentially disrupt profitability and jeopardize job security thereby creating a backlash. This cause and effect explains the hesitancy on the part of many governments and the tendency for inaction until community distaste for pollution overwhelms economic fears. Similarly, the desire to substitute new technologies in the form of alternate travel modes and propulsion systems poses difficulty in that there is an absence of a clear choice. Despite growing recognition of sustainability, the array of technologies for dealing with air pollution offers no obvious solution, partly because research is ongoing and the full benefits and disadvantages are still being defined. What is more, acceptance of a particular method involves embracing the associated framework and neglecting others, which makes it a major commitment that few are willing to accept. The existing technologies and infrastructure also restrict the allowable paths for environmental protection.

3.2.1 Technology and Infrastructure

Most modern countries are designed with a generous system of roadways intended to meet transportation demands and drive economies, but these same networks encourage energy consumption rather than conservation. Nations have dedicated resources to large transportation systems, and once invested they are locked into their networks, meaning changes in transportation practices must take place within the confines of existing parameters. In order to pursue more environmentally friendly patterns, options are usually limited to curbing unnecessary travel, instituting more efficient modes, and creating technological efficiencies for fuels and vehicles that can be substituted for current ones. These strategies represent disparate approaches to the problem, but they are means that can be used effectively in combination. Demand reduction exists on a spatial level and can be instituted through policies, which will be covered in subsequent chapters. Alternatives to private vehicle travel such as bus and rail are valuable substitutes in urban areas where pollution volume must be controlled. Unfortunately, such solutions are complex, because just like road building activities, the construction of metros, for example, involves increasing the total pollution in a given area, which can be

the opposite of the environmental intentions for building. [54] A metro may be the right long term decision for an urban area, but in fairness such decisions are complex and require complete consideration. Lastly, engine and fuel technologies are a principle source of current and future remedies to air pollution from transport ills. The remainder of section 3.2 will focus on this subject.

The necessity of acceptance and integration of improvements or substitutions can be a hindrance in pollution control. In the case of technology substitutions, newly instituting systems may or may not be accepted by the market. The responsibility for this ambiguity lies in the conflict between the market demand and service provision. It is the condition in which manufactures resist launching a product before the services to support it are established and supporting industries do not wish to prepare for new technologies until a legitimate demand develops. These conflicting forces stem from risk aversion and the public's unwillingness to embrace new developments that are untested. Consumers are reluctant to switch to unproven technologies that may have unforeseen complications or for which maintenance and other services are difficult to access. In addition, new products suffer in price competition against the economies of scale enjoyed by established competitors. With the large investments of money and research required and the risk of unproven systems, the transportation sector is and will continue to be slow in supporting new systems, especially alternative fuels.

Another barrier is the magnitude of change necessary for environmental preservation, which can appear overwhelming when considering the vast networks that supply and support vehicles and infrastructure systems. Gas and service stations and maintenance garages are primary examples of the facilities in place that have to adjust in order to accommodate changes. The industries that produce and service automobiles are a huge consortium of businesses and workers. Any changes to their processes or products have broad impacts that create the need for secondary adjustments. If a manufacturer changes its product by modifying the engine block for example, it causes a series of repercussions.

[54] Kumar, M. (2003) Environmental Management During Metro Railway Construction Especially in Highly Polluted and Densely Populated City. In: Brebbia, CA and LJ Sucharov (Eds) Urban Transport IX: Urban Transport and the Environment in the 21st Century. WIT Press, UK.

If more drastically, a new engine design is introduced for a new type of fuel, all of the businesses that work with that vehicle must buy new equipment and retrain their employees. Such transitions are enormous undertakings for an industry and could potentially damage the economy by bankrupting smaller, less profitable entities. The related component to this is the physical transitions that become necessary. If an alternative form of fuel becomes standard for automobiles, gas stations will have to be adapted at great expense and difficulty. In most cases, physical convertibility for the storage and transfer of new fuels means high costs. Of course a noteworthy exception exists in the application of alternatives in fleet operations. REFERENCEIn both freight and urban public transportation, infrastructure expenditures can be limited given the use of closed systems or minimal outlay for refueling and service due to relative proximity. Therefore, buses or trucks can be run on a less polluting fuel, and costs are minimized with one or only a few facilities necessary for operation within an urban area. Governments and private companies have and will continue to capitalize on the distinctive characteristics of vehicle fleet operations.

Despite the backdrop of challenges to mitigating transport air pollution from its primary source of motor vehicles, progress has been achieved, mainly through enhancements and improvements to existing gasoline and diesel engines that has caused significant gains in efficiency and pollutant reduction. Unfortunately, these benefits are not extensively shared globally as less developed regions with lower income levels have older, lower quality vehicles on average. Developing countries are handicapped in this way, and they must rely on other nations for technological and manufacturing leadership.

3.2.2 Technology of Engines

Through advancements in technologies, pollution emissions have and continue to be reduced. In the transportation arena, automobiles are both the greatest users of petroleum and producers of carbon dioxide gas. Correspondingly, many improvements to combustion in engines and to mixture processes for fuels have been made and research is ongoing in these efforts. This progress is driven by market pressure and environmental concern and also by the threat of alternative technologies that spurs continued

developments in internal combustion engines.[55] Research benefits automobile owners by reducing the quantities of fuel necessary, and it cuts down pollution, assuming average vehicle distances traveled remains steady. One example of progress is the adoption of fuel injection systems in the majority of new automobiles rather than carburetors as the method of mixing fuel and air, because fuel injection is a more efficient control mechanism that results in less air pollution.[56] The proper combination of fuel and air in combustion aids in peak performance and prevents conditions where engines operate inefficiently with higher concentrations of gas to air making the system run rich and leaving unburned fuel or with lower concentrations of gas to air making it run lean.

Among the environmental developments for vehicles, the invention of catalytic converters has made a tremendous impact in reducing harmful chemical emissions. These devices transform the hydrocarbons, carbon monoxides and nitrous oxides released in the exhaust by oxidizing the two former and reducing the latter, making vehicle exhaust far less dangerous. In conjunction, sensors are also imbedded in vehicles to monitor the oxygen content of the exhaust and when necessary make adjustments in the engine. Unfortunately, the catalytic converter must be heated to operate, which means exhaust flowing after ignition undergoes little, if any, conversion. Attempts to resolve this issue by preheating the converter or relocating it closer to the engine have not constituted acceptable alternatives. The traditional 12-volt electrical systems in cars does not have enough power to heat the converter, and even if it could warm up time would still be a major inconvenience for car owners.[57]

Other developments to gasoline and diesel engines in recent decades have centered on making engines function with less energy expended but maintaining power and performance levels that consumers' desire. These improvements have capitalized on the benefits of adjusting the stroke/cylinder bore ratio and combustion ratio in combustion chambers. Electronic control over the ignition, injection, and exhaust gas recirculation

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[55] Korver, Wim. (2001) Traffic and transport in the twenty-first century: market chances of new drive concepts for land-based transport. In: Transport and Environment, Feitelson, Eran and Verhoef Erik (eds.). Edward Elgar Publishing, UK.
[56] How Stuff Works. (2004) <http://auto.howstuffworks.com/question377.htm>
[57] How Stuff Works. (2004) < http://auto.howstuffworks.com/catalytic-converter3.htm>

has also been employed and further refinement of the timing of motor functions along with the use of microprocessors to optimize gear changes and acceleration promises potential for better engine efficiency.[58] Likewise, new materials that allow less friction between the stroke and cylinder or less thermal conductivity can decrease energy consumed in motor operation, resulting in overall fuel savings. Developments in partial load operations and warm up processes are the other areas that show promise for engine technology.[59]

In contrast to gasoline engines, diesel motors are progressing more rapidly and have greater prospects for advances. Engineers have found the means to better control direct injection with higher pressures from mechanical systems and electronic controls. Diesel engines have been overshadowed by gasoline engines in private passenger transport, because of a handful of disadvantages associated with the system. Diesel motors are typically both heavier and more expensive than their counterparts. By design, they generate high torque rather than horsepower, meaning less acceleration capacity. Other detractors such as more smoke, noise, vibration, and slow starts in cold weather have discouraged use in passenger vehicles, but modern developments have overcome some of these cosmetic problems and also enabled reductions in motor costs. The fuel efficiency of diesels and long engine life endear them to freight transport and machinery operation, where diesels will remain important, but the less extensive supply network discourages diesel motors for other applications.[60]

The state of two stroke engines in contrast to the four stroke internal combustion engines is notable. Two strokes are lighter and produce more proportional power by firing every revolution rather than every other, but they also expel more pollutants from unburned fuel and oil lubricant burn off. Two stroke engines have been used principally in motorcycles, boats, off road vehicles, and landscaping equipment. While research is ongoing, the high pollution properties of two strokes are leading to legislated emission standards in some countries that strongly discouraging them for vehicles.

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[58] ATLAS Project. (2004). <http://europa.eu.int/comm/energy_transport/atlas/htmlu/combdintro.html>
[59] ATLAS Project. (2004). <http://europa.eu.int/comm/energy_transport/atlas/htmlu/combdintro.html>
[60] How Stuff Works. (2004). <http://auto.howstuffworks.com/question399.htm>

Meanwhile, there are major projects dedicated to creating engines that do not rely solely on fossil fuels but instead much cleaner resources. Some of these alternatives are generating more interest, electric hybrid vehicles in particular have come onto the market; the popular form of this car incorporates a petrol engine in combination with an electric motor to operate with greater efficiency. The latter traps the power otherwise expended during braking and stores it so that it may be used later to propel the car at lower speeds. Hybrid cars are on the market in many countries, but because of small market share, which is growing, economies of scale make it less competitive in price than traditional vehicles. This and other technologies will be addressed in the next section on fuels.

3.2.3 Technology of Fuels

The popularity of fossil fuels came into being during the industrial revolution when the transition was hailed as a leap of progress. Unfortunately, utilizing this energy produces negative side effects, but techniques for reducing them have been developed, and there is potential for more improvements through research. The energy product obtained from refining crude oil is powerful hydrocarbons that make up fuels like gasoline. Experimentation with petroleum fuels has been ongoing and has often involved putting additives in the fuels. Around the time of the First World War, fuel producers began adding tetraethyl lead to gasoline, because the chemical increased the octane rating, compressibility before spontaneous ignition, which allowed lower grade fuels to be enhanced. While this practice spread, it created severe problems that still exist today, because lead is a toxic material. It affects humans by increasing blood pressure, the risk of heart disease and causing nerve damage. It has long been associated with causing mental illness. Phase out of lead occurred in the United States between 1976 and 1986; it has also been completed in Europe, but many other nations especially in the third world still include lead in their fuels. This practice causes major health deterioration in urban settings where concentrations are the highest. In the United States as in some other countries, lead phase out occurred in conjunction with the introduction of catalytic converters, because lead disrupts their functioning. The US Environmental Protection

Agency estimates that 221,000 tons of lead were emitted in 1970 with 78% coming from on road transportation and another 4% from off road, but in 1996 the total figure had dropped to 3,915 tons mainly due to the phase out of leaded fuels.[61] In poorer nations, however, it is difficult to lead such changes when funding is scarce and the impact of using the additive tetraethyl lead cannot be easily correlated to a specific cost.

Other dangerous additives to fuels are included in their production. Sulfur plays a major role in the formation of the sulfuric acid known as acid rain, which damages plants and animal populations, and it attacks the respiratory systems of humans in both gas and particle form.[62] The main sources from human activity are from thermal power plants burning coal or oil that has high sulfur content, but emissions from vehicles and domestic burning of coal contribute to local concentrations that are harmful.[63] Like lead, sulfur inhibits the operation of catalytic converters and must be removed from fuels to capitalize on the cleaning power of these devices. Fuels contain other toxic substances like benzene, which is a carcinogen, and monitoring their presences is important for fuel improvements. Controlling these composites can sometimes be handled by examining a property exhibited by the fuel. In this case, controlling the evaporative property of a fuel called Reid Vapor Pressure provides the best mechanism for restricting toxins like benzene and volatile organic compounds.

Alternatives to petroleum fuels include electricity from non fossil sources, ethanol, methanol and compressed natural gas, and these potential substitutes have cleaner lifecycles. These methods vary in practicality and potential for successful implementation given development that has occurred so far. For classification, they are broken down into electric, fuel cell, biofuel, and gaseous fuels.

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[61] Environmental Protection Agency. (2004). <http://www.epa.gov/air/urbanair/lead/what.html>
[62] Environmental Protection Agency. (2004). <http://www.epa.gov/air/urbanair/so2/hlth1.html>
[63] World Bank Group. (1998). Pollution Prevention and Abatement Handbook. July.

3.2.3.1 Electric and Hybrid[64]

The concept of electricity powered vehicles is far from novel, but widespread adoption of the technology has not occurred. There are two forms of electric vehicles; one is pure electric relying solely on batteries that must be recharged from a power outlet. This system allows travel up to limited distances, which acts as a market limitation for consumers that resist such restrictions. Despite the evidence that most trips fall within the range of pure electric cars, objection to these limits are common, because drivers do not want to make sacrifices and do not like to give up power. Recharging stations are a potential solution, but they will not likely be created in the absence of demand. Hybrid vehicles may be the answer, because they might shift cultural opinion making pure electric cars more acceptable. There are two types of hybrid, series and parallel, but both share the innovation of capturing power from braking to charge batteries. The series hybrid draws electric energy from batteries for propulsion at lower speeds and then uses a mechanical heat drive for higher velocities and acceleration. When the mechanical system is running, it also slowly charges the batteries. The parallel version uses a small diesel generator as the means to move the vehicle until additional power for higher speeds and acceleration is achieved by drawing off the batteries. The parallel setup differs from the series hybrid in function by recharging the battery when stationary in addition to while braking.

Electric vehicle hybrids can be incorporated into existing car designs or created uniquely, which allows substituting with lighter materials and helping to offset the added weight from batteries. Battery technologies and their advancement are critical to future possibilities for electric cars. Currently, the two main types are lead acid and nickel-cadmium, the latter being the more powerful and costly. Research for improvements may produce systems that are more competitive with other vehicles, leading to increased market share. A major benefit of using electric vehicles is the preexisting network of power plants that can support increased demand from transportation. This capacity does have a limit, and if electric vehicles did find wider commercial appeal new power sources would be required. Timing of power demand is a critical aspect of adding electricity

[64] ATLAS Project. (2004). <http://europa.eu.int/comm/energy_transport/atlas/htmlu/elec_hybrid.html>

consumption to existing power systems. If owners recharge their cars at home and not at work, it would most likely occur during the evening and night times at off peak hours. On the other hand, the equipment to transfer power safely would be costly to install, creating a deterrent. In addition, electric vehicles are much more expensive than traditional types, but hybrids are more competitive. It is likely that hybrids will continue to become popular until new prototypes of electric vehicles show greater promise. When considering a commitment to this fuel source, the growth of battery manufacturing and their disposal or recycling poses a dilemma. Batteries can be hazardous to the environment and human health once they have served their useful purpose.

3.2.3.2 Fuel Cells[65]

Fuel cells are electrochemical devices that create electric power by simulating burning between separated fuel and oxygen and then capturing the electrons flowing from the former to the latter. The main parts of a fuel cell are an anode, cathode, and electrolyte, and it is the latter that allows ion but not electron or reactant movement. They differ from batteries in that the fuel and oxidants are supplied as needed to deliver power. Fuel cells can be distinguished by their electrolyte; the main types relative to a transportation discussion are alkaline, phosphoric acid, solid oxide, and protein exchange membrane or solid polymer fuel cells. The differences exist primarily in the temperature and chemical conditions required for a particular fuel cell's operation. The alkaline fuel cell does not have a cold start up problem, but it does require hydrogen and oxygen. Its high costs make it more suitable for other applications. The PAFC does have a slow start up, which is a bad characteristic for cars, but it has potential for commercial uses where this is less of a problem. The solid oxide fuel cell takes a while to heat up and works at extremely hot temperatures. The protein exchange membrane fuel cell has a high power density and represents a strong choice for vehicle use with quick start up and lower temperature operation. Unfortunately, the catalyst is expensive and the water product must be treated. The prices for the production of fuel cells are very high and would have to decrease sharply for them to be practical. Most of the developments of this technology has occurred for military and space exploration purposes; industries that can afford these high

[65] ATLAS Project. (2004). < http://europa.eu.int/comm/energy_transport/atlas/htmlu/fctransport.html>

costs. The PEMFC type does have the potential for significant reduction in terms of price, and prototypes have a 250 kilometer range with a top velocity of 110 km/hour.[66]

Ideally, hydrogen or methanol could become the catalyst of future fuel cells. A major drawback of hydrogen is the complicated handling and storage of it both on board vehicles and at distribution centers. Methanol requires an onboard reformer to function, but it is simpler and than hydrogen with greater distance capability. Future possibilities depend heavily on the nature of gas prices.

3.2.3.3 Biofuels[67]

Biofuels are made by processing vegetable and wood crops to create combustible solutions that can be added to traditional fossil fuels in small quantities or in some cases used as a major substitute. They offer benefits of reducing chemical byproducts that contribute to global warming, and they can eliminate sources of local pollution when used as the primary fuel. Without notifying the general public, the United States incorporates three and a half million tones of bioethanol into fuels, principally petrol, each year constituting one percent of total quantities.[68] Biofuels do release some carbon into the atmosphere when burned, but the quantity is matched by the carbon recycled by initially growing the biomass. The three main forms of biofuels are diesel, methanol, and ethanol. Their production requires the dedication of land for growing the farm crops that go into making the fuels. This provision can be difficult to satisfy, because these activities are less profitable for farmers than selling vegetables for human consumption. Another challenge is overcoming the deterioration properties of these fuels that affect engine parts and hoses. Bioethanol, for example, has lower lubrication capacity, which means combustion products cause more wear and tear on engines, especially on sophisticated injection equipment. While this problem can be solved by upgrading to better materials, it is more expensive to do so. Despite the drawbacks, adoption of these technologies can be successful. In Brazil, almost half of the eleven million light vehicles

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[66] ATLAS Project. (2004). <http://europa.eu.int/comm/energy_transport/atlas/htmlu/fctdtechstat.html>
[67] ATLAS Project. (2004). < http://europa.eu.int/comm/energy_transport/atlas/htmlu/biofuel.html>
[68] ATLAS Project. (2004). < http://europa.eu.int/comm/energy_transport/atlas/htmlu/bioomark.html >

run on bioethanol, and the remaining six million vehicles use a blended fuel with partial ethanol composition. The ethanol comes from sugar cane and other biomass sources.

Biodiesel acts as a comprehensive substitute for diesel fuel or as a partial additive, but it is up to three times more expensive to produce and lacks consumer support. Additionally, biodiesel and its gas byproducts produce an unfavorable odor, making it less attractive to consumers. There is, however, strong potential for developments in biodiesel fuel and research is occurring to support it. The other form biomethanol is derived from wood and can be directly used in petrol engines. Similar to other alternatives to fossil fuels, infrastructure presents the greatest barrier to transition toward biofuels. This obstacle can be limited by using biofuels for specific fleet operation, like public transport buses or other vehicle fleets, whereby fuel supply problems are overcome through a centralized system.

3.2.3.4 Gaseous Fuels[69]

Still more alternatives exist and both natural gas, which is basically methane, and liquid petroleum gas, which is a mixture of butane and propane, have been used in transportation systems. Natural gas can be used either in compressed or liquid forms, and both have limitations. In order to keep natural gas as a liquid it must be kept at negative 162° C at atmospheric pressure.[70] The difficulties handling natural gas require major infrastructure in the form of pipeline networks, fueling stations with distribution piping, and vehicles equipped with large storage tanks that are designed for collision safety. On board tanks must be heavier to contain the higher pressurization necessary for natural gas due to its lower energy density; the tanks are usually located in the roof. For a motor to run on natural gas, it must have spark and not compression ignition, resulting in efficiency greater than gasoline but lower than diesel engines. Compressed natural gas has been used successfully in the US and Canada for a number of years, and it is growing in Europe.

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[69] ATLAS Project. (2004). <http://europa.eu.int/comm/energy_transport/atlas/htmlu/altfuel.html>
[70] ATLAS Project. (2004). <http://europa.eu.int/comm/energy_transport/atlas/htmlu/gasdintro.html>

Liquid petroleum gas, LPG, is more prevalent than natural gas. Among its advantages are smaller storage requirements and cleaner, quieter operation due to its ability to be contained as a liquid and then used as a gas. It has a high octane rating and compares to natural gas in being more efficient than gasoline but less than diesel engines. The result of using LPG over gasoline is reduction in carbon dioxide and over diesel is reduction of several other pollutants. The Netherlands and Italy were the first leaders in using LPG, but now it is developing in North America, Australia, Japan, South Korea, and Thailand. Future potential for LPG adoption is strong but will be limited by availability.

Both of these power supplies are typically retrofitted into existing vehicles, converting older engines to run on either natural gas or LPG. Thus, bi-fueling becomes possible and removes some of the concern about availability of gas supply. Nevertheless, questions about cost and benefits of investment still remain unanswered. While these fuel technologies are most commonly used for urban fleets that are serviced by centralized stations and maximize emissions benefit by their reduction of pollution within cities, the lack of government regulations and therefore uncertainties over future viability and pricing pose the biggest barrier to increased usage.

3.3 Mexico City Policy Failures

The repercussions of transportation pollutions are most problematic in large cities where pollution concentrations are highest. This statement is particularly true for mega cities, many of which suffer from severe local pollution levels. Governments typically wait for conditions to escalate before attempting to combat pollution because these efforts affect economic development. Ironically, the alternative is pacifist treatment of pollution issues that eventually allows the formation of an economic drain and serves as a detractor to businesses and investment. Confronting emissions from a legislative position introduces new risks and can even induce counter productive behavior if inappropriately managed. Therefore, transportation policies must not restrict economic growth and prosperity while altering manufacturing practices and imposing industry restrictions.

Mexico City is among the most populated cities in the world, and its urban area currently ranks second in the world in number of inhabitants.[71] This area known as the Mexico City Metropolitan Area flourished during rapid expansion caused by urbanization in the second half of the 20th century. In 1940, Mexico City had 1.757 million people, but by the year 2000 there were about 17.682 million with 8.6 million of them living in Mexico City and the rest spread across adjacent municipalities in the State of Mexico.[72] This influx cultivated urban sprawl and led to transportation deficiencies. The government, meaning the Federal and both Mexico City and the State of Mexico, worked to solve mobility problems and also reduce externalities once they became an issue in the 1970's while continuing to promote economic growth, but their efforts were typically ineffective and allowed the MCMA to become an example of extreme pollution conditions. This evolution occurred because of many factors. The uneven political forces, flawed management of public transport systems, poor land use patterns, and road infrastructure projects produced the horrific air pollution concentrations from transportation, the primary source of most pollutants, in part due to high frequencies of traffic congestion but mainly because of chaotic transportation activity.

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[71] United Nations. (2003). World Urbanization Prospects: The 2003 Revision.

[72] Gustavo, Garza. (2000). 4.2 Ambitos de Expansion Territorial. El Colegio de Mexico. Referenced In: Lopez, Alejandro. (2001). Metropolitan Mexico City: Transportation Policies and Economic Development.

Before discussing the policies of this city, its geographical features must be identified and acknowledged as contributors to local pollution levels through the containment of emissions and the resulting amplification of their impact. The Mexico City Metropolitan Area lies in a valley at 2,240 meters mean sea level. It is surrounded by mountains on three sides, diminishing air flow through the valley and leading to more thermal inversions that trap air and any pollutants therein.[73] The high elevation also contributes to the problem. At this height, there is an increased rate of photochemical smog creation from sunlight. In addition, human populations are more vulnerable to health risks from pollution at this altitude, because the oxygen content in the air is lower. These elements make the MCMA particularly susceptible to pollution problems.

3.3.1 Infrastructure Background

Public transport for passengers began in Mexico City with trams in the 1920's. This system, operated by a private company that was later nationalized, experienced ongoing labor strikes, which led to the government providing subsidies to stabilize service. Trams were eventually displaced by trolley buses and the metro system that was started in 1967. The road construction program Ejes Viales adopted in 1979 would develop roadways to serve the expanding metropolitan area and was planned to include a large expansion of trolley buses with right of ways and reverse lanes on one way traffic roads.[74] This enhancement of the public infrastructure constituted well rounded policy that would provide service improvements while expanding infrastructure for private vehicles. Instead of following through with this plan and the 3,400 buses required, there were just over one thousand made available by 1988 and only one-third of those were actually in operation. In 1998, less than one hundred more vehicles were reported in operation.[75] This failure to execute all elements of the public transportation policy was likely constrained by political gridlock and financing conflicts, but nevertheless it furthered the growth of the private vehicle fleet.

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[73] Molina, Luisa and Mario Molina (eds). (2002) Air Quality in the Mexico Megacity. Kluwer Academic Publishers, Boston.

[74] Lopez, Alejandro. (2001). Metropolitan Mexico City: Transportation Policies and Economic Development.

[75] Setravi. (2000) Prgrama Integral de Transporte y Vialidad 1995-2000. Referenced In: Lopez, Alejandro. (2001). Metropolitan Mexico City: Transportation Policies and Economic Development.

One of the factors in the evolution of MCMA transportation is in the oversight and financing. The federal government traditionally funded projects in Mexico City to support the economic interests of the country, and the political ties between the entities also played a role in this support. The proportion of federal dollars invested has varied between administrations and by the end of the 1980's declined significantly to closer reflect income from tax dollars. In addition, the government bodies responsible for planning and running the transportation systems have not remained consistent. After the federal government transferred transportation down to the city level governance, planning still suffered from insufficient coordination and resources. Despite measures between the State of Mexico and Mexico City for metropolitan planning, the formation of joint advisory boards and councils has been ineffective.

The other major modes of public transport in the Mexico City Metropolitan Area are the metro, motor buses, and colectivos. By its second year of operation 1970, the metro had an impressive 39.7 kilometer system. In 2000, the network totaled 201.7 kilometers.[76] It is noteworthy that investment in the metro system has correlated to fiscal revenue per capita in the MCMA, highlighting the potential impacts of good public transportation.[77] However, subsidy programs for the metro system have not improved modal share and ridership remains low except for the main lines. Unlike the metro, motor buses once dominated the transportation services. The government allowed private operation of this mode, which moved the most passengers per day during the 1970's and into the 1980's but then lost market share to an alternative. Colectivos began as taxi cars that operated on fixed routes for a peso, and they became very popular because of their lack of government regulation and resulting flexibility to passenger demands, which allowed them to take business from motor buses. As operations continued, drivers began taking advantage of larger automobiles and then minibuses. By 1990, Colectivos transported

[76] Urban Rail (2004). http://www.urbanrail.net/am/mexi/mex-history.htm
[77] Lopez, Alejandro. (2001). Metropolitan Mexico City: Transportation Policies and Economic Development.

more passengers per day than any other mode in Mexico City, and since then they have retained control of this dominance.[78]

3.3.2 Policies

As a result of this progression, road vehicles dominated transportation movement creating a diverse vehicle fleet and increased congestion problems. The failures of the government to provide sufficient means of public mobility forced lower income people to turn to older, cheaper vehicles that used more polluting technologies. These realities contributed to the air pollution crisis in the MCMA.

Early efforts to improve environmental regulations were mainly aimed at satisfying international trade requirements, but later local pollution levels made the issue a priority. In 1988, an inspection and maintenance program the Programa de Verification Vehicular went into affect geared toward both gasoline and diesel vehicles.[79] Despite this and other policies of PICCA and PROAIRE enacted in the 1990's, the MCMA did not make sufficient progress in air pollution reductions. In 1998, further deterioration had struck when forest fires to the south caused soot and other contaminants to sweep into the region and elevate particle matter and ozone concentrations that remained exceedingly high until the next year. This event produced public and political inflammation over air pollution legislation.[80]

While there have been successful policies in MCMA transportation, many have been too difficult to execute and others have not worked. One of the motivations to the inspection and maintenance program is likely a test performed between 1986 and 1988 on 600,000 vehicles that reported that 85% of diesel and 75% of gasoline vehicles did not pass emissions standards.[81] The constitution of the inspection and maintenance program was

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[78] Lopez, Alejandro. (2001). Metropolitan Mexico City: Transportation Policies and Economic Development.
[79] Molina, Luisa and Mario Molina (eds). (2002) Air Quality in the Mexico Megacity. Kluwer Academic Publishers, Boston.
[80] Auer, Mathew. (2001). Policy Studies Journal, January 1. Volume 29: Issue 3.
[81] Walsh, M.P. (1989). Motor vehicle emissions in Mexico: A strategy for progress. World Bank.

smart, but officials neglected diesel vehicles and motorcycles in the process.[82] Diesel vehicles are a small percentage of the fleet and were given less strict standards because of it, but they still perform considerable operations. Unfortunately, freight hauling diesels transporting in and around the MCMA were typically registered outside of the MCMA and were subject to the lower Federal Governments standards. This loop hole should have been addressed and corrected. In the case of motorcycles, the omission resulted from difficulties in testing them and the relatively small number. This exclusion may have been a mistake given the polluting capabilities of two-stroke engines often used on motorcycles. Overall, the program was a good idea that evolved over time to better function. This transition included moving from public to private operation and the addition of restrictions on testing locations.

The government plan known as PICCA, enacted between 1990 and 1995, included mandates on catalytic converters, vehicle inspections, and improvements to traffic controls and roads, but it is most famous for the MCMA policy Hoy No Circula.[83] In 1989, this policy was implemented, and it divided the private vehicle fleet by license plate number and mandated that automobiles could not drive on a set weekday each week with the intention of promoting car pooling and public transportation alternatives. Police supported this policy by issuing fines to drivers that did not obey the law of not driving their cars on a specified day of the week. Critics of the policy have since pointed out the numerous flaws. It blindly attempts to cut trips rather than reducing the most unnecessary ones, treats trips as if they are all time sensitive, and assumes people will not share, transfer, or rent vehicles. Critics also point out the practice of purchasing additional vehicles to circumvent the restriction.[84] People would buy a secondary car, often an older, cheaper model, which meant more engines were on the road with older technologies and less pollution sophistication. The unexpected reactions to this policy made it ineffective. In fact, researchers found that the consumption of gasoline rose

[82] Lopez, Alejandro. (2001). Metropolitan Mexico City: Transportation Policies and Economic Development.
[83] Molina, Luisa and Molina, Mario (eds). (2002) Air Quality in the Mexico Megacity. Kluwer Academic Publishers, Boston.
[84] Molina, Luisa and Mario Molina (eds). (2002) Air Quality in the Mexico Megacity. Kluwer Academic Publishers, Boston.

above prior levels after a two quarter transition period. [85] In response, the government revised the policy in 1996 to penalize older, more polluting vehicles based on categories of model year to promote fleet turnover.

Many policies aimed at retrofitting vehicles with better technologies can be difficult to introduce and more importantly to enforce. They are easier to accomplish when the government offers subsidies for such transitions, such as those offered to manufactures for furnishing trucks with liquid petroleum gas, LPG. Incentives to companies and vehicle owners have aided efforts to hasten vehicle turnover, especially where increasing cars with catalytic converters is involved. Correspondingly, while Mexico is far from a leader in unleaded fuels it has made better progress than most nations in reducing this fuel additive. The state owned oil company PEMEX has reduced lead and sulfur percentages of its fuels, and unleaded fuel is widely sold.

3.3.3 Combating Pollution

Whether instituted for economic reasons or to allay public dissent, government incentives and regulations normally drive changes in the transportation sector. The failures of Mexico City to meet its transportation policy goals demonstrates the difficult and complex decisions involved in selecting new technologies and infrastructure investments.

The infrastructure funding in the MCMA led to the network that was largely responsible for the pollution crisis. Despite efforts in the 1970's to 1990's, air pollution continued until the suites of policies enacted in the nineties helped curb overall pollution emissions improving air quality and visibility. The failures and more recent achievements in policy show the challenges in legislating transportation, because it often takes years before impacts can be seen and policies can be reevaluated.

From this case, it is clear that megacities must be treated uniquely, even in contrast to large cities, where different types of policies are effective. In addition, the assimilation of suites of policy measures that act progressively should be the chief objective of

[85] Eskeland, Gunnar S and Tarhan Feyzioglu. (1995) Rationing Can Backfire: The Day Without a Car in Mexico. The World Bank Policy Research Working Paper 1554.

planners. The early layout of a system with support for various modes of transport provides an equitable infrastructure to the public and reduces passenger vehicle dependencies. Investments in technologies and aggressive protection of environmental conditions are necessary in developing megacities to preclude the type of dilemma faced in the Mexico City Metropolitan Area.

4 *Sustainability*

4.1 Defining Sustainable Development

The 1987 World Commission on Environment and Development, the Brundtland Commission, first brought the idea of sustainable development into the forefront of world policy. This notion represents the basic concern for the amount of damage mankind is doing to the environment and how environmental damage affects the opportunities for improving or maintaining the quality of life both among people of the current generation and across generations. There have been a number of proposals to address this concern; among them are calls for mutual sacrifice, transfers from developed to developing countries, transfers from present to future generations, resource and product prices more sensitive to the state of the environment, and project valuation methods, beyond standard discounting, that place greater emphasis on environmental assets.

Although sustainable development has been defined in various ways, it consistently involves the following common themes: assigning values to the environment, extending the time horizon for projects, enhancing equity, differentiating between growth and development, and emphasizing sustainability as opposed to survivability.

4.1.1 Value of the Environment

Sustainable development requires placing greater value on the environment. Historically, economic pursuits have undervalued environmental worth, despite its importance to economic growth and improved quality of life. As a result of this underestimation, overuse of the environment has been commonplace. There are several reasons for this result: some environmental resources are common, i.e., anyone can use them at no cost; some environmental resource benefits are not valued by the market, e.g., natural beauty; and some environmental resources are not correctly valued by the market because their costs do not reflect the full damage to the environment from their use.

For example, the mismanagement of forest resources is caused by all of these factors. Since many forests do not have clearly defined ownership, anyone can cut down trees

without bearing the cost imposed on other users of the forest for that action. One of the forest's most important values lies in its potential as a storehouse of biodiversity, as it is the richest ecosystem in terms of biomass and biodiversity on land. Tropical moist forests, which cover only seven percent of land areas, provide a habitat for approximately half of all known species.[86] This value, however, is neither recognized by markets where ownership rights do not exist nor taken into consideration when harvest schedules are set. Finally, some forests are over-harvested because of government subsidies that discourage the most efficient use of the land and cause it to be used for inefficient agriculture.

In order to manage the environment in a sustainable way, the various benefits it offers must be accounted for. As such, sustainable development requires finding new ways to value the environment, account for the stock of natural assets, and incorporate the effects of actions on the environment in prices.

4.1.2 Extending the Time Horizon

Since environmental projects have repercussions well into the future and since sustainable development is concerned with preserving environmental quality, sustainable projects must be evaluated using long term horizons. Predictions for projects should be extended from the typical durations of 5 to 10 years to periods covering many subsequent generations. For instance, the typical time frame for global warming analyses is approximately 35 years, which is the time it will take for total carbon in the atmosphere to double. However, Cline argues that this timeframe should be much longer – on the order of 250 to 300 years. The limitation of carbon level forecasts to the estimated doubling interval of carbon in the atmosphere is shortsighted; furthermore, there is reason to believe that damages caused by warming do not vary linearly, meaning that once warming reaches some threshold damages will increase at a greater rate.[87] This case expresses the importance of increasing forecast timeframes and justifies why decision makers should incorporate longer-term considerations in their analysis.

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[86] World Bank. (1992). World Development Report 1992: Development and the Environment. New York: Oxford University Press.

[87] Cline, William R. (1992). The Economics of Global Warming, Washington, DC: Institute for International Economics. June.

4.1.3 Equity

Equity, both intragenerational and intergenerational, is a major concern addressing the quality of life of the least advantaged of the current generation and the opportunities of future generations. In addition, there is a strong intragenerational equity concern that recognizes that today's developed countries have consumed most of the Earth's resources and emitted most of the pollution, to date, that will affect future generations. Yet, developing countries claim a right to growth, which will further burden the environment's ability to assimilate waste. It seems developed countries have a responsibility to the future both for their actions and the actions of developing countries. Thus, sustainable development requires both a transfer to the future and a transfer from developed countries to developing countries so that the latter may grow in a more environmentally benign manner.

One example of the intra- and inter- generational equity aspects of sustainable development is deforestation. Some deforestation has been blamed on the poverty of developing countries, which overexploit their forests because the resource is one of their few means of attaining wealth. Furthermore, some of the benefits of limiting deforestation – the forest's use as a carbon sink and storehouse of biodiversity – are enjoyed by all countries; however, the costs – in reduced development and consumption by not exploiting the forest – are born by the developing countries. This creates a situation that some argue justifies compensating developing countries for a more sustainable management of their forest resources, since the benefits of such a program accrue to all.

4.1.4 Growth versus Development

Economic growth is measured by increases in real gross national product per capita. Conversely, development is a more subjective concept that relates to achieving a set of social goals like increasing welfare, improving the quality of the environment, having greater distributions of wealth, improving health and education, and increasing individual freedoms, self-esteem, and self-respect. Sustainable development is not only concerned

with the continuing ability to increase income through economic growth, but also the ability to achieve more qualitative goals. Traditionally, the progress of nations has been measured through change in GNP growth, but as the World Bank's World Development Report 1992 says, "Economic growth is an essential means for enabling development, but in itself it is a highly imperfect proxy for progress." Most measures of economic growth do not require consideration of environmental conditions, but sustainable development calls for quantifying values for the depletion of resources and the expenses of combating pollution and erosion to give a more accurate depiction of a country's progress.

While per capita gross national product, per capita energy consumption, and carbon emissions per million persons are used to define growth, development must be examined through measurements of life expectancy, infant mortality, political freedoms, and civil liberties. Sometimes a country's growth and development levels correlate, but more often this relationship is imbalanced, driving the need for an accounting measure to correctly quantify development in a way that indicates a country's overall performance.

Toward this end, the United Nations developed a single index for development called the Human Development Index (HDI) to compete with the more common but apparently flawed GNP. The HDI consists of longevity, knowledge, and command over resources needed for a decent life. Longevity is measured by life expectancy at birth, knowledge by adult literacy and mean years of schooling, and command over resources by gross domestic product per person after adjusting for purchasing power. The United Nations uses the HDI to make the argument that there is no automatic link between GNP and development.[88] It has used the index to compare countries with similar GNP's but disparate development levels to successfully illustrate their point that income alone is a poor indicator of human development.[89] The Human Development Index does possess shortcomings in that it excludes factors of political freedom and personal liberty, making it an arguably incomplete measure. Despite this imperfection, the United Nations efforts

[88] United Nations Development Programme (UNDP). (1993). Human Development Report. New York: Oxford University Press.
[89] Ibid

have advanced the process of assessing national progress and have contributed to changing the way countries evaluate their growth.

4.1.5 Sustainability as Opposed to Survivability

Sustainability does not mean that future generations will be able merely to keep their consumption above a subsistence minimum. Sustainability refers to more than that the species should survive; it requires that the current quality of life be sustained and perhaps improved. For developed countries intergenerational equity requires that future generations have the opportunity for a quality of life no worse than the present generation. For developing countries intragenerational equity demands that they be allowed to develop so that future generations can approach the quality of life enjoyed by developed countries.

There are, however, a number of areas of controversy in sustainability. Some, like Brown et al., have criticized the anthropocentric or human centered view of sustainability.[90] They argue that all nature should be sustained not just those aspects that are important to maintaining man's quality of life. Others, like the World Bank, place an emphasis on intragenerational equity. They believe that sustainable development should alleviate poverty, both within nations and between nations. However, the greatest controversy over sustainable development between alternative groups of thought dictates how future generations should be compensated for environmental use, change, or injury. Two different schools have emerged: the neoclassical and ecological schools. While nearly everyone agrees that some capital stock should be preserved, there are two very different sustainability conditions: (1) future generations should have at least as much capital wealth as the present generation or (2) future generations should have as much of both natural wealth and man-made capital wealth as the present. The neoclassicists adhere to the former view, believing in the perfect substitutability between man-made and natural assets. The ecological school of thought considers the two types of wealth imperfect substitutes on moral and technical grounds.

[90] Brown, Lester R. (1991). Saving the Planet. The Worldwatch Institute.

4.1.6 Project Evaluation

Discount rates are used in project evaluation for two basic reasons: (a) to take into account people's time preference of money – people prefer money today over money tomorrow, and (b) to account for the marginal productivity of capital – that a dollar's worth of resources today will generate more than one dollar's worth of resources tomorrow. Discounting is used to convert future costs and benefits into their present values in order to evaluate the economic viability of projects. Choosing an appropriate discount rate is especially controversial for environmental projects. They often have costs and benefits that occur well into the future, and the full effect of discounting tends to make these distant flows insignificant for making decisions today. So, the higher the discount rate the less long term damages will affect acceptance decisions and the less attractive investments benefiting future generations will be.

Indeed, the main argument against discounting is that it runs counter to the concept of intergenerational equity, as high rates will hurt future generations. On the other hand, some environmentalists argue that using an artificially low discount rate does not necessarily benefit future generations. The best way to provide for the future's interest is by investing in the projects with the highest returns and then using the proceeds to provide for environmentally beneficial projects.[91] These sentiments were echoed in the World Bank's Development report.[92] Not only should discount rates not be adjusted for factors like uncertainty, they should not be manipulated when confronting irreversibility and intergenerational equity either; these concerns are better handled in different ways. Uncertainty can be accounted for by adjusting project costs and benefit flows.

With respect to irreversibility and uncertainty, future generations can be compensated, directly, through increases in man-made capital or technology and the maintenance of a constant natural resource base, or indirectly, through investments made today that accumulate knowledge in order to reduce future risks and uncertainty. The difficulty with the former is the unpredictability of the preferences of future generations and the

[91] Dornbusch, Rudiger and James M. Poterba. (1991). Global Warming. Cambridge, MA: MIT Press.
[92] World Bank. (1992). World Development Report 1992: Development and the Environment. New York: Oxford University Press.

future value or substitutability of various resources. By contrast, the indirect method of compensating future generations through increased knowledge and understanding is a valuable way of insuring intergenerational equity in the face of uncertainty and irreversibility concerns. It is important to remember that environmental risk is a supply side risk in that we know we will need it in the future but that we don't know what state it will be in. More generally, when faced with these problems future generations can be served best by investments that will reduce uncertainty and risk, e.g. research, and by the adoption of 'no-regret policies' – low cost solutions and solutions that have other additional benefits.

4.2 Achieving Sustainable Development

The main driving force behind sustainable development is the belief that if we continue to use the environment without concern for the effects our actions have on the environment, we do so at the expense of future generations. Thus, the main concern of sustainable development is intergenerational equity - the idea that we should make sure future generations have the same opportunities to achieve the quality of life that we enjoy.

To describe further what sustainable development requires in the constraint of the environment, three types of environmental resources, services, or benefits must be considered. They are:

Type I: Resources used in production, like oil, coal, natural gas, and the use of forests as timber. The risk of a limit to growth/development is that these resources may run out.

Type II: Resources that provide "natural" or environmental services, e.g., health and life support, biodiversity, natural beauty or esthetic value, recreational benefits, ecological and climatic control/maintenance, and educational and scientific knowledge. If these resources are lost, future generations may not be as well off since these resources do not have substitutes.

Type III: The environmental service of sink or assimilator of the wastes of economic progress. This service is limited as environmental conditions, like ozone depletion, acid rain, global warming, and the shortage of landfill space, have shown. Growth/development may be limited by the environment's ability to handle the resulting pollution, or it may be achieved at the expense of quality of life.

Thus, for sustainable development, the purpose of the resource, categorized by the three types above, is most important. In reality though, these resource classifications are not mutually exclusive in that some resources have characteristics typical of more than one resource type based, on their multiple uses. For example, rain forests have value as sources of timber (Type I), ecosystems (Type II), and carbon sinks (Type III). Types I and II resources present a resource management problem while Type III presents a pollution control problem.

4.2.1 Resource Management

Although there is great debate over how the resource base should be transferred from one generation to the next, the belief that each generation should inherit a resource base no less than its predecessor is uncontested. The issue is how readily increases in man-made wealth should be able to offset losses in natural stock and still leave future generations no worse off. Much of this debate centers on the level of confidence in technological innovation and substitution. Many ecologists claim that in the past we have relied on technology to increase man-made capital in order to ensure the prosperity of future generations and reward them for the loss of environmental stock, but we can longer count on this idea. In opposition, neoclassicists are optimistic about the power of technology believing that either input can be increased to produce the same output or substitutes for exhaustible resources can be found. Otherwise of course, the situation is hopeless. If a resource is both necessary, having no substitutes, and exhaustible then there is little reason to discuss sustainability.[93] Martin Wietzman postulates that one reason for the rift between ecological economists and neoclassicists is the ecological view as a function of carrying capacities, biological limits to the size of a population or growth rate.[94] This view questions the adaptability of the human race, which has overcome many obstacles in the past through substitution and technological progress and should be expected to do the same in the future.

When growth is fueled by technological innovation and not merely by increased natural resource consumption, more efficient growth can be complementary with improved environmental quality. Technology can save energy and resources and reduce pollution. It can reduce it through: "clean coal" technologies, more efficient energy uses, or renewable resources, such as a sustainable energy process like solar or wind power. Technology also can reduce pollution while saving energy by providing substitutes for energy intensive, polluting activities. For instance, information technologies like the fax machine, conference calls, and picture telephones have and will continue to reduce transportation use and its associated pollution. Technology can also turn pollutants into

[93] Solow, Robert. (1992). An Almost Practical Step Toward Sustainability, Resources for the Future.
[94] Weitzman, Martin L. (1992). Comments and Discussion: Lethal Model 2: The Limits to Growth Revisited, Brookings Papers on Economic Activity. Volume 2, Washington, DC.

resources by teaching how to use a waste product in a productive way. Thus, innovation can help solve the problems of both environmental pollution and resource depletion.[95] However, if renewable resources are used at a rate greater than their natural regeneration rate or if nonrenewable resources are used at a rate faster than technological innovation can substitute for them, growth in the present may come at the expense of the resource base of future generations.

It is important to remember that changes in technology govern resource value. Thus, the resource base is not static, but dependent on the dynamic state of technological innovation. Many contend that improvements in technology and not Type I resource inheritance or conservation have enabled societies to develop and sustain progress. Michael Porter claims that, "National prosperity is created, not inherited. It does not grow out of a country's natural endowments."[96]

The neoclassicists argue that resource prices will indicate scarcity, and exhaustion of a resource is not a problem since higher prices of scarce resources will encourage substitution and the development of alternative, backstop technologies. Yet, Richard Norgaard contends that if resource owners do not have enough information, i.e., they do not know how much resource is in the ground, then prices cannot be counted on to indicate scarcity or encourage either the most efficient use or the innovation of alternative technologies.[97] Type I resources, in particular however, have fairly accurate markets.

Sustaining Type I and Type II resources is a management problem. This problem requires deciding which resources are essential for long term maintenance of quality of life and which are merely inputs to production and thus can be substituted. Those resources or services that cannot be duplicated or done without must be sustained; however, those that are merely inputs for production can be replaced. Furthermore, since

[95] Hill, Lewis. (1990). Resources, Resistances, and Economic Growth. International Journal of Social Economics. Volume 17, Issue 6, pp 60-66.
[96] Porter, Michael. (1990). The Competitive Advantage of Nations. Harvard Business Review (March/April).
[97] Norgaard, Richard. (1985). Environmental Economics: An Evolutionary Critique and A Plea for Pluralism, Journal of Environmental Economics and Management, Volume 12.

the goal is development, there is a lot of flexibility in how those resources can be compensated for. For those resources that are only production inputs, and thus for which substitutes are readily available, efficiency should govern their use, and future generations should be compensated through investments.

4.2.2 Environmental Valuation

As discussed above, Type II resources do not have markets and thus tend to be undervalued. It is important for sustainable development to value these resources since they must be preserved and to recognize that environmental projects result in costs and benefits to society. There are a few economic methods for doing this; however, these methods are unsatisfactory for valuing most Type II resources. After evaluating the major economic methods, an alternative approach that may be more suitable to value these types of natural resources will be recommended.

The total economic value of environmental projects can be considered to be made up of user value and intrinsic value. User value is twofold: the benefit people receive from actually using the environment, and the potential benefit, or option value, received from using an environmental asset in the future. Option value includes the value of future use by the individual, the value in use by descendants and future generations (bequest value), and the vicarious value (use by others). Intrinsic value also called existence value refers to worth unrelated to human use. This value is based on people's "concern for, sympathy with, and respect for the rights and welfare of non-human beings."[98] The equation for total economic value of the environment is:

Total Economic Value = Actual Use Value + Option Value + Existence Value

Where: Option Value = Future Use Value + Bequest Value + Vicarious Value

[98] Pearce, David W. and R. Kerry Turner. (1990). Economics of Natural Resources and the Environment. Baltimore: The Johns Hopkins University Press.

Obviously, option value and existence value are very difficult to quantify as they depend mostly on irreversibility, uncertainty, and uniqueness. However, there are economic methods used for quantifying actual use value. Three benefit-cost analysis approaches are the hedonic price method, travel cost method, and contingent valuation method. The hedonic price method examines either property prices or wage rates to derive the value of certain environmental amenities from differences in prices or wages. The pitfalls of this analysis are the assumptions that must be made; it considers market conditions perfect with perfect information access, relies on the existence of groups of housing bundles and employment opportunities that are identical except for environmental quality and conditions, and overlooks the complexity of having prices reflect pollution due to the difficulty of perceiving its negative effects, especially on health. The second approach, termed the travel cost method and often used for valuing recreational sites, equates worth to the quantity of money people spend to visit a place. The costs measured are those for transportation, foregone earnings, entrance fees, etc. The simplicity of this system fails to account for multi-purpose travel, underestimates the value to people who choose to live locally, ignores option value, and neglects site quality. With regard to the latter, some would argue that wilderness is most valuable and best preserved when there are few visitors.[99] Instead of using observed consumer behavior like hedonic price and travel cost, the contingent valuation method uses hypothetical valuation or bidding games. People are asked how much they would be willing to pay for an improvement in the environment or how much they would be willing to accept for a decrease in environmental quality or service. This approach consists of four major problems: hypothetical bias, strategic behavior, inadequate information, and instrumental bias. They involve the difficulty to give a meaningful hypothetical price, manipulation of responses based on uncertain uses for the collected data, bias in the phrasing of questions, and interviewer unintentional influence over subjects.

Even though cost-benefit-analysis is often used to assess the value of Type II resources, the traditional attempts to quantify this value using market approximations are often not

[99] Hyman, Eric L. (1981). The Valuation of Extramarket Benefits and Costs in Environmental Impact Assessment, EIA Review. Volume 2, Number 3, pp 226-64.

interpretable for environmental resources. As such, the vector approach method, which values environmental assets in more meaningful, qualitative terms, yet still allows them to be weighed against more traditional economic factors, is recommended. This procedure considers factors in different forms and does not require the conversion of all relevant elements to monetary quantities, as some aspects of the environment do not lend themselves to easy economic valuation. The vector approach can be used to account for uncertainty, irreversibility, and uniqueness, and it essentially changes the point in the decision process where the most subjective decisions are made. It also allows these decisions to be more transparent. Often, economists choose the value of an environmental asset, which does not have a market, early in the decision process. Then, a policy maker makes a choice by comparing the costs and benefits, most likely without understanding the assumptions made beforehand. In contrast, the vector approach asks policy makers to make the subjective decision at the end of the decision process, when there is greater accountability and scrutiny.

Environmental Criticisms of Traditional Cost-Benefit-Analysis Methods and the Solutions Afforded by the Vector Approach

Environmentalist's Criticisms	Vector Approach Answers
People have legitamate concerns that are not voiced through consumption decisions	Ask citizens for feelings on most important aspects of the asset
Most important aspects are not measurable in monetary terms, so either they will not be considered or the value derived from Cost-Benefit Analysis (C-B-A) will be meaningless	Do not attempt to put all factors into monetary terms, ask experts and citizen to comment on important aspects, but not to guess at monetary values
C-B-A is elitist and undemocratic: decisions are based on expert opinions and not those of ordinary citizens	Can consider citizens' desires and convictions as well as experts' opinions
Public preferences (opinions) should be judged on the mertis of the arguments not on willingness to pay	Look at the merits, consider a number of different factors and measure them in their most meaningful form, then systematically, objectively value overall costs and benefits (which are listed in both qualitative and monetary terms) much as people do with many everyday decisions

Figure 5: Environmental Valuation: CBA and Vector Methods

4.2.3 Environmental Accounting Systems

A new framework for determining the sustainability of society's use of Type I resources is needed. A meaningful accounting system, which considers resource depletion and environmental damage, should replace GNP as a measure of progress. Sustainability requires that a portion of the income from the flow of capital stock be invested to replace income from resources as they are exhausted, but GNP's measure of wealth discourages this action. When resources are removed from nature, a country's GNP benefits from the sale, but the land is not debited for the deterioration. In addition, GNP counts expenditures that combat pollution as income. Thus, the Alaskan oil spill in 1989 actually increased GNP by about $2 billion, even though it was probably the most environmentally damaging accident in U.S. history.

Alternative systems have been created in the past; the United Nation's Human Development Index (HDI) and Daly and Cobb's Index of Sustainable Economic Welfare (ISEW) were two such attempts to improve the measure of progress by accounting for the damage done to the environment, the depletion of the natural stock, and the quality of life. While improvements and important steps, both systems were incomplete. Alternatively, Solow[100], Pearce et al.[101], and Schmidheiny[102], among others, have argued in favor of establishing a true net national product. This measure would subtract defensive expenditures, monetary value of unmitigated pollution damage, depreciation of man-made capital, and depreciation of environmental capital defined as ecosystem function damage, renewable capital, and exhaustible capital from current income. In this way, countries choosing to increase current income at the expense of future generations by running down their capital stock would be penalized.

This new accounting measure, a true net national product, defines a society's ability to develop in a sustainable way, and it allows managers to determine the state of the environment and the types of investments necessary to ensure a sustainable "opportunity

[100] Solow, Robert. (1992). An Almost Practical Step Toward Sustainability, Resources for the Future.
[101] Pearce, David, Anil Markandya, and Edward B. Barbier. (1989). Blueprint for a Green Economy. London: Earthscan Publications Ltd.
[102] Schmidheiny, Stephan. (1992). Changing Course. Cambridge, MA: MIT Press.

set". This net national product, the nation's total assets, must be preserved from year to year through investments and proper management to achieve intergenerational equity. According to Solow, sustainability requires "enough investment to maintain the broad stock of capital intact. It does not mean maintaining the stock of every single thing; tradeoffs and substitutions are not only permissible, they are essential."

The Norwegian, French, and Japanese governments have tried to incorporate these ideas into their systems of natural resource accounting. Norway and France both use a physical accounting system where the stock and quality of natural resources are monitored. The Japanese use a measure of Net National Welfare (NNW), which is based on Nordhaus and Torbin's Measure of Economic Welfare (MEW).[103] Japan's NNW corrects National Income for environmental damage and the cost of highway accidents, as well as other factors. Nevertheless, a "true" net national product measure is necessary for all nations to gauge the amount of investment necessary to compensate future generations for the use of Type I resources today.

In theory the amount of investment required for sustainability is fairly straightforward. It can be written in equation form as follows: at time t society has an allotment of capital K_t (both man made, e.g., plant and equipment infrastructure, and human capital, e.g., level of education and health of the population) and (natural) resources R_t; at time $t+1$, some resources have been used, so $R_{t+1} < R_t$, but capital has grown so $K_{t+1} > K_t$. As long as the increase in capital minus any depreciation on capital offsets the loss of resources, development can be sustained. Thus, if:

$$K_{t+1} - K_t - D > R_t - R_{t+1},$$

Where D is the depreciation on capital between periods t and $t+1$,

development can be sustained.

[103] Nordhaus, William. (1992). Lethal Model 2: The Limits to Growth Revisited, Brookings Papers on Economic Activity. Volume 2, Washington, DC.

4.2.4 Pollution Control

While sustaining Types I and II resources pose management challenges, Type III resources are a pollution control problem. Possible environmental degradations in the forms of global warming, ozone depletion, acid rain, deforestation, soil depletion, loss of biodiversity, and pollution of the air, water, and soil threaten to create greater limiting factors on growth than resource exhaustion. Pollution exists as an externality because polluters can use the assimilative capacity of the environment at no direct personal cost. However, this abuse results in the "the tragedy of commons" as Garrett Hardin explains in a herdsmen analogy.[104] If commons are a shared grazing land, each herdsman will increase his utility by adding more animals. The benefits for adding an animal accrue only to the individual herdsman, but the costs – less grazing land – is shared by all herdsmen. Thus, everyone increases their number of animals since their individual benefits always outweigh their individual costs. The tragedy is, of course, that since all the herdsmen increase their herd, the grazing land in the commons will be depleted quickly.

In the past, government command and control measures that implement regulations and standards have been used for pollution problems, but they have many disadvantages. The government can set either performance or specification standards. The prior exist in the form of limits on total pollution allowed or percentage reduction requirements. Specification standards dictate a technology that must be used to abate pollution, for example, requiring power plants to install scrubbers. Specific performance limits fail by classifying activity as passing or unacceptable with no incentive to reduce beyond the set limits. Meanwhile, percentage reduction requirements neglect the varying marginal costs of abatement, which are the actual costs of reducing to a pollution level that differ from source to source. Specification standards have also been widely criticized because they stifle innovation. Firms should be allowed to use the most cost effective method to reduce pollution and should be encouraged to seek new technologies. Some criticize regulations, because if they are complex enough to be fair and efficient so that they

[104] Hardin, Garrett. (1968). The Tragedy of the Commons, Science. 162, December 13, pp 1243-5.

account for differences among firms and pollutants and minimize costs, the regulatory job becomes impossible.[105]

Instead of command and control methods, the externalities should be internalized by using market forces. Market pollution control measures will lead polluters to the most cost-effective reduction measures, eliminate the gap between prices and social costs, and encourage substitution away from environmentally harmful behavior and products. Three market-based methods for accomplishing this are pollution charges, permits, and ending subsidy programs that may increase pollution.

A charge or tax can be used to offset the difference between prices and social costs. Charging firms for the luxury of hurting the environment will encourage the allocation of resources toward environmentally sound products. Charges also include an inherent equity benefit since they take money from the individuals or organizations that inflict the damages. They also generate revenue that can be used to cover monitoring expenses or other costs in a pollution reduction program. When charges are enforced for each unit of pollution emitted, the incentives to reduce volume or develop new technologies to decrease pollution are always present. Finally, charges allow the freedom to set prices high enough to achieve any amount of pollution reduction, which is ideally where marginal costs are equal to marginal damages.

In creating this type of market-based system, governments should charge or tax differently for different pollutants, reflective of a pollutant's particular danger to the environment. They should set them on a "prime time" schedules that increases prices during times of the day and year when pollution is most harmful. There is also the matter of variance in tax or charge across geographic areas; these discrepancies would manipulate pollution discharge by particular areas, and it is best to instead use a standard rate. A government must decide on the manner of assessing fees whether it is based on

[105] Dales, JH. (1968). Pollution, Property and Prices. Toronto: University of Toronto Press.
Kneese, Allen V. and Charles L. Shultze. (1975). Pollution, Prices, and Public Policy. Washington DC: The Brookings Institution.

pollution volume or the use of products that cause environmental harm. Another option is a deposit-return charge, which involves product charges that are refundable when a product is discarded in an environmentally benign manner. Goods such as bottles, tires, motor oil, lead-acid batteries, and vehicles can be set in such a system.

The second system involves the creation, distribution, and purchases of permits. A pollution permits market would operate much like the stock market. A pollution permits board would determine how much pollution was acceptable and then sell individual permits allowing that much pollution. For example, if each permit allowed one ton of pollution per year, a firm dumping 2000 tons of waste would need 2000 permits. The market would set the price through an auction system while a board would determine minimum prices. Once the market was fully operational, firms would buy and sell permits to each other. Permits could be issued for different lengths of time. Like the stock markets anyone could buy them, including environmental groups interested in further reducing pollution. With an open market, speculators could buy into the market with expectations of appreciation.[106]

Permits have not been utilized nearly as much as charge systems, but it can be argued that the reason for this is that most charge systems have been used to generate revenue not control pollution. The basic mechanisms of a permit system are bubbles, offsets, and banking. Bubbles allow firms to reallocate emissions between existing points as long as total emissions under the bubble remain at the same level. Offsets allow firms to install new sources as long as emissions from existing sources are reduced by an amount greater than the emission from the new source. Banking allows emissions credits when they reduce pollution to levels below that which is required by current technology standards. These credits can be applied to other sources or sold to other firms. The major goals of such systems seems to be pursuing the most cost effective way of keeping pollution levels from increasing while allowing for economic growth.

[106] Dales, JH. (1968). Pollution, Property and Prices. Toronto: University of Toronto Press.

There is no hard, fast rule for determining whether charges or permits are superior for controlling pollution. Charges are best where pollution is easy to monitor and the tax is easy to apply. One main advantage charges have over permits is that, if the charge is based on total emissions, firms may have stronger constant incentive to reduce pollution. Conversely, the pollution permit market has a number of advantages, one being that permits require less information about individual firms' costs of pollution control to achieve the desired reduction in a cost effective way. In the end, the choice depends on the presence of transaction costs, the uncertainty surrounding marginal costs and benefits, as well as the factors summarized in the table below. No matter which system is used ultimately we will have to pay for less pollution, and a healthier environment, through higher prices or less consumption.

CHARGES VS. PERMITS TABLE

	Advantages	Disadvantages
Charges		
	1. Polluter pays	1. Not sure what final pollution output will be
	2. Efficient Pricing - cost to environment reflected in prices	2. Difficult to know exact social costs for setting tax
	3. Efficient - Polluter with lowest marginal cost of reduction cuts pollution most	3. May not get immediate reduction if trial and error method is used
	4. Strong constant incentive to reduce pollution	4. Have to adjust for inflation and economic growth
	5. May make internalization of costs more visible	5. Need different taxes for different times, locations, and pollutants
	6. Technological advance more likely to lead to lower pollution levels	6. Not most effective if emissions are to be completely eliminated as for hazardous pollutants
Permits		
	1. Polluter pays	1. Allocation of resources between pollution abatement and other uses determined by quotas not market
	2. Efficient Pricing	2. Impractical for multiple source-pollution
	3. Polluters most able to reduce pollution are encouraged to reduce pollution the most	3. Trade-off between liquidity of market and ability to control geographic and type of pollutant concentration
	4. Requires less information than charges to arrive at a desired level of pollution if costs are low	4. Could have strategic behavior - resulting in less than optimal outcome - if the market is small
	5. Market sets price; government can set pollution amount through quotas	5. Initial allocation of permits becomes more important to efficient outcome, and informational advantage over charges decreases if transaction costs are high
	6. Market adjusts price for inflation and growth	
	7. Environmentalists can buy permits and thus reduce pollution further	
	8. Best for intermediate size market	

Figure 6: Pollution Control Comparison

Another policy aimed at managing Type III environmental resources through correct pricing of the environment involves ending subsidy programs that encourage environmentally damaging behavior. Subsidies can cause pollution by encouraging the use of fossil fuels, energy, and pesticides and discouraging the innovation of more environmentally benign substitutes. In developing countries, energy use itself is heavily subsidized as prices are on average only one third of supply costs. This under pricing increases pollution directly as developing countries use about 20 percent more electricity than if consumers paid true marginal cost of supply.[107] It also increases pollution indirectly since the under pricing discourages investment in new, cleaner, and more efficient technologies. For instance, Indonesia's elimination of their subsidy on pesticides, which had been more than 80 percent of the retail price, reduced excessive pesticide use and saved over $120 million a year.[108] Even subsidy programs aimed at reducing pollution by encouraging pollution control expenditures can have the opposite effect as well as being bad policy on other grounds. In a subsidy system, the pollution of each firm may go down, but industry pollution may actually increase if new firms enter a market that has been made more attractive by the existence of the subsidy program.

4.2.5 International Implications

The framework for sustainable development discussed so far is suited primarily for the country level. However, the environment's ability to sustain its various resources faces great challenges, like global warming, ozone depletion, acid rain, deforestation, and loss of biodiversity, that pose additional complications. There are two aspects that make these challenges particularly difficult to handle. First, there is great uncertainty as to the extent of the actual damages; second, they are international, trans-boundary pollution problems that neither affect all countries the same in terms of damages nor could be distributed equally as costs in the form of charges or permits. Thus, global warming, ozone depletion, acid rain, and deforestation probably will not be solved by pollution charges or permit systems alone. Biodiversity and deforestation post additional problems since they

[107] World Bank. (1992). World Development Report 1992: Development and the Environment. New York: Oxford University Press.
[108] Ibid

involve Type II resources that are not easily valued and that have both, sometimes competing, Type I and Type II resource attributes.

For biodiversity, deforestation, and global warming, the first possible steps at the national level are better management and more efficient resource use. Yet, transfers for world benefit are also needed; those that encourage cutting back deforestation, transferring technology to developing countries for more efficient energy use, and pooling diversity funds to target species for conservation using a framework like Martin Weitzman has recommended. Weitzman argued that sufficient efforts to conserve all species in the name of biodiversity cannot be made, so there must be a way to prioritize the limited resources allocated to conservation optimally.[109] By defining diversity on a genealogical tree of species, he theorized that biodiversity would be maximized if the species that are lost have the shortest final branch of the tree. In other words, those with the closest living relatives are the least consequential. This classification creates a framework for making conservation choices.

In assessing global warming, there are two camps - those for aggressive action and those for limited action. The two agree for the most part on the probable extent of global warming damage; the major reason for the vastly different conclusions is the amount of weight the two sides place on the less likely, more catastrophic outcome. The various models of the costs and benefits of climate change are roughly the same. It seems the debate should focus on answering one question. How much emphasis should society place on preventing the worst possible outcome, no matter how unlikely that outcome is? If one believes that society is not that risk averse, then a significant step toward sustainable development would be a policy that aims to:

1. Reduce emissions at modest cost.
2. Improve economic performance and increase efficiency (i.e., end energy subsidies and inefficient deforestation).
3. Invest in research to avoid over or under reaction.
4. Transfer energy saving technologies to developing countries.

[109] Weitzman, Martin L. (1991). What to Preserve? Discussion Papers 1574. Cambridge, MA: Harvard University Institute of Economic Research. (October).

4.3 **The Business Perspective**

Stephan Schmidheiny, along with the Business Council for Sustainable Development, has made the argument that just as good economics is not contrary to sustainable development, neither is good business. He agrees that government should move away from command and control regulations and toward economic driven policy to reduce pollution since economic mechanisms allow for the most cost effective measures, do not pin industry down to a particular technology that may not be the most efficient, and encourage constant innovation and pollution reductions. He claims the cost of command and control approaches are 2 to 20 times more expensive than the costs of economic instruments. Schmidheiny also argues for the end of subsidies that degrade the environment by encouraging inefficient and unsustainable behavior. He believes the cost of people's actions to the environment should be incorporated into prices. Schmidheiny writes, "The cornerstone of sustainable development is a system of open, competitive markets in which prices are made to reflect the costs of environmental as well as other resources."[110]

4.3.1 Trade and Market Responsiveness

Stephan Schmidheiny argues that free trade is a prerequisite for a sustainable world, because it allows nations and companies to benefit from comparative advantages. In turn, this leads to the most efficient allocation of world resources. Ending trade restrictions would stop farmers in developed countries from overusing chemicals, energy, and land to produce crops that tropical farmers can grow more efficiently, like sugar and rice. Free trade helps development and alleviates poverty as developing countries can benefit from their competitive advantage in low wage, high labor intensive jobs like agriculture and textiles. The U.N. claims that protectionism – through import quotas and subsidies to domestic firms – costs developing countries $100 billion for agricultural products and $50 billion in textiles.[111] Thus, many countries would be better off if developed nations stopped giving aid, but opened their markets. Free trade also facilitates technology transfer is important for technology transfer.

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[110] Schmidheiny, Stephan. (1992). Changing Course. Cambridge, MA: MIT Press.
[111] United Nations Development Programme (UNDP). (1991). Human Development Report. New York: Oxford University Press.

Trade should not, however, attempt to internalize environmental costs. The best way to keep environmentally harmful products out of one's markets is not through protectionism but through product labeling and consumer consciousness. For example, the U.S. government tried to ban Mexican tuna, claiming that Mexican boats killed too many dolphins in the process of harvesting tuna. However, a General Agreement on Tariffs and Trade (GATT) arbitration panel determined that the ban was contrary to GATT. Yet, through heightened public awareness of the problem and product labeling, tuna firms not concerned with the plight of dolphins have been penalized in the marketplace.

With growing environmental concern among consumers, companies are positioning themselves to not only compete for product loyalty but also reap the benefits of reducing wastes and inefficiencies in their operations. Companies can cut down on waste through good housekeeping, materials substitution, manufacturing modifications, and resource recovery. Not only do these measures improve company image, they reduce costs. In fact, some firms are finding it advantageous to go beyond requirements and cut pollution to gain respect and earn good will. This evolution has created new market opportunities for niche businesses in areas like public relations, cleanup technology, and remediation and waste reduction consulting.

4.3.2 Technology Transfer and Business

Technology transfer was cited previously as a way for developing countries to conserve resources and reduce pollution while still being able to pursue economic growth. Some technology transfers will have to come, no doubt, in the form of aid from developed nations. Some transfers, however, can occur through mutually beneficial business ventures. In 1956, the Shell Petroleum Development Company first discovered oil in Nigeria, a country with so few skilled workers that Shell used expatriates as management and production employees. With operational expansion, this imported labor pool grew more costly, and Shell concluded that training the local work force would greatly reduce costs and carry national favor. So, the company introduced a program for scholarships for secondary schools and local and overseas universities and technical colleges. Twelve

years later, Nigerians held 45 percent of operations jobs and 46 percent of exploration positions. In 1990, they held 62 percent of management positions and 90 percent of all jobs. Besides saving costs, Shell's efforts boosted the Nigerian economy and spurred technological advancement in other fields. Unfortunately, the profitability of pollution reduction and business opportunities for technology transfer are aimed mostly at Type III sustainability – the environment's capacity to assimilate waste. The resource management aspect of sustainability, Types I and II, particularly regarding the conservation of resources like biodiversity, will require more than a business sector motivated by correct market signals and concerned consumers. Types I and II sustainability will require a more committed effort by government at national and global levels.

On a positive point, an interesting partnership developed between Costa Rica and the world's largest pharmaceutical company Merck that seems promising in terms of sustainability. Costa Rica and Merck have found a biodiversity agreement that creates profit opportunities for them both. Merck has given Costa Rica one million U.S. dollars to protect an area of tropical forest in exchange for the exclusive right to investigate the plant resources of the area. Both parties will share the proceeds from the medicines developed from this area. Given the importance of the diverse biota of the tropical rain forests to medical research, this partnership may start a trend.

4.3.3 Global Implementation

Cooperation among nations for sustainable development is essential due to the international complexity of most environmental problems, for instance: most pollution has been and is currently emitted by developed nations, but the developing world will emit a considerable amount in the future; most of the world's tropical rainforest are found in only a few countries, but everyone benefits from their sustainable management; and because of the trans-boundary nature of much environmental pollution, the countries that cause the pollution are not always the ones affected, e.g., acid rain and ozone depletion. The motivation for sustainable management of the environment predominantly comes from the need for intergenerational equity. The concern for intragenerational equity,

which manifests itself primarily through transfers from developed to developing countries, is important not only because it impresses upon our concept of justice, but because of the public good nature of environmental stewardship and the relationship between pollution, population, and poverty. Developed countries should see sustainable management of environmental resources by developing countries as a public good. As such it will be under-provided, unless the developed countries are willing to compensate developing countries for providing the service. Poverty, population growth, and environmental degradations form a vicious cycle in many developing countries, where poverty leads to population increases as parents try to compensate for high infant mortality and provide for their own old age while high populations lead to increased hunger, unemployment, and housing shortages. Poverty and population growth also lead to environmental degradation through the overexploitation of marginal lands and the lack of environmentally sound technologies. A worsening environment in turn causes disease and decline in quality of life. This cycle can directly impact developed nations with the population growth of developing countries, and as the gap between rich and poor and the mobility of people increases, and particularly, as the limits of the environment's sink capacity are tested. Thus, intragenerational equity is interrelated with our ability to assure intergenerational equity.

To address this cycle and help developing countries overcome, developed nations can transfer technology, eliminate trade barriers that hurt developing economies, and forgive debt that cripples developing countries' future economic growth. For their part, the developing nations can discourage inefficient import-substitution; promote both environmental and productive infrastructure; increase human capital through education, training, health, and empowerment; and promote market reforms, like expanding the presence of market forces and ending energy subsidies.

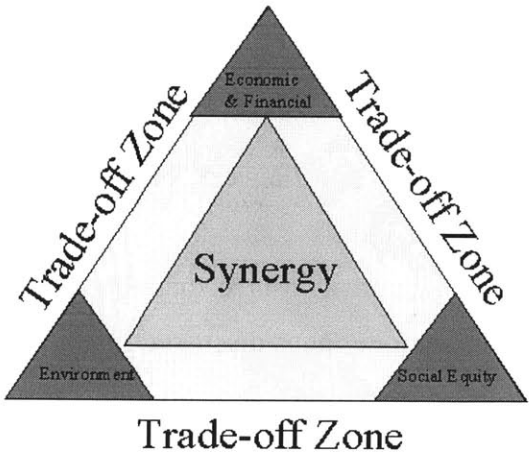
5 *Transportation Policy and Sustainability*

5.1 **Development Tradeoffs**

Economic growth and prosperity is a primary concern for nations whether they are among the wealthiest or the least developed countries in the world. As described in Chapter four, however, the distinction between growth and development being income level measures versus more qualitative success for society identifies different goals for governments. Seeking growth at great costs to social welfare or the environment can lead to more rapid wealth accumulation, but as discussed it sets a course for future instability. Each nation makes choices based on their priorities that shape the structure and conditions of development created in their pursuit for affluence. Often, circumstances including political dynamics, resource distribution, and industrial forces influence the strategic courses available to governments. At their heart, economies rely on investment to create improvements to infrastructures and services that occur in degrees and drive further growth. The process of fostering these activities involves governing decisions that control the rate of expansion and the acceptable corollaries produced by the policies legislated. When governments ignore the ramifications of unsustainable economic development strategies, they allow negative consequences that include environmental degradation and social inequality.

This statement applies particularly to the realm of transportation where planning not only affects the efficiency of mobility but also determines the negative repercussions. Inevitably, there are tradeoffs in the decisions made about transport in urban areas, as depicted in the visual representation below. Transportation networks are designed to service space in a specific manner based on the criteria established through urban planning, and if this plan neglects regions or fails to provide transport to various demographics it will be unsuccessful. In environmental terms, transportation policies can be lax in regulation creating opportunities for exploitation, or there can be more strict government measures that may serve the best interests of city inhabitants while possibly hampering growth. Restrictions imposed on industry can slow financial progress, but it can also limit environmental externalities and other detrimental effects.

Figure 7: Sustainability, Synergy, and Tradeoffs



[Source: Cheatham][112]

Instead, transportation plans must incorporate long term objectives that ensure networks best satisfy the goals of urban areas today and in the future. While policies cannot be optimal for all three conditions of economy, environment and social equity, each of these factors and the tradeoffs must be evaluated fully in selecting individual transportation policies and comprehensive sets of policies for any given city, rather than solely considering financial expansion.

5.1.1 Economic and Financial Sustainability

In order for development to proceed in the most expedient manner, the assets and resources of nations and their cities must be used on the highest yielding projects. This stipulation requires quantitative analysis that can closely model the costs and benefits of investment opportunities to determine the sources of highest return. It is essential that such considerations factor in the overall impact of development strategy. For example, heavy commitment of developing countries to foreign sources of oil weakens their economies, making them subject to the variable and sometimes arbitrary fluctuations in international prices. [113] Thus, the decisions of the present affect future dependencies.

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[112] Cheatham, Benjamin M. (2002). Sustainable Urban Transportation Development in Mega-cities: A Review of Policies, Regulations, and Technolgies, Master's thesis, MIT.

[113] Lowe, Marcia D. (1990). "Alternatives to the Automobile: Transport for Livable Cities." Paper 98. Worldwatch Institute, Washington, D.C.

The practice of introducing competitive market structure into transportation aids governments that are short on cash in providing transportation infrastructure for their cities.[114] Soliciting private companies for build, operate, transfer or BOT projects ensures that despite insufficient funds for projects increased transport capacity can be delivered to a city. Typical ventures include toll roads and private bus operators. The most important element in successful use of public-private partnerships are good contracts and regulations organized by government entities, which means they must have knowledgeable, experienced professionals negotiating the arrangements.

In addition, governments and planners must address the economic sustainability of projects before their inception to understand financial impacts. When public transport modes such as bus or rail are provided by a city, the result of having those systems will be the net of revenue collected and operating expenses. Where the expenses supersede monies gathered, the government must support the system to maintain its operation. In public transportation projects, financial stability varies as figure 8 below post construction profitability of city metro systems in the far right column.

Figure 8: Comparison of Metro Financial Performance

Financial Performance of Some Metro Systems							
City	Length (km)	Population (millions)	Passengers per km (millions)	Revenue per Passenger (dollars)	Cost per Passenger (dollars)	Operating Cost per km (millions)	Revenue to Operating Cost
Santiago	37.6	4.9	4.92	0.35	0.19	37.8	1.84
Singapore	83.0	4.0	4.67	0.57	0.34	71.9	1.67
Hong Kong	82.0	7.1	9.36	0.96	0.61	65.2	1.56
Buenos Aires	47.4	12.6	5.46	0.59	0.43	68.8	1.39
São Paulo	49.2	17.8	9.32	0.62	0.61	65.4	1.02
Seoul	286.9	12.5	6.56	0.38	0.44	64.6	0.87
Pusan	54.2	4.0	4.43	0.39	0.46	103.2	0.83
Mexico City	191.2	18.1	6.66	0.15	0.28	41.9	0.53
Kolkata	16.5	12.9	4.86	0.11	0.23	47.6	0.42

Note: Figures in US dollars and statistics taken in 2000.

[Source: World Bank][115]

[114] Sustainable Transport (1996). The World Bank, Washington D.C.
[115] Gwilliam, Ken. (2002). Cities on the Move: A World Bank Urban Strategy Review. The World Bank, Washington D.C.

While the costs of metro construction can rarely be recovered, it is more likely that the system will be properly operated and maintained when continuous financial support is not required. Conversely, figure 8 should not be confused with success ratings, because the fee charged per rider is central to the resulting revenue to operating cost ratio, and governments are obligated to limit the rider fee to prevent mobility disadvantages to the poor as the next section explains.

5.1.2 Social Sustainability

While public transportation modes need to be self sustaining financially, it is imprudent to inflate passenger fees in this interest if it hurts the stability of the lower income classes. Social responsibility involves making affordable transport available and attractive to city inhabitants, and if subsidies are necessary they should be employed. Transportation systems must serve all regions of a city providing mobility for people of different income levels. Furnishing large cities with sufficient infrastructure for pedestrian, bicycle, and public transit not only contributes to economic development but it generates mobility efficiency that also benefits the environment. Reliable transport for urban workforces supports the economy, and affordable access to retail and entertainment destinations for all people promotes growth. The high costs of providing good public transportation services often derail appropriate levels of investment because of the drain on government finances. For example, heavy rail metro systems can cost as much as $100 million per route kilometer for fully automatic, underground systems.[116] These expenses, however, are controlled by system design complexity and mode choice, which is why buses are very popular in developing countries because of their low relative costs.

In addition to the need to give mobility options to all classes, other issues such as resettlement for inhabitants displaced by new infrastructure or real estate projects must be addressed at large. When road infrastructure and automobile traffic dominate the urban model, new roads are continually needed, and the cheapest avenue for these projects can be land occupied by poor neighborhoods. In cities of the USA, it has been estimated that

[116] Gwilliam, Ken. (2002). Cities on the Move: A World Bank Urban Strategy Review. The World Bank, Washington D.C.

as much as half of the land in urban cores is used for roads, parking, and other features of car infrastructure.[117] Therefore, the more automobile dependent a city's people are, the more land is reserved for mobility. While the practice of displacing people without due compensation has declined in developed countries, it is still a concern around the world.

Governmental preoccupation with growth is common, and it often allows rapid urbanization and motorization to occur as an easier but less sustainable path to increased economy. [118] In countries with lower income levels, motorization is a harmful force on the poor, for whom the purchase of private vehicles lies beyond their financial resources. When private vehicles are the dominate consideration in planning, people are forced to purchase them when their income levels allow these expenditures. Otherwise, they are denied the same access as other people to places of work, education, recreation, and retail. The disproportionately higher use of poor people's time and income on transportation are key problems with government agenda failures. In Manila, for example, poor people spend twice that of the non-poor in percentage of income for travel, 14 as compared to 7 percent of annual income.[119] Social equity identified and explained in Chapter three has grown into a dominant global issue that many international organizations support as a chief priority in transport decisions.

5.1.3 Environmental Sustainability

Many current and future megacities in the developing world face severe challenges in managing the environmental effects of transportation practices. For this reason, it is critical that the ecological impacts of transport be incorporated into policy making and project selection. When cities decide to fund new road additions rather than public transit that may run on electric or other more novel energy like the biofuels common in Brazil, they encourage the air pollution and other negative externalities produced by societal dependence on fossil fuels.

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[117] Renner, Michael. (1988). Rethinking the Role of the Automobile. Paper 84. Worldwatch Institute, Washington, D.C.
[118] Conversations with Professor Fred Moavenzadeh. (2004) MIT Department of Civil and Environmental Engineering. Cambridge.
[119] Sustainable Transport (1996). The World Bank, Washington D.C.

As discussed in Chapter two, there are many existing technologies including catalytic converters and unleaded or non-sulfur petroleum based fuels that can reduce pollution emitted in countries that have not implemented these measures. While over three quarters of the gasoline sold in the world is lead free, efforts to complete the ban must continue in Indonesia, Venezuela, and countries of Sub-Saharan Africa.[120] Moreover, environmental sustainability requires that society reduce its high levels of consumption of the earth's renewable and nonrenewable resources so that future generations will not be put in danger. Increasingly, governments and corporations are recognizing the economic benefits that accompany strategies to minimize waste. The activities of building roads, manufacturing vehicles and parts, and extracting and supplying fuels use up tremendous quantities of materials, energy, and labor. Therefore, alternatives must be evaluated and adopted to reduce the resource consumption rates that restrict future sustainability.

5.1.4 Investment Choices

From a broader perspective, the many basic needs including water supply, sanitation, waste collection, housing, power, and transportation infrastructure pose various problems to large cities that have to be solved or at least addressed. Judging investments for budgeting poses specific challenges when policies and programs affect different areas and do not lend themselves to comparison easily. The decisions to invest in different plans revolve around a city's priorities and the benefits associated with each type of investment, because resources must be dedicated in the manner that best utilizes them. With set funds and assets governments are pressured to minimize expenditures and maximize return on investments to best achieve prosperity goals. It is difficult to resist mechanisms that produce better immediate results despite long term consequences. This dilemma explains the common devotion to motorized vehicles as the dominant transport mode. The next section will identify the direct costs of private vehicle dependence and the negative consequences, particularly economic, of this course of growth. Too often these aspects are overlooked in comparison with public transport investment options, leading to unsustainable systems that improperly account for economic considerations.

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[120] Gwilliam, Ken. (2002). Cities on the Move: A World Bank Urban Strategy Review. The World Bank, Washington D.C.

5.2 Private Motorized Vehicle Dependence

In Chapter two, many of the negative environmental consequences of widespread use of private and commercial vehicles were identified. Automobile dependence continues to increase and with it the serious transportation problems faced by cities around the world. The convenience and speed of automobiles and road infrastructure can drive economic growth with undeniable advantages to individual users. Unfortunately, the price of over reliance includes depletion of energy resources, consumption intensive behaviors, environmental degradation, economic damage, and reductions in mobility caused by congestion. It is vital in this discussion to identify the extent of change that is necessary in transportation to reverse these unsustainable trends. Private motorized vehicles benefit society where they are used when other modes are unsuitable like in rural areas, but for large cities public and non-motorized transportation must be the focus of networks based on greater efficiencies. The economic growth potential powered by automobiles has been the foundation for suburbanization and sprawl in many cities of the developed world. This practice, however, neglects the long term impacts of such policies on city characteristics and conditions.

Cities designed or built to favor private motorized vehicles often share common traits that include expansive, interconnected roads, insufficient or poorly integrated public transportation, and low density land occupancy surrounding city centers. The layout of extensive road networks encourages inhabitants to migrate outside of city centers to suburban areas where the provision of infrastructure funded by the government offers convenient access to the city by private vehicle. Therefore, it is the government selection of infrastructure projects that influences population densities and land usage for a city. This point highlights the power held by transportation planners to influence the development path of a region. In an area designed for automobiles, the pressure to forgo other modes causes public transportation avoidance that furthers the already lopsided modal share by reducing demand. When people turn away from public means, planners are discouraged from investing in enhancing these modes for fear of wasting funds. The result is the withering of non-motorized and public transport due to the relative inadequacy and the subsequent disregard for reinvestment based on low usage.

5.2.1 Congestion

With traditional urban planning methods, one of the greatest economic detriments is traffic congestion. This phenomenon can be defined as a decrease in the level of service experienced, caused by excess demand or other forces.[121] It costs nations billions of dollars each year.[122] Some congestion is unavoidable whether it is due to unforeseeable accidents or planned construction and maintenance activities, but the current levels of it in megacities are extreme. Sometimes roadway services are at fault, because they fail to respond quickly to problems and keep roadways open, but the real source of consistent occurrences lies in a mismatch between supply and demand. Regardless of the reason or combination of reasons, congestion reduces mobility by limiting the power of vehicles to deliver fast and convenient transportation, which hinders both private and public road-based modes. It prevents the intended operation of this infrastructure. The overcrowding increases average driving time leading to more pollutants emitted and longer trip times. The latter controls the main inputs to the financial repercussions, which are rises in freight handling costs and lost work time.[123]

Ironically, this problem afflicts both large and small cities, where demand for road infrastructure exceeds the supply. The observation of demand rising to meet new road supply above current demand has been repeatedly studied and stated, provided private vehicles are affordable to travelers.[124] The common occurrence of traffic levels exceeding supply reveals a failure in the automobile focused urban layout, whereby the favoritism towards this mode, making it the best and often only realistic method of transport, creates a largely inefficient system during peak flows.

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[121] Schallaböck, K. and R Pertersen. (1998). Germany; in Round Table110. Traffic Congestion in Europe. EMCT, Paris.
[122] United Nations Center for Human Settlements. (1996). An Urbanizing World: Global Report on Human Settlements. Oxford: Oxford University Press.
[123] Lowe, Marcia D. (1990). Alternatives to the Automobile: Transport for Livable Cities. Paper 98. Worldwatch Institute, Washington, D.C.
[124] Downs, Anthony. (1992). Stuck in Traffic: Coping with Peak-Hour Traffic Congestion. Brookings Institution. Cambridge.

While the environmental, social, and reduced mobility problems of the private vehicle dominant urban model are interrelated, they must be addressed specifically as well as in conjunction with one another. Consider technology development and the difference between environmental problems of transportation and congestion. Replacement for fossil fuels as the energy supply for transport is still a hope of the future and not yet a reality of tomorrow given the barriers to change. If, however, technology could provide an environmentally friendly solution that allowed vehicles to operate without pollutant emissions, a major detriment to the urban areas would be alleviated. Nonetheless, this change would not affect the economic burden of congestion. Therefore, the potential of fuel and engine technological advancements does not remove the necessity of planning sustainable transportation systems. Conversely, there are in fact numerous developments in the field of Intelligent Transportation Systems that show promise for making infrastructure operate more efficiently, but these technologies are not surreal solutions that will solve traffic problems alone. They can help alleviate them, but other actions are necessary for correction. In summary, mechanisms for dealing with congestion apart from environmental problems are necessary, and new technologies may facilitate improvements but only through strategy and policy development.

5.2.2 Two-Wheeled Vehicles

Motorcycles, mopeds, and similar vehicles are very popular for passenger transport in large cities of developing nations because of their versatility and retail price as compared to automobiles. These vehicles make efficient use of road space with their ability to through traffic. They also cost a fraction of the price of automobiles making them comparable to the costs of public transport, which is a plus for lower income commuters. Unfortunately, these vehicles typically use two stroke motors, which are more polluting. They are also prone to accidents with little protection given to drivers and the common intermixing with buses. In Asian countries such as China and India, two wheeled vehicles are especially popular. In Taiwan ownership reached .55 per capita, but in other Asian cities motorcycles have climbed to almost three quarters of total vehicle fleet.[125]

[125] Gwilliam, Ken. (2002). Cities on the Move: A World Bank Urban Strategy Review. The World Bank, Washington D.C.

The high ownership levels make dealing with this mode of travel particularly important to these governments and differ drastically in possible approaches from private automobile dependent models.

5.2.3 Land Usage

The automobile orientation of many major cities around the world causes fringe expansion and the consumption of land for transport and related needs. When vehicles can take suitable paths to periphery locations around the outside of a city, companies are more likely to locate on the outskirts, because access is readily available in a way that it would not be if automobiles were less dominant, which would encourage denser development within a city's center and on immediately adjacent properties. This pattern of expansion illustrates the importance of how precious space within a city is dedicated. As the most land intensive means of travel, motorized vehicles consume space with their ever growing road networks, parking requirements, and numerous locations for gas and service stations. The space occupied by roads running through and around cities and by lots for parking eliminates land that could be utilized for developments, allowing greater density. Many urban environments exceed the flat availability and turn to high rise or below ground parking facilities and elevated highways for automobiles. In fact cities spend amazing sums of money to create alternative methods of supplying ever increasing road supply to demanding travelers. In one of the oldest cities in the USA Boston, Massachusetts, the government embarked on one of the most expensive urban road projects in history, the Central/Artery Tunnel, which included several miles of underground highway as the only alternative to the pressing need to reduce congestion. For a city with a metropolitan population of almost 5.7 million in 2000, the entire project cost the government a total of 14.6 billion dollars after successive overruns from the original estimates.[126] Yet, this city is only the eighth largest populated metro area in the United States and now owns the most expensive road project, which is not an encouraging sign for transportation.[127] Incidentally, this project has decreased the overall quality of roads in the metropolitan area by draining the budget of funds for maintenance.

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[126] Boston Globe. (2004) <http://www.boston.com/globe/metro/bigdig>
[127] Demographia. (2004) <http://www.demographia.com/db-world-metro2000.htm>

5.2.4 The Price of Infrastructure and Parking

Pursuing the urban model that favors private motorized vehicles commits a city to all of the investment requirements and ancillary costs necessary to construct and upkeep road networks. The obvious and most intense element is the dedication of capital to build new infrastructure, and while this price is usually the main figure considered by legislators there are many other funding needs. Principally, roads tend to lead to other new roads, but the entire network requires maintenance and repairs for activities such as patch work, road marking and signage, trash and debris cleanup, and snow or ice removal in colder climates.[128] One of the often ignored costs in planning is highway services. Many organizations must be in place to ensure good operation of any road system. Police or equivalent groups patrol roads, manage traffic, enforce parking restrictions, and investigate accidents and auto theft. In addition, other units are needed to respond to emergencies by caring for injured people and removing accidents to reopen lanes for operation. Research by Stanley Hart, a civil engineer in California, estimated that it cost the city of Pasadena $15.7 million for these services in 1989. From this calculation, he projected that the annual cost of highway services beyond user fees for the United States amounts to $68 billion, which greatly supercedes the $33.3 billion in capital outlays and $28 billion in maintenance costs paid by the government.[129] While the proportions of these figures differ from those in developing nations, they still provide an indication of the related fees for operating roadway infrastructure and show why developing nations struggle in providing services. The effectiveness of these groups impacts vehicle flow and congestion rates in all cities. The absence or poor performance of these activities in underdeveloped countries are typically due to institutional failures and insufficient funds.

The final consideration in the four major categories of costs is parking. This issue differs from capital, maintenance, and service elements in that private enterprises often pay for this burden. While governments can provide spaces along streets within cities, typically for a fee, retailers, entertainment venues, and restaurants pay for the development of parking space for their clientele. Other providers include developers providing space for

[128] World Resources Institute. (1992). The Going Rate: What It Really Costs to Drive.
[129] Ibid

high fees in parking garages and companies that create spots for employees. Regardless, the space consumed and price paid for parking in cities prevents other developments and passes on very high costs that facilitate vehicle use. When companies provide spaces for their workers, they are able to deduct the cost in the USA and in some other countries, and the employees receive a tax free benefit. This transfer of costs skews the true price of car ownership and should be revised to more accurately reflect actual conditions. In addition, parking space should not be excessively availability. In the USA and Australia, central business districts of fifteen large cities averaged more than 500 spaces available for every 1000 jobs in 1995, as compared to the approximately 100 spaces averaged in six high income Asian cities, which have much stronger public transportation networks.[130]

5.2.5 Variation in Over Reliance

Studies of automobile dependence reveal that levels vary considerable between cities of similar sizes. This discrepancy illustrates the potential to limit automobile travel within cities based on investment decisions made, incentives offered, and regulations imposed. For example, cities built and developed before the adoption of automobiles when pedestrian traffic dominated movement and domesticated animals played a significant role have different orientations than those constructed with motorized vehicles in mind.[131] Thus, older cities struggled with the technological revolution that made cars the dominant means, because the infrastructure allowable could not service the demands required. In addition some cities were forced to limit vehicle travel within urban development due to existing natural constraints like limited land availability for expansion. For these reasons and others that include good leadership and foresight, some cities have relatively low rates of automobile use per person.

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[130] Kenworthy, Jeff and Felix Laube. Urban Transport Patterns in a Global Sample of Cities and their Linkages to Transport Infrastructure, Land Use, Economics and Environment. World Transport Policy and Practice, Eco-Logica Ltd. Volume 3, Number 3, 2002.

[131] United Nations Center for Human Settlements. (1996). An Urbanizing World: Global Report on Human Settlements. Oxford: Oxford University Press.

In fact, major distinctions exist between the large cities of different continents revealing the influence of different ideologies. North American cities have the highest rates of dependence followed by those in Australia. The megacities in these places typically follow the private automobile urban model, and the result is predictable. European cities have lower rates than Australia, particularly Paris and Munich where public transport is popular. In Asia, however, there are three megacities that show lower dependence than any of these other regions; they are Singapore, Tokyo, and Hong Kong.[132] The Asian model favors the dense urban environments and good public transportation that allow successful operation of a city with limited automobiles usage. In addition, there are cities in Europe with higher income levels but less reliance behavior on cars than Australian counterparts, showing that economic growth and vehicle dependence are not synonymous.

5.2.6 Overcoming Dependence

The current state of the world finds numerous cities struggling with transportation pollution externalities and congestion effects, and these cities range in diversity as much as the people and cultures of the world. Industrialized countries have megacities with existing networks that function inadequately, and developing nations have megacities with limited infrastructure in place and broad plans to expand to service the influx of people due to urbanization. The cases of megacities at difference levels of development vary greatly in the possible approaches for instituting sustainable transport.

The reality of urban transportation is that most large cities suffer from the problems discussed in this chapter to varying degrees, depending on region and particular circumstances. Of course if solutions were easy to select and implement, this would not be the case. Fortunately, there are success stories among particular cities that have committed themselves to long term programs that support sustainable transportation policies. The provision of quality bus service and adherence to transit oriented

[132] United Nations Center for Human Settlements. (1996). An Urbanizing World: Global Report on Human Settlements. Oxford: Oxford University Press.

development, which is a land use strategy to combat private vehicle demand, underlies the story of one city in South America.

5.2.7 The Development of Curitiba

In Brazil, Curitiba has a history that demonstrates the potential for overcoming the problems posed by transportation. This city experienced urbanization during the second half of the twentieth century, and eventually city planners and government officials decided to take action to control the growth patterns. They decided to rely on major corridors extending out from the city to serve as tracks for transportation and mass transit with an emphasis on busing. The transit lines, designed as a trinary road system, consist of segregated bus lanes, local vehicle traffic lanes and long distance high speed lanes.[133] Buses were chosen as the primary public transportation mode because of their cost effectiveness. Zoning laws were implemented to cause high density development along the five major corridors and limited intermediary regions to lower densities. These policies were supported by strong institutional government forces and leadership committed to the development agenda of Curitiba.

The transportation transition occurred over the course of decades, and the city endured setbacks on the way to success. The bus system in particular suffered as the government repeatedly changed the pricing scheme and administration, until finally settling on a simplified system that eliminated competition between the private bus companies through profit sharing. Other issues were severe overcrowding after the system initially opened and bad interior bus conditions when the fee for outlying routes was temporarily removed for social equity interests. Eventually, the city installed bus transit stations and resolved the disagreeable aspects of their public network. The product of all of Curitiba's efforts became clear when the city achieved a 70% bus mode share for city travel, a 25% lower

[133] United Nations Center for Human Settlements. (1996). An Urbanizing World: Global Report on Human Settlements. Oxford: Oxford University Press.

per capita gasoline consumption compared to eight similar Brazilian cities and one of the lowest levels of air pollution and accident rates in Brazil.[134]

[134] Rabinovitch, Jonas. Curitiba: towards sustainable urban development, Environment and Urbanization, Volume 4, Number 2, October 1992.

5.3 Public and Non-Motorized Transportation

Public and Non-Motorized Transport (NMT) are more sustainable methods of movement in urban areas. The benefits of motorized public transportation are significant savings in energy and resources. The efficiency of these modes as compared to private vehicle leads to better environmental conditions. In developing nations of the world, NMT is more dominant than in more progressive regions. Large cities across the globe have extreme variations in modal splits due to development potential and government transportation policies. Poorer countries have greater dependence on NMT, but as income levels rise people transition to public transportation. Eventually, some cities then transition heavily to private motorized transport whether with automobiles or two-wheeled vehicles. Government transportation policy affects this progression, as evidenced in major Asian cities like Tokyo, Hong Kong, and Singapore where despite economic development public transportation retains 70% or more of mode share.[135] In order to redirect the trends of motorization, cities must induce ridership on public modes and promote NMT by improving service and accessibility. This approach, in combination with increasing car ownership expenses, can forestall private motorization and reshape transport networks to reduce negative impacts.

5.3.1 Non-Motorized Transport

NMT methods are the best modes in the sustainability contexts of space, energy, and resource efficiency, and they do not include any of the major harmful repercussions of motorized transportation. Walking is the best of these, but it is limited to the shortest distances. Of course, this varies in underdeveloped areas where people are forced to walk extended durations due to an inability to pay for other means. Bicycle travel, also non-motorized, provides great mobility to city residents able to purchase bicycles. Efforts to enhance pedestrian and bicycle traffic can be accomplished by increasing access points to locations throughout a city. This orientation entails giving a greater share of streets to these efficient modes or even building separate lanes and paths for them.[136] Especially in

[135] Economic and Social Commission for Asia and the Pacific. (2001). Review of Developments in Transport and Communications in the ESCAP Region 1996-2001. United Nations, New York.
[136] Lowe, Marcia D. (1990). Alternatives to the Automobile: Transport for Livable Cities. Paper 98. Worldwatch Institute, Washington, D.C.

megacities of the developing world, infrastructure for non-motorized transport is needed to improve safety and oppose the appeal of motorization. Removing city parking is one method of making room for pedestrian and non-motorized traffic on existing roads. Transitions to bicycle traffic are not simple, because this mode requires special investment for parking in the form of bicycle racks for instance. In countries with prevalent bicycle use, guarded storage has become necessary due to threats of theft, illustrating the special concessions necessary to sustain bicycle use. Most importantly, NMT can be utilized as an extension of other modes increasing the reach of motorized public transport.

5.3.2 Mass Urban Transportation

Megacities must have transportation networks that can handle the heavy volumes of traffic that must be moved daily. The dominant forms of public transport are bus and rail, whether they are extended or minibuses, rapid or light rail, and they must accommodate passengers comfortably with reasonable travel times. Ridership on public modes depends of the integration between physical networks and pricing configurations.[137] Feeder lines must connect with trunk lines and major corridors to provide interconnectivity and good access. The physical integration of public transport, like that between metro and bus, involves good transfer facilities, scheduling, and convenience that raise service level and reliability. In addition, the pricing of services needs to be as simple as possible, which is becoming easier as new technologies offer electronic tools and payment options. Integration of systems can still be difficult, however, particularly when private companies operate activities for the government. In planning integrated systems, the value of both fixed and flexible modes must be recognized. When routes are unchangeable as with rail, adjustments to demand levels and new growth patterns cannot be made, but more flexible means such as taxis, minibuses, and paratransit can adjust as necessary over time.

Passenger rail systems provide great mobility in quantitative terms for large cities where demand volume is especially high, but this means is very expensive. As a fixed network,

[137] Gwilliam, Ken. (2002). Cities on the Move: A World Bank Urban Strategy Review. The World Bank, Washington D.C.

rail is particularly useful over heavily traveled corridors, where demand for services is high. Passenger rail is rare in Africa, Australia, and the Americas and is predominantly used in China, India, Japan, the former Soviet Union, and Western Europe.[138] In Western European countries, rail is typically instituted underground due to constraints on land availability. Many of the existing passenger rail networks are decades old, requiring maintenance and upgrading more than new construction. The dominant power sources for these systems are diesel engines and electricity, with the latter increasingly used in developing countries.

Bus is a preferred means of public urban travel for governments of developing countries, because it is a relatively low cost method and can be added to easily to existing road infrastructure. More progressive developments, however, incorporate specialized right of way with bus service instituting bus rapid transit (BRT), which requires greater investment but separates buses from traffic congestion. Dedicated bus infrastructure has been widely adopted and implemented in Latin America. In terms of power, the dominant bus fuel is diesel, but the potential to upgrade fleets to alterative fuels are comparatively inexpensive and mainly prevented by institutional challenges. The concentration of bus use for urban transit is in China, India, Latin America, and Africa.[139]

In addition, the paratransit mode made up of informal and typically unregulated taxis, minibuses, and various non-motorized vehicles have grown popular as responsive road based publicly available means. In Manila, Caracas, and Bogotá, this form has a commanding share of public transit.[140] They have grown into a key consideration in planning and policy making as a competitor of other modes. Paratransit regulation affects traffic levels and in some cities has a great impact on the form of negative externalities. In some places, Santiago and Buenos Aires, these flexible modes are regulated, but in Lima and Mexico City they are more chaotic. Paratransit plays a major role in Africa and Asia, but organization and beneficial regulation varies widely.

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[138] World Business Council for Sustainable Development. (2001). Mobility 2001: World Mobility at the End of the Twentieth Century and its Sustainability.
[139] Ibid
[140] Ibid

5.4 Sustainable Transportation

In the same way that owners and designers of common buildings have traditionally ignored the effects of their decisions on maintenance and operation by focusing solely on immediate costs and concerns, urban transportation planners have too often failed to factor in the gross effects of their entire systems. Some have dismissed opportunities to minimize a host of long term costs and repercussions, while others have formed cities that provide better conditions and higher quality of life. Rather than the urban model of road concentrated investment that favors private vehicle use, megacities should focus on two main tactics for directing transport, which are designing systems that integrate various modes of travel to minimize resource, economic cost, and time expenditures and reduce the aggregate need for movement.

Furthermore, various areas of improvement can be targeted to improve existing networks and to reshape future growth that will better serve the interests of communities. The current state of transport in major urban areas of the developing world fails to deliver maximum use of existing supplied infrastructure through insufficient traffic management. In addition, the true costs of certain modes are distorted by government funding and subsidies that alter the composition of urban travel. By granting right of way to public and non-motorized traffic, governments have opportunities to reconfigure transit orientation. In broader efforts, changes to the allocation of land that focus on transportation planning and include mixed developments can reduce overall travel necessity.

5.4.1 Better Traffic Management[141]

Traffic management allows road networks to provide their full capacity by maximizing throughput and reducing accidents. Firstly, there must be mechanisms in place to regulate flow including properly designed intersections, markings and signage, and traffic lights with optimal synchronization. Second, enforcement of these regulations must be implemented to prevent illegal behavior. A major factor in poor countries is the

[141] Bull, Alberto (ed.) (2004). Traffic Congestion: The Problem and How to Deal with it. United Nations, Economic Commission for Latin America and the Caribbean. Santiago, Chile.

insufficient supply of traffic management tools including simple regulations that improve the throughput of vehicles.

Megacities in developing countries have less sophistication, and therefore struggle as their roadways and other transport infrastructure are less productive. Certain aspects are deficient due to a lack of knowledge in designing elements like road intersections for example, while physical components are too expensive to install. These traffic management tools are vital, but neglected especially when enforcement does not exist to make sure vehicles obey them. Cities with insufficient people on staff or the inability to deliver training on urban transportation and traffic management suffer with enforcement difficulties that multiply congestion rates and mobility problems.

5.4.2 Right of Way

In most developing nations, the majority of people fall into the lower income bracket and are forced to travel on public transportation or walk. In the past, road based or interfacing public transportation has not been distinguished from private, meaning that congestion affects all modes equally. Prioritizing modes is an alternative that can change the operational dynamics of networks. In cities that make concessions for public transit right of way, like bus rapid transit, public transportation vehicles can be made far more attractive through dedicated infrastructure. This commitment of city infrastructure to public modes serves the interests of equity, because travelers of these means contribute less to congestion and other repercussions. While awarding right of way to public and non-motorized modes is important and necessary, it can also be the target opposition in automobile dependant societies.

In Bogotá, Columbia a bus rapid transit network called TransMilenio was instituted to improve public transport service levels. It first opened in 2001 with 20 kilometers of exclusive bus lanes, 162 diesel buses with 160 person capacities, 32 stations, and 60 diesel feeder buses with 80 person capacities. The result was a decrease in traveler time by 32 percent, in air pollution from buses of 40 percent, and elimination of bus related

accidents.[142] The total first phase increased operation to 41 kilometers of exclusive lanes, but the plan is to have 388 kilometers in operation after fifteen years since the inception in 1998. The management occurs through a public company TransMilenio S.A. funded by 3 percent of operating revenue. It runs the system from a control central that tracks vehicles with GPS and passenger demand in real time so that adjustments can be made. Granting right of way to bus operation improves public transportation service and reliability, lowers emissions from buses, decreases private vehicle usage and demand, and has been a success in Bogotá.

5.4.3 Pricing Auto Travel and Parking

Vehicle travel must be assigned the appropriate costs that it represents, often called the true costs. This includes the price of infrastructure, environmental externalities, and road decay. Forcing travelers to pay more, especially for travel during peak congestion periods, is the best tactic for dealing with the increasing motorization rates in the developing world, where these hikes carry far less social implications due to the relative low rates of overall automobile ownership. Methods of realizing this include high licensure fees, fuel taxes, congestion pricing, and high parking costs. It is important for these and other options to be clear and available for policy selection. Various forms of congestion pricing and road use taxation exist and are being implemented more frequently as technology has been developed for more convenient charging operations. These plans will grow more complex as flat rates of cordon pricing schemes can be replaced with peak time variable charging and eventually total mileage tracking in combination with variable pricing. The complexity of operating these plans and the barriers to integrating them into city life make progressive staging of programs logical. Still, these programs cost fortunes to implement, administer, and enforce that developing megacities may not be able finance and run. Governments must then turn to high fees and fuel taxes that are easier to enact and collect.

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[142] Gwilliam, Ken. (2002). Cities on the Move: A World Bank Urban Strategy Review. The World Bank, Washington D.C.

Parking must also be priced more consistently with the opportunity cost of land that it occupies to control vehicle usage in urban centers. This mechanism is more effective than policies that limit the number of spaces.[143] For parking, policies can be created to overcome existing practices like company subsidies. In California, the government requires companies to compensate all employees not commuting by motorized means for parking provide free of charge to other workers but that they do not use.[144] This legislation attempts to equalize treatment to non-drivers by forcing companies to pay them the average cost of commercial parking space. This type of policy is a step that advances toward treating parking space as it should be priced.

Subsidies on fuel cost are prevalent in many countries of the former Eastern Block, Middle East, and Asia. These practices are reversals of the standard fuel taxation practices in most of the industrialized nations of the world. Such economic disturbances influence the treatment of energy sources, taking the misfortune of not pricing it for all externalities to a lower level of not even pricing it to the public for the cost of production. Unfortunately, reversing fuel subsidies has proven difficult as repeated demonstrated by riots in Nigeria for fuel price increases. In 1998, Indonesia experienced popular opposition causing the government to repeal hikes.[145] It is important for developing nations and other subsidizing countries to alter such economic practices, but this change must be done carefully

5.4.4 Structured Land Patterns

During times of industrialization, it became important to separate housing from industry with health and sanitation in mind. This practice is less necessary in many industries of today, which means housing can be located near places of work and intermixed with retail and recreation facilities. In addition, the technique of zoning land for development with higher densities around public transport stations can increase ridership. In general, higher densities are good for transportation by consolidating demand geographically.

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[143] European Conference of Ministers of Transport. (1995). Urban Travel and Sustainable Development. OECD Publications, Paris.

[144] Ibid

[145] Metschies, Gerhard. (2001). Fuel Prices and Vehicle Taxation. GTZ, Eschborn, Germany.

Good urban planning locates goods and services in a pattern that reduces the need for travel to more distant locations. Land use must be exercised in a scheme that supports the goals of sustainability by zoning to create dense land developments. This integration can be difficult, because it requires commitments across government divided responsibilities. Cities that have been successful in controlling the dominance of automobiles have done so by integrating land use and infrastructure. In the figure below, a dozen cities are listed in ascending order of a land utilization measure. The corresponding percentages of the three primary travel modes for commuting to work are then given to show the correlation between land density and transport mode share.

Figure 9: Mode Split Based on Land Use

Travel Modes for the Journey to Work in Cities of Different Densities, 1980				
	Degree of Land Utilization	Choice of Transport Type for Travel to Work		
City	Housing and Places of Work per Hectare	Private Automobile	Public Transport	Foot and Bicycle
Phoenix	13	93	3	3
Perth	15	84	12	4
Washington	21	81	14	5
Sydney	25	65	30	4
Toronto	59	63	31	6
Hamburg	66	44	42	15
Amsterdam	74	58	14	28
Stockholm	85	34	46	20
Munich	91	38	42	20
Vienna	111	40	45	15
Tokyo	171	16	59	25
Hong Kong	403	3	62	35

[Source: Kenworthy and Newman][146]

[146] Kenworthy, Jeff and Peter Newman. (1989). Cities and Automobile Dependence: A Sourcebook. Gower Publishing Company Limited, England.

5.5 Governing Transport

The governance of urban centers has increasing fallen on the shoulders of local government institutions since the global emphasis on decentralization in the 1980's. The intention of this delegation and devolution was to allow better control and decision making by those governing the welfare of cities.[147] Unfortunately, governments can only act within the constraints of their organizational strength and policy knowledge. The point of failure in many instances of urban development mismanagement lies in insufficient, fragmented, and even corrupt government entities that do not execute the policies and enforce the laws of a city. Similarly, a comprehensive understanding of conventional and innovative measures for governing are needed so that decisions can include the most suitable practices.

In transportation, many cities have failed in the past to plan efficiently and create good networks. Some have tried to rely on older policies and those successfully demonstrated in other locations. Delhi attempted to follow the guidelines of other, more developed countries and failed to resolve its transportation crisis. Currently, more cities are choosing unorthodox policies to solve the great problems associated with urban transportation. This departure has allowed some urban governments to discover successful alternatives to some of their most pressing issues. London, for example, stepped out of convention in 2003 to become the first major European city to implement a cordon pricing system to combat congestion. While not an original concept, since Singapore instituted a similar program back in the 1970's, new technologies have solved many of the hurdles that previously discouraged implementation. Initiatives like this one are a great advantage in financial terms, because they collect additional money for the government to then reinvest. This money can be dedicated in a socially equitable way by paying for enhancements to public transit and non-motorized transit.

[147] United Nations Center for Human Settlements. (1996). An Urbanizing World: Global Report on Human Settlements. Oxford: Oxford University Press.

5.5.1 Delhi: Inappropriate Transportation Planning

The government of this Indian megacity has been conscious of the principles of urban transportation for decades and has acted accordingly in designing their network.[148] In fact, Delhi exhibits a number of the characteristics desired by urban planners for effective organization. With low rates of vehicle ownership, the city has high population densities and abundant development concentrations. Non-motorized, public, and pedestrian transportation are commonly used, making this city an embodiment of many advantageous urban features.

This perspective paints only a partial picture of conditions in Delhi, which adopted principles heralded by planners in more developed nations, and it fails to consider the pollution and congestion levels in the city. In the early 1990's, the World Health Organization listed Delhi as one the ten most polluted cities in the world[149], and the city's total number of annual traffic deaths were twice that of all other major Indian cities added together[150].

This incredible discrepancy between a thorough city layout and poor externalities results from the differences between vehicles fleets and social and economic conditions in India and higher income nations. The government in Delhi considered its actions sophisticated, but it failed to account for natural limitations. At that time, this Indian city's institutional controls over traffic were nonexistent and regulation of vehicles was not possible. Motorcycles and scooters were the dominant mode of travel constituting seventy percent of registered vehicles.[151] They fought for road space with taxis, buses, and trucks but also with rickshaws, handcarts, and animals. These various and incompatible modes caused congestion and frequent accidents, even without high levels of automobile usage. In this transportation failure, the greatest mishandling was the disregard for the particular aspects of this city that must be addressed and resolved to form an efficient transportation network. The development course of this city serves as a reminder that successful

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[148] WRI, UNEP, UNDP, and World Bank. (1996). World Resources 1996-1997: The Urban Environment.
[149] World Health Organization and UNEP. (1992). Urban Air Pollution in Megacities of the World. Oxford, Blackwell Publishers.
[150] Better Traffic Policing Urged. Indian Express. Delhi, India. February 26, 1994.
[151] WRI, UNEP, UNDP, and World Bank. (1996). World Resources 1996-1997: The Urban Environment.

policies are not necessarily transferable between megacities and that policies must be tailored to suit local conditions.

5.5.2 Reshaping Travel Patterns through Pricing

Different policy instruments that increase incentives for public and non-motorized transport exist. The installation of tolls with congestion pricing features that make driving particularly expensive during peak hours is one measure for making cars use more costly. The development of electronic mechanisms for toll payment, that prevent the bottlenecks of manual tolls, have made this measure popular, and there are many other forms of congestion pricing like area pricing schemes. Another means for discouraging automobile dependence is high parking prices within city centers that discourage commuting. It is important in policy administration to discourage private vehicles for travel to and from work, but in order to do this effectively and equitably other modes that offer comparable service must be established. In less developed nations, this method is more applicable because lower income families are less likely to have cars and therefore the introduction of greater expenses does not hinder them as much. In fact, when collected revenue is redistributed to public transportation projects this practice is particularly good for the less economically advantaged. In wealthier nations, automobile ownership is the dominant means of travel and therefore levying heavy tolls is less socially responsible because it takes away from poor families disproportionately.

With all of the economic considerations surrounding transportation, revenue collecting programs are particularly attractive to governments. These methods include taxes and tolls that are not new developments, but charging fees based on traffic levels as a management tool is different. Despite implementation in Singapore during the 1970's, very little activity has occurred in the development of congestion pricing programs. Due to technological process, however, governments are finding this concept more favorable. In the following example, a recent initiative aimed at reducing congestion in a developed city offers insights into possibilities.

5.5.3 London: Dealing with Congestion

This United Kingdom capital city has played a major role in the Island's geographical history. The city layout has evolved over time, but much of the city proper was developed hundreds of years ago before accommodation for motorized vehicles in transportation planning. As such, congestion is traditionally high in the city, which induced the movement towards a pricing model that charges drivers for access to London's center. With the election of a new major in 2000, London prepared to enact a 21 square kilometer area pricing scheme aimed at limiting congestion and deriving revenue for transportation projects. The congestion charging program began in February of 2003 and has since been successful in improving transportation efficiency and providing an income stream, but potential for improvement remains.

The design of the policy favors simplicity aimed at success in implementation and based on a straightforward cost structure. The program consists of a flat charge of five pounds for any vehicle entering the city center between 7:00 am and 6:30 pm on weekdays only. Exempt from the charge are licensed taxis, buses, motorcycles, and vehicles used by disabled people; residents within the zone pay 10% of the standard fee. Payment alternatives have improved since the program's implementation, and mobile phone messaging has become particularly popular. The enforcement of the scheme is performed by complete documentation of license plates on vehicles entering the designated area and their comparison to a list of pass purchasers. Thus, anyone not paying for access to London's interior receives a bill for eighty pounds, but like London's parking fines this cost is reduced by one-half if paid within two weeks and alternatively increases by 50% if unpaid after four weeks.

London's cordon pricing plan has not met initial estimates, but the program has paid for itself and produced additional monies that the city has reinvested in public transportation. Figure 10, below, shows the projections prior to operation considering only the first three years of preparation and five years of operation from 2003 to 2008. The two columns distinguish between total net present values and annual values for the projects expenses and revenue.

Figure 10: London's Financial Projections

Congestion Charging Program Projected Costs and Revenues*

	Total (NPV)	Per Operating Year
Start Up Costs	£180	£36
Operating Costs	£320	£64
Total Costs	£500	£100
Charge Revenues	£690	£138
Penalty Revenues	£110	£22
Total Annualized Revenue	£800	£160
*Values are given in Millions		

[Source: Litman][152]

The first full year of operation ending in February of 2004 showed that original estimates of daily users were too high, resulting in revenue of £100 million instead of the anticipated £138 million. As a result, the intention to spend 38% of annual revenue on the bus and subway systems has been altered to provide fewer funds for these endeavors. The program actually netted £68 million for reinvestment in 2003/2004, and the government expects this will increase to £80 million for the second year of operation.[153] Nevertheless, the congestion pricing scheme is paying for its installation and generating millions of dollars in income for the city's transportation budget. Therefore, the project is a beneficial financial venture from a cost-benefit standpoint, and this analysis does not even factor in the environmental and mobility advantages to the inner city that are difficult to quantify but still exist.

As the first area pricing plan in a major European city, London's program sets a precedent for similar policy measures and serves as an example to other cities about what can be done to confront urban transportation problems. The program has reduced peak congestion by 30% and raised bus rider ship by 14%.[154] Still, London's scheme neglects important elements that include price variation based on distance traveled, peak congestion periods, or the importance of routes used. The costs of the program are certainly high with a large commitment to the administration necessary to run the

[152] Litman, Todd. (2004). London Congestion Pricing: Implications for Other Cities. Victoria Transport Policy Institute.
[153] Greater London Authority. (2004). The Mayor's Annual Report 2004. <http://www.london.gov.uk/mayor/annual_report/docs/ann_rpt_2004.pdf>
[154] Ibid

operation, but the monies necessary for a more complex system would certainly escalate the total costs and would affect profitability. While critics discuss the return on government investment and express concerns over reduced trips into the city, the program has certainly proven to be a good measure, and efforts to expand congestion area pricing westward to cover more of London are underway. Other future developments may include newer technologies and vehicle tracking for more accurate pricing.

5.5.4 Institutional Organization

Institutional deficiencies can derail even the most well suited transport agendas and policies. City government must be well organized and defined with responsibilities identified, overlaps removed, and cooperation stipulated between appropriate agencies through hierarchy structure. As previously emphasized, coordination between land use and transport must be organized, like in Curitiba and Singapore, where the collaboration has yielded positive development results.[155] The jurisdictions and functions of city governance must be laid out purposefully. If they are not, poorly integrated networks can result from uncoordinated planning and contention between government entities struggling with opposing ideologies that favor selfish interests. When planning of roadways and public infrastructure are separated institutionally, disputes arise and if roadway authorities have more power, as more often the case, they can force less suitable design of networks.[156] Moreover, government efforts to clearly and appropriately structure must be supported by staffing and training. Forgoing expenditures on personnel and training may seem economical, but without proper oversight all of the monies dedicated to city programs will be used inefficiently. Therefore, developing nations must finance training and sufficiently sized staffs, drawing from international resources as necessary.

Distribution of government authority plays a role in the capability of large cities to govern effectively. Most megacities extend over metropolitan regions encompassing

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[155] Gwilliam, Ken. (2002). Cities on the Move: A World Bank Urban Strategy Review. The World Bank, Washington D.C.

[156] WRI WRI, UNEP, UNDP, and World Bank. (1996). World Resources 1996-1997: The Urban Environment.

geographical areas of multiple cities or counties. When national governments fail to consolidate power, city officials contend with each other, unwilling to surrender authority or financial control and making progress difficult as evidenced in Manila, Caracas, and Lima.[157] Overcoming this pitfall and forcing the necessary consolidation has helped Bangkok to improve transportation with the assistance of special legal and regulatory treatment. There are a variety of ways to structure government, but it must be done with particular allowances for the complexity of planning and operating large networks and the importance of assigning responsibilities to the correct level of administration.

5.5.5 Protecting Development and Finding Balance

The expenditures necessary to have an extended road network can overwhelm government budgets, resulting in inability to maintain and replace infrastructure, which hurts growth potential. This is particularly true of developing nations that look to foreign investment as a major source of growth. When international companies make investment decisions, they heavily weight the quality of existing infrastructure in selecting project locations.[158] On the other hand, large public projects require huge investments on the part of the government or a least commitments when public-private partnerships are instituted. It is essential for urban governments to balance budget allocation to public and private modes. While dedicating roadways to transport is essential for mobility, it must be accompanied by alternatives for passenger movement. Such dispersion improves overall efficiency and sustainability of cities, making them better prepared for future challenges and pressures by controlling rather than reacting to change.

The balance of government investment is critical to transform automobile dependant systems and the chaotic systems of the developing world into more balanced networks. As Vukan Vuchic argues in his book, modal balance is crucial in large cities that must rely heavily on multiple modes serving distinct roles.[159] Resources must be divided to maintain a balance between the priorities of providing good public transportation services

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[157] Gwilliam, Ken. (2002). Cities on the Move: A World Bank Urban Transport Strategy Review. World Bank, Washington D.C.

[158] United Nations Center for Human Settlements. (1996). An Urbanizing World: Global Report on Human Settlements. Oxford: Oxford University Press.

[159] Vuchic, Vukan R. (1999) Transportation for Livable Cities. Center for Urban Policy Research.

while keeping roadway traffic at suitable levels. Public transportation must be attractive enough in quality and level of service that it rivals the advantages of owning private vehicles. This goal, however, should not be exceeded, whereby road demand falls below capacity resulting in superfluous infrastructure and reduced toll revenues. Thus, there is a fine balance in building a successful urban transportation network, which also requires continued monitoring and reassessment to maintain its sustainable design.

Solving transportation problems in large cities poses numerous cases but with one of two basic scenarios that are distinguishable in some instances by the development levels of the home nation. In certain megacities, the urban form has been established through decades of building, and automobile dependence holds a place in the cultural lifestyle. These environments are expensive to reshape, but they usually have larger budgets and can pursue system improvements by focusing on vehicle alternatives and system efficiency. The latter can be accomplished through developments in intelligent transportation systems that regulate roadway demand, effectively increasing supply without physically changing it. On the other side, urban growth in many poorer regions has occurred with limited transportation supply, and this allows more freedom to shape a network through transportation corridors, land use planning, and other measures that produce a better framework for transport efficiency. In addition, these cities should focus on engines and fuels with available technology to improve their vehicle fleets that lag behind the status of those in more developed countries.

5.5.6 Demand versus Supply Solutions

The last two sections in this Chapter have discussed urban mobility and identified important aspects of progressing from the problematic conditions to better alternatives. In order to lay out policies for evaluation and selection, the distinction between supply and demand management must be developed. Travel demand management revolves around influencing the travel patterns and their characteristics to improve efficiency. Supply side management is the more traditional provision of infrastructure, but it has more recently incorporated technologies and innovations that increase the effective

capacity. These two approaches will be developed in sections of the next chapter in the context of market based and regulatory policies, both are important tools.

6.1 Travel Demand Management

The growing failure of traditional supply-side solutions to sufficiently reduce air pollution, lessen congestion, or improve mobility has lead to a growing realization that demand management strategies must be employed. The family of policies and regulations that aim to reduce demand for private vehicle travel is termed Travel Demand Management (TDM). TDM is a general term for strategies that result in a more efficient use of transportation resources by impacting the level of demand for these resources. TDM can also encourage people to use the optimal transport mode. There are a variety of TDM strategies, each with differing objectives and results in terms of travel behavior modification, the basic goals of TDM polices may be summarized as:

- To increase travel mode choices
- To provide incentives for use of optimal travel mode
- To increase economic efficiency
- To increase travel choices for disadvantaged residents
- To reduce emissions from motor vehicles
- To improve the livability
- To complement other environmental initiatives
- To achieve reduced costs of implementation, monitoring, and enforcement

There are arguments against the use travel demand management in the form of government imposed constraints. For example, one claim is that demand-side measures can create cleavages between those who bear the costs and those who reap the benefits. Other arguments propose that travel demand management policies are ineffective, interventionist, and regressive. The latter specifically refers to socio-economic sustainability and the reality that flat charges take a greater share of the income from the more disadvantaged of city residents.

The counterpoint to the regressive argument against TDM programs is that lower income level commuters tend to value having good transit. Some TDM strategies do involve regressive fees. Congestion pricing tolls and parking pricing increases represent a greater

portion of income for the poor. However, these policies are no more regressive than any other taxation mechanisms, particularly if there are viable travel alternatives that allow lower income level people to avoid the fees. The social-equity impact of road pricing largely depends on how the revenues are used. When revenues are redistributed into public transportation systems in ways that benefit underprivileged populations, these groups can achieve net gains. The funding can not only create quality public transit systems but can slow the degradation of roadways and infrastructure by diverting demands on them. This concept is central to the demand-side management programs. TDM strategies that induce shifts to public transit use can also benefit lower income people and non-drivers by improving the utilization, profitability, and quality of these transport alternatives. [160]

TDM policies have also been criticized for their lack of effectiveness at managing travel demand. Historically non-pricing incentive policies have not been very effective. The data analyzed by Litman of the Victoria Transport Planning Institute (1998) indicated that stand-alone, incentive based TDM policies typically result in no more than ± 1.5% reduction in demand. Additionally, some TDM initiatives require heavy capital investments in order to achieve a single trip reduction. The same VTPI study concluded that the most effective incentive based policies include direct transit subsidies, parking discounts, and High Occupancy Vehicle lanes. Litman concludes that in order to achieve statistically significant results, in terms of reduced demand, that TDM incentive policies must be combined with pricing mechanisms.[161]

"Many countries are assuming that growth of motorization means they have to start building highways as fast as they can, which is probably true. But it would be a mistake to think they could build them fast enough to meet the needs of this demand. The only real option that cities of the developing world have to avoid horrendous congestion in the coming years is some combination of congestion pricing and traffic management." (Source: Gakenheimer)[162]

The policy matrix below illustrates the continuum along which most transportation initiatives may be classified. Some programs such as "No Car Days" fall squarely within

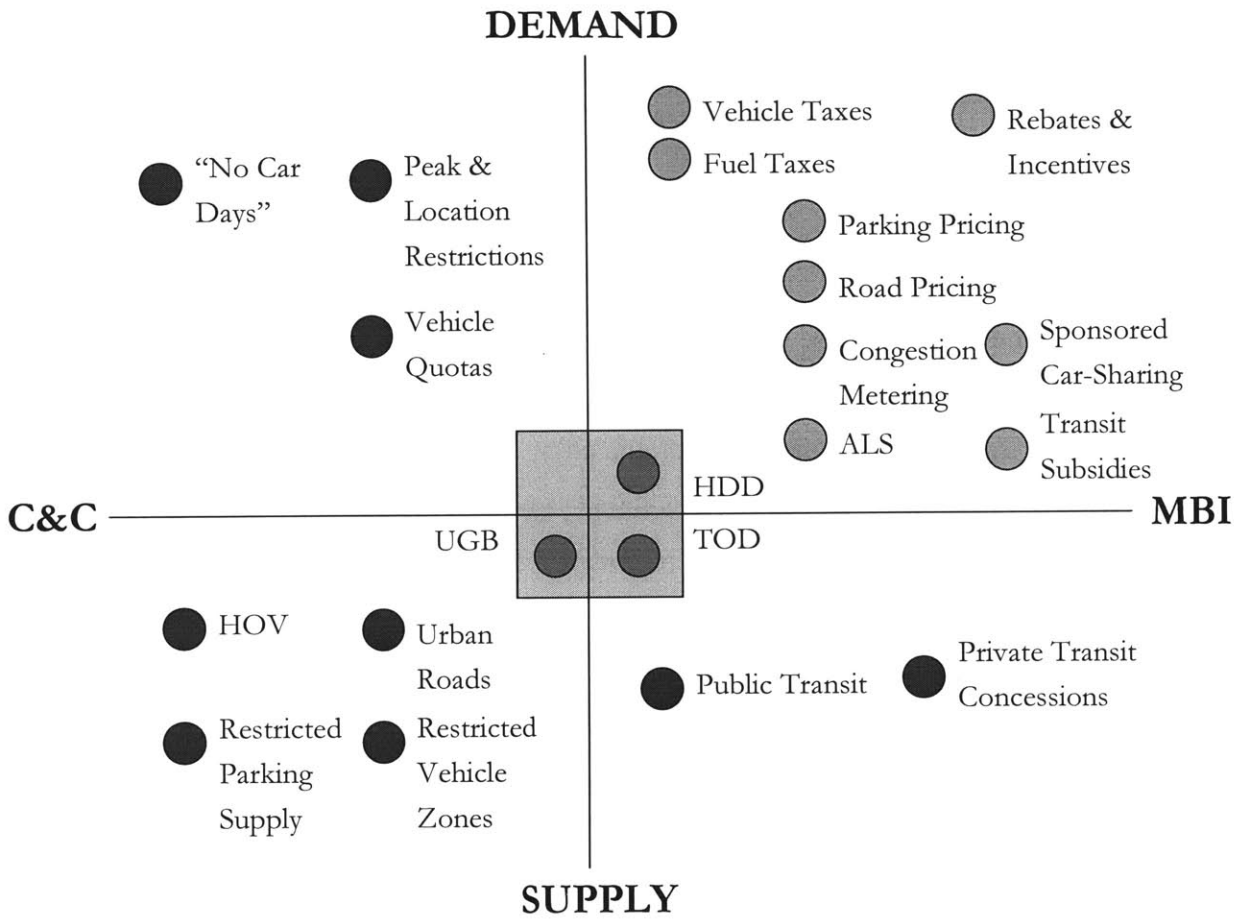
[160] Litman, Todd. (1996). Using Road Pricing Revenue: Economic Efficiency and Equity Considerations. Transportation Research Record.

[161] Litman, Todd. (1998). Evaluating Criticism of Transportation Costing. Victoria Transportation Policy Institute. <http://www.vtpi.org>

[162] Gakenheimer, R. (1996) What to do with all those cars? MIT Center for Transportation Studies. Newsletter #39. Cambridge.

the defined quadrants and are easily categorized. Other initiatives span across the quadrants and may influence both supply and demand, or have characteristics that are not easily designated as Command and Control or solely Market Based.

Figure 11: Transport Policy Matrix



The following four subsections in this chapter outline demand and supply-side policies with a description of the program and examples of their implementation in different cities. Demand-side management has developed more recently and holds considerable potential. The remaining two subsections of this chapter describe land use planning practices and intelligent transportation system, which have significant implications in urban transportation applications.

6.2 Demand-Side Command & Control Regulations

6.2.1 Car Day Restrictions

No Car Day policies generally mandate that residents of the city avoid using their cars during a specific day of the week, month, or year. Car use restrictions may apply to all vehicles or to certain categories of vehicles. Alternately, no car days may only apply to vehicles with certain license plates numbers, often alternating between even and odd numbered plates.

In Mexico City, the policy took the form of "No Hoy Circula"[163], which stipulated that cars with even numbered license plates would have access to the city center on alternating days with odd numbered plates. The results were catastrophic. Many wealthy residents acquired a second older vehicle; grandfathered by the emissions law, and drove this vehicle on days when their normal car was prohibited. Lower income residents shifted travel mode and began using taxis with increasing frequency. The increase in demand for taxis lead to a predictable increase in the taxi fleet supply. The number of cars circulating remained roughly unchanged, while the average travel speed decreased, levels of air pollution increased, and social costs of inconvenience and delay mounted.

On February 24, 2000 the mayor of Bogota Enrique Penalosa declared the first "Car Free" day in Latin America under the title "Sin Mi Carro". For twenty-three hours, almost all 832,000 private vehicles remained parked, and the city's residents took to the street on foot, bicycle, bus and taxi. The effects were dramatic with a significant decrease in noise pollution, air pollution, and traffic accidents. More importantly, however, there was an overwhelming public support for the effort. *Sin Mi Carro* was designed less as an effective traffic-management tool than as a public-relations campaign aimed at raising consciousness and changing attitudes and garnering support for innovative transportation policies.

[163] Makler & Zegras. (1999). Regional Strategic Transportation Planning in Mexico City. Mexico City Project Seminars. MIT, Cambridge.

6.2.2 Vehicle Quotas

Vehicle quota's set limits on the number of vehicles of a given type that are allowed within the boundaries of the city. This is most commonly enforced through restricting vehicle ownership and limiting the number of driving licenses for a particular vehicle type.

Singapore has the Vehicle Quota System (VQS) that fixes an annual limit on the number of vehicles that can be purchased. Instead of allowing the market to determine the optimal number of vehicles on Singapore's roads, the government controls the vehicle population in order to achieve a specific target for the vehicle population in line with traffic conditions and road capacity. The quotas, however, when coupled with rising personal incomes and increasing demand for cars, have lead to a cost of ownership that is exceedingly high. The high up-front cost of owning a vehicle also serves to discourage the effect of other TDM policies as the marginal cost per trip is actually reduced with each trip taken. Thus, the policy has resulted in maximizing the use of the vehicle fleet, and encouraging the purchase of large expensive foreign vehicles that are in effect taxed at a lower relative rate than smaller cheaper cars. This translates into an effectively regressive tax, and the high fixed costs result in people feeling relatively less impact from the variable costs of fuel taxes, parking fees, and congestion charges.[164] Overall the program has been successful in controlling vehicle numbers but has left the public with less discretionary income, which leads to reduced welfare and lower consumption, certainly not the intended consequences of the VQS.

6.2.3 Peak & Location Restrictions

Peak and location restrictions are modified versions of the vehicle bans and "no car days". Essentially the regulations operate identically. Certain vehicles, distinguished by class or license plate are forbidden from entering a specified zone during highly congested times, often during the morning and evening rush hours. Peak and location restrictions are the command and control alternative to Singapore's Area License Scheme which stops short of prohibiting entry, instead charging drivers for the marginal cost of contributing to congestion.

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[164] The Economist (1998). A Survey of Commuting, September 5. pp. 3-7, 10-18.

Bogota's "Pico y Placa" regulation[165] fights mounting vehicle congestion problems. In Bogota, 30% of trips are made in the expanded downtown area, creating congested corridors. A vast majority of these trips are less than 8km in length. Approximately 70% of Bogota's air pollution is caused by automotive vehicles, of which 50% is attributed to private cars. These factors, in conjunction with a high rate of motorization growth, and low public transport vehicle speeds impelled the municipal government to act to reduce the number of vehicles in circulation. The Pico y Placa, translated into English as peak and license plate, restrictions were instituted to combat ever-worsening traffic congestion in the city center, to reduce air pollution, promote public transport use and to increase livability. Pico y Placa is a regulation that restricts 40% of privately owned vehicles from traveling into and within the entire urban perimeter during peak weekday hours. The restriction on private vehicles is made according to the last number on the license plate. Restrictions are in effect from Monday through Friday during the morning and evening rush hours (7:00am - 9:00am and 5:30pm - 7:30pm). Pico y Placa affects a large portion of the total vehicle fleet with 99.9% private vehicles and 90% total fleet affected.

[165] The Commons. (2000). Pico y Placa. Paris. <http://www.ecoplan.org/votebogota2000.org>

6.3 Demand-Side Market Based Initiatives

6.3.1 Sponsored Car Sharing[166]

Sponsored car sharing is a subsidized automobile rental service intended to substitute for private vehicle ownership. Municipalities provide direct subsidies to users or indirect subsidies to companies offering car-sharing services. To induce a modal shift from car ownership to car sharing, the program must be accessible, affordable, convenient and reliable. The typical charge to users is $1-$2 per vehicle-hour plus and additional charge of 15-25¢ per kilometer. Charges typically cover all the vehicle-operating expenses including fuel, maintenance, insurance, repair, and cleaning. Analysis by VTPI has demonstrated that car sharing becomes an attractive and viable alternative to ownership if the vehicle is driven less than 10,000 km/year. Car sharing provides a good incentive to minimize trips with 40-60% reduction per capita. Car Share vehicles typically replace three to four private vehicles. Sponsored car sharing may be an innovative way to encourage clean fuels, fuel efficiency, and to discourage motorcycle ownership.

Figure 12: Vehicle Use Options Compared

Criteria	Carsharing	Private Ownership	Conventional Rental	Taxi	Public Transit
Convenience	Medium	High	Varies	High-Medium	Medium-Low
Fixed Charges	$100/yr	$2,000-4,000/yr	None	None	$600/yr max
Time Charges	$1.50/hour	None	$20-40/day	None	None
Charge / Mile	20-40¢	10-15¢	5-10¢	$1.00	21¢

[Source: VTPI][167]

6.3.2 *Rebates and Incentives*

Tax rebates can be employed to encourage businesses and individuals to alter their travel modes and commute time, and to participate in voluntary TDM programs.

Seoul employed a traffic tax rebate program[168] as a means to control infrastructure demand. After decades of rapid economic expansion, coupled with a ballooning private vehicle fleet, the city of Seoul imposed a "traffic tax" on businesses and individuals to help fund mass

[166] Litman, Todd. (2001). Car-sharing Vehicle Rental Services That Substitute for Private Vehicle Ownership. VTPI On-Line Encyclopedia. British Columbia. <http://www.vtpi.org/tdm/tdm7.htm>

[167] Ibid

[168] Kuranami, Winston, Kimura, Rose and Nakagawa (2000). Study on Urban Transport Development. PADECO Co. Ltd. World Bank Press. Washington DC.

transit investment. In the mid 1990's the city began experimenting with a number of innovative, voluntary TDM programs including staggered work hours and car pool programs. To encourage business to provide the needed infrastructure and support, the city government began a program of traffic tax rebates for businesses that agreed to implement TDM measures. Thus, if businesses voluntarily instituted staggered work hours, provide company buses, or provided their employees with transit subsidies they benefited from a rebate of the traffic tax on a predetermined scale.

6.3.3 Fuel, Vehicle, and Traffic Taxes

Taxation mechanisms have been employed to achieve three objectives: (i) to reduce congestion; (ii) to generate income for mass transit; and (iii) to discourage car ownership.

Seoul's taxation strategy[169] was the product of an extended period of unsustainable development. Tremendous population and income growth resulted in a 20% increase in private vehicle ownership annually in Seoul. By the late 1980's, the traffic congestion problem was severe, the morning and evening peaks extended for the majority of the day especially around the Central Business District. Further, mobile source emissions accounted for 77% of Seoul's air pollution, with diesel fumes as a major contributor. Congestion and pollution were further exacerbated by a decline in diesel prices. Thus, the "traffic tax" was imposed on businesses residing in Seoul's CBD during the early 1990's to fund mass transit initiatives. Vehicular taxes were imposed to reduce private car ownership, and thereby congestion, but also to encourage saving and restrict consumption of luxury goods. Vehicular tax measures in Seoul are drastic by Western standards, in place since 1985; these taxes account for up to 75% of the original vehicle price. At first, the tax strategy was successful at reducing vehicle ownership; however, by 1995 the government began reducing constraints and lowering emissions standards. [170] In general, the low elasticity of travel demand coupled with an opaque charging mechanism results in the need for very high taxes to achieve a substantial reduction in vehicle use. Taxation is

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[169] Kuranami, Winston, Kimura, Rose and Nakagawa (2000). Study on Urban Transport Development. PADECO Co. Ltd. World Bank Press. Washington DC.
[170] Ibid

less efficient in altering user behavior than road use pricing because it is levied without regard to location, time, and congestion.

6.3.4 Mass Transit Subsidies

Direct subsidies to economically disadvantaged citizens can bolster ridership on mass transit systems, reducing demand for private vehicle use. Subsidies may be made by government or employers. Alternately, but less effectively, subsidies may be granted by governments directly to the operators of mass transit system in order to reduce user fees.

6.3.5 Road Pricing

Road pricing policies seek to encourage optimal use of the road system and to reduce congestion by charging drivers for the marginal cost they are contributing to congestion. As traffic levels increase towards saturation the marginal cost of one additional vehicle increases dramatically. Therefore, road pricing is most effective when the charge is sensitive to the current congestion level or alternately to a time of day when the congestion levels may be approximated. By pricing the externalities caused by use, road pricing achieves a highly efficient allocation of resources.

Due to the low elasticity of travel-demand, road pricing has the potential to generate substantial revenues. These revenues are typically used to recover the cost of providing roads and to fund mass transit investment. However there are serious considerations regarding road pricing effects on social equity. Equity concerns are minimal in developing cities as most drivers of private vehicles are in the upper income categories. Further, the use of marginal pricing without a clear understanding, on the part of the public, of the full external costs of congestion may generate strong public resistance. To ensure effective implementation of road pricing policies governments must understand that road pricing is feasible only if there are viable transit alternatives. Additionally, marketing and public consultation must be incorporated into the planning process.

Stockholm's road pricing experiment[171], known as the Dennis Package, was conceived of with the primary goal of generating revenue for road and public transport investment, not congestion relief. The Dennis Package established a cordon around the city center and levied a toll on all vehicles passing into the city-center during the day. The Dennis Package was primarily an investment plan whose total price was projected to be USD$6.1B. The use of tolls for cost recovery was meant to finance $1/10^{th}$ of the total cost of the new ring roads, which were intended to relieve congestion in the city center by allowing high-speed by-pass of the city center. The aim there was to enhance the speed and safety of city buses servicing the city-center.

The tolling cordon around the city-center employed both cash and electronic payment systems. Electronic payments were made by anonymous smart-card technology and enforced using digital photography of violating vehicles' license plates. Congestion reduction as a direct consequence of the pricing scheme is difficult to isolate as the new by-pass roads diverted a large percentage of traffic from the city center by themselves. However, the analysis of projected traffic volumes concluded that the combination of tolls and by-pass roads would result in a significant increase in travel speed and a steep decline in automobile use. The net effect was that total vehicle miles traveled (VMT) remained unchanged from pre-investment levels, with the result being a dramatic increase in accessibility without adding any environmental externalities. The scale of the cordon increased its effectiveness by eliminating untolled entries. To counter public resistance to the program, seasonal passes were made available to commuting families, to reduce the individual burden of the tolls.[172]

The success of the Dennis Package road-pricing scheme has lead to further study being conducted on differential pricing schemes on a national level. The study conducted by Sveder and Nylander criticizes the cordon scheme for reducing city-center traffic by inducing regional traffic. They claim that the net effect on traffic, regionally, has been a modest reduction of 2%. Their recommendation is to expand the cordon scheme for

[171] Gomez-Ibanez & Small. (1994). Road Pricing for Congestion Management: A Survey of International Practice. Transportation Research Board. National Research Council. Washington DC.
[172] Ibid

Stockholm into a comprehensive 5-zone plan, and to replicate this for all Swedish cities with populations over 60,000. The initial estimates of revenues generated would be in excess of USD$9B per annum, or more than the total state income in 1997. Furthermore, the social cost-benefit analysis determined that congestion is the primary source for social marginal cost for road traffic. As such, differentiated road user charges have the potential to improve social benefits while efficiently utilizing existing road capacity.[173]

6.3.6 Congestion Metering

The concept of congestion metering takes road pricing to its absolute theoretical limit. The marginal cost of congestion induced by the vehicle would be calculated and charged in real time without any pricing inefficiency. The prices adjust automatically in response to the actual level of congestion encountered, falling to zero in free-flow conditions. This can be achieved by linking the in-vehicle transponder to the speedometer and odometer. Once the vehicle enters a tolled zone, the calculation of travel speed and distanced traveled would provide the data needed to compute the applicable marginal charge.

In the Cambridge, England congestion metering trial[174], cars within a 12-15 mile radius of the city were to be fitted with an electronic metering device. This device connected to the odometer, so that congestion could be monitored based on speed and distance traveled. The owner of the vehicle had an onboard metering device that would be issued with a smart card, which could be refilled electronically at garages, gas stations, and banks. The meter would be dormant outside the center, but activated by beacons in the center sending information via microwave transponders to it, to charge for units of congestion. The original proposal called for an initial charge of $0.36 (1990) for traveling a certain distance at speed of less than 10km/h with more than four stops. The transponders would deactivate when departing. Visitors would be accommodated with daily passes sold at a fixed price.

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[173] Sveder & Nylander. (2001) Internalization of External Cost: An Assessment of Road Pricing in the Stockholm Region. Transek AB. Solana, Sweden.

[174] Ison S. (1998). A concept in the right place at the wrong time: congestion metering in the city of Cambridge. Transport Policy No.5. London

Brian Oldridge, the champion of Cambridge's congestion metering trials, retired in 1993 and the plan died soon thereafter. The county council was particularly concerned with a severe public backlash to a scheme whose charges are unpredictable and unavoidable. They were also concerned that from a driver's perspective the highest charges would be levied while the user was stuck in traffic and already aggrieved. There is also a potential legal danger to assessing congestion charges, since drivers will undoubtedly challenge the notion that they, rather than city-planners, construction work, accidents etc. were the cause of the congestion for which they were being charged.[175]

6.3.7 Parking Pricing 176

Parking pricing initiatives use the cost of parking to alter consumer travel behavior. Full-cost parking pricing requires that motorists pay directly for the cost of using parking facilities, including all external costs. Parking pricing may be implemented as a TDM strategy to reduce vehicle traffic in a specific area, to recover parking facility investment costs, or to generate revenue for other investments. Full-cost parking charges represent a significant shift from the status-quo application of charges. "Most vehicle parking is provided free or significantly subsidized. Of the 95% of U.S. employees who commute by automobile, only 5% pay full parking costs and 9% pay a subsidized rate, and parking is not priced at more than 98% of non-commute trip destinations. When parking is priced, there are often substantial discounts for long-term leases and sometimes there is no hourly or daily rental option, leaving motorists with little financial incentive to use alternative modes." [177]

In the mid 1980's Eugene, Oregon tested parking prices[178] when it raised rates at two municipal garages and several surface lots. Rates at the garages increased from $16 to $30 over a period of one year. Surface lot rates increased from between $6-16 to $16-34.

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[175] Gomez-Ibanez & Small. (1994). Road Pricing for Congestion Management: A Survey of International Practice. Transportation Research Board. National Research Council. Washington DC.

[176] Litman T. (2000). Parking Pricing: Direct Charges for Using Parking Facilities. TDM Encyclopedia. Victoria Transport Policy Institute. British Columbia.

[177] Bureau of Transportation Statistics - USDOT (1992). A Summary of Travel Trends. National Personal Transportation Survey. <http://www.fhwa.dot.gov/ohim/nptspage.htm>

[178] Marwick, P. & Mitchell and Co. (1985). West University Neighborhood Parking Pricing Demonstration Program in Eugene, Oregon. Final Report for the U.S. Department of Transportation. Houston.

Meter rates remained unchanged, but fines were increased for commuters parking in short-term stalls for shoppers. Monthly parking-permit sales declined from 560 to 360, a decline of 35%. Half of the daily-parking facility users participated in car-pools or rode the free shuttle, while the other half changed parking locations. The Eugene parking program demonstrated the potential for using pricing to shift user preferences for parking location, and highlighted the need for enforcement strategies to accompany pricing.

6.3.8 Area Licensing Schemes (ALS)

Area licensing schemes are crude versions of road pricing which define tolled areas within a city during peak congestion times. Essentially, there is little difference between an area licensing program and a location restriction, aside from the obvious choice given to "purchase" access to the restricted zone.

The Area Licensing Scheme was introduced in Singapore's central business district in 1975. The primary objective of the ALS was to limit traffic and alleviate congestion during the peak commute times in only the most congested areas. By raising the cost of driving to the CBD in privately owned cars, the Land Transit Authority created a strong disincentive for their use.[179] The secondary objectives of the Area Licensing Scheme (ALS) were to improve overall accessibility and mobility within the CBD. Accessibility and mobility were thought to be of paramount importance to the area's economic life and vitality. In the system, all vehicles had to display a valid license during the restricted hours. Traffic personnel stationed at the central business district (CBD) entry points recorded the registration number, make, and color of any vehicles that failed to display the proper license. All violations were recorded without stopping the offending vehicles in order to promote a smooth flow of traffic, and identified violators were mailed tickets.

The effectiveness of the ALS in the Singapore CBD has been tremendous. Traffic flow was substantially eased and pollution from mobile sources in the CBS dropped dramatically. Total traffic in the CBD decreased 73% shortly after the ALS was

[179] Third World Network. (1999). Control of Private Vehicles in Urban Areas: The Vehicle Quota System and The Area Licensing Scheme. United Nations Development Programme - Special Unit for Technical Cooperation among Developing Countries. New York.

instituted; the congestion was partly transferred to the surrounding districts, which faced an increase of 23%. Carpooling increased by 33%, resulting in a net decrease of 44%. However, although congestion was brought under control in the CBD, elsewhere congestion worsened. Public buses took longer to reach their destinations, as boarding times increased due to higher demand. The high cost of monitoring and enforcement of this complex system was also a problem. Singapore's solution to the high cost of monitoring and enforcement has been to institute the most advanced and successful Electronic Road Pricing system in the world.

There were some initial fears that the ALS would adversely impact the viability of the CBD as the commercial center of Singapore. These fears were proven unfounded. Reduced congestion, air pollution, and noise created a more livable city center and this improved environment attracted financial and service-oriented businesses. Employment in the CBD rose by 30% in the years following the ALS implementation[180].

The ALS had as initial capital cost of just S$6.6M (USD$3.7M). The ALS monthly operating costs from 1975 to 1985 were approximately S$59,000. The 1989 expansion of the restricted zone and extension of the tolling hours had an initial cost of S$170,000 and increased the monthly operating to S$295,000. During this period (1975 - 1997) the average annual revenue from licenses was S$38M and an additional S$3.85M was generated from fines, for a total of $41.85M per year. It is estimated that the Singapore government achieved a rate of return of 1590% from its Area Licensing Scheme[181]. More significantly, the ALS and also the VQS program worked in Singapore because they were complemented with legislative and fiscal measures, rigorous land use planning, reorganization of transport policy institutions, investments in the public transport system, traffic management measures, and effective enforcement.

[180] Tay, R. (1996). Congestion Alleviation in Singapore: A Review of Demand Management. In C. Lim (Ed). Economic Policy Management in Singapore (pp 313-44). Singapore: Addison Wesley.
[181] Menon A. et al. (1993). Singapore's Road Pricing System: Its Past, Present and Future. In ITE Journal. Volume 63, Number 12.

6.4 Supply-side Command & Control

6.4.1 Restricted Vehicle Zones

Private vehicle bans have been employed to reduce congestion in city centers by forbidding all private vehicles from entering specified zones during certain times of days, or all day long. Typically, road space previously used by private vehicles is used solely for mass transit busing or for pedestrian and cycles only.

In 1983, in response to a burgeoning private vehicle fleet and poor air-quality Tehran instituted a Restricted Travel Zone[182], which limited 90% vehicles from 23Km^2 in the center of the city. Exempted vehicles included taxis, buses, and emergency vehicles. In order to obtain a permit to travel through the Restricted Travel Zone, all vehicles must pass a rigorous mandatory emission inspection and control program. Enforcement of the RTZ, however, has been greatly compromised by a lack of resources and trained officers. Consequently, subversion of regulations and restrictions is the norm. In spite of the private vehicle ban the average CO, PM_{10}, SO_2 levels in the CBD in 1998 were three times the World Health Organization (WHO) minimum standard. However geography, fuel quality, average fleet age, lack of public transport, inefficient planning, a lack of green space, poor enforcement, and low fuel prices all contributed to off-setting any environmental benefits.

6.4.2 Restricted Parking Supply

Reduction of the total available parking supply or restricting the expansion of the current supply can induce a shift in driving behavior by increasing the time spent searching for parking. Reducing parking supply also tends to increase parking prices, and supports strategic transportation and land use objectives if implemented as part of an extensive TDM initiative.[183] The strategy can be effective if strong enforcement capacity is prevalent but may also lead to harmful spill-over effects in the forms of "moving parking lots", as drivers circle areas in search of parking locations. This effect is difficult to overcome due to the information asymmetry caused by the small yet persistent chance

[182] Gozaresh. (2000). Get Your Masks Ready; Tehran's Poisonous Air is on the Way. Social and Economic Monthly. Tehran.
[183] Litman, Todd. (2000). TDM Encyclopedia. Victoria Transport Policy Institute. British Columbia.

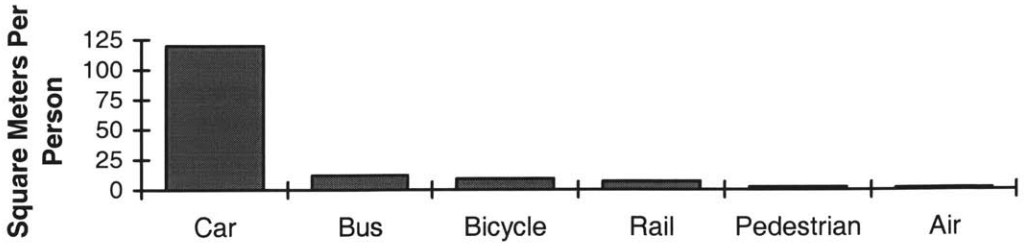
that a spot will be available, or open up in short course. Therefore, it is imperative that a reduction in supply be accompanied by a corresponding increase in price, to discourage driver speculation.[184]

Mexico City severely curtailed the number of public parking spaces available, but the policy backfired on them and the overall TDM strategy. The "extra" cars started double-parking in the city streets, reducing capacity. The parking police were overwhelmed with infractions and could not adequately enforce the double-parking prohibition. The result was constancy in the number of cars, increase in pollution level per car, decrease in road capacity, and severely hampered mobility for the entire city including the public buses.[185]

6.4.3 High Occupancy Vehicle Lanes (HOV)

High Occupancy Vehicle lanes are a road-supply reallocation strategy employed by governments to reduce congestion on major thoroughfares. The concept is to increase the number of people traveling on the roadway without increasing the number of vehicles. Since single occupant vehicles (SOVs) are one of the least efficient modes of transport, encouraging ride-sharing using HOV regulations has the potential to dramatically increase the number passengers serviced. Figure 13, below, shows contrasting space efficiencies.

Figure 13: Road Space Required by Mode of Travel



[Source: Teufel] [186]

[184] Conversations with Professor Fred Moavenzadeh. (2001) MIT Department of Civil and Environmental Engineering. Cambridge.
[185] Leautaud, Juan and Perez-Barnes, Cesar. (1997). Energy and Infrastructure for Mitigating Air Pollution in Mexico City. MIT, Cambridge.
[186] Teufel, D. (1989). The Future of Motorized Transport. Transportation the Environment and Sustainable Development. Die Zuykunft des Autoverkehrs. p. 184.

An added benefit is that as groups assemble to take advantage of HOV, the overall congestion level of the roadway decreases. This poses an inherent dilemma for policy makers though. If HOV lanes are properly utilized, their positive impact on the flow of traffic on non-HOV lanes may discourage their use. There is also an environmental concern regarding HOV lanes. As HOV uses frees-up additional road space for SOV vehicles, the net effect may be to increase the total number of vehicles using the road and thus negative impacts such as air and noise pollution will be increased.[187]

Since 1993, the city of Jakarta in Indonesia has had an HOV lane program that was applied to major roads in the central region of the city, during the morning rush hour. It is better known as the "three in one" scheme. The idea was to increase the number of passenger moving through the congested areas at the height of the morning rush while at the same time reducing congestion. However, due to the presence of many "jockeys" who were willing for a fee to ride in vehicles, to raise vehicle occupancy to the requisite three, the scheme has been widely abused:

> "You may have noticed that Jakarta traffic isn't getting any better, even without demonstrations by students or other activities as Indonesia reinvents itself. A new form of entrepreneurship has arisen: kids are hiring themselves out as extra bodies to qualify for the HOV lanes, helping harried drivers get to work—and themselves to school." [Source: Nilles][188]

Theoretically, the police department was responsible for traffic management and HOV enforcement. However, they did not have the skills, experience, or inclination to do this job properly, and in Jakarta, since there was no law against the paid passengers, the scheme eventually collapsed.[189]

6.4.4 Public Road Construction

As previously stated, the construction of additional urban road capacity is problematic. There are three primary reasons for this; first new road supply tends to unleash pent-up

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[187] Humphrey, N. (2001). Reviewing the Status of HOV Lanes. TR News Number 214. Transportation Research Board. Washington DC.
[188] Nilles J. (1999). The Olympics, Jakarta Traffic, and Telework. Pacific Link Newspaper. Jakarta.
[189] Sayeg P. & Bray D. (1999) Prospects For Implementation of Electronic Road Pricing. Traffic Technology International. London

demand, which eventually leads to additional congestion; second, expenditures on roads pose an unrecoverable financial burden on municipal governments; finally, increasing road capacity can degrade transit service and revenues by encouraging car use. Transportation supply optimization measures such as HOV lanes and signal timing do not appear to be sufficiently effective to compensate.

Roadway land is often treated incorrectly as a "sunk" cost. Douglass Lee points out, "Land in urban right-of-way has alternative uses, and this value is included in published figures only when the purchase of new land is a part of current expenditures. Normally, any long-lived business investment is expected to earn a rate of return at least equal to the interest rate on borrowed funds."[190] Failure to collect rent on land used for roads imposes a financial burden on municipal governments, encourages urban expansion to replace land "lost" from the tax rolls, and skews expenditures toward roadway transportation, reducing the overall efficiency of the economy.[191]

[190] Lee, Douglass. (1992) An Efficient Transportation and Land Use System. Volpe National Transportation Research Center, Cambridge. <http://ohm.volpe.dot.gov.

[191] Litman, Todd (2001). Land Use Impact Costs of Transportation. Victoria Transport Policy Institute. <http://www.vtpi.org>

6.5 **Supply-side Market Based Initiatives**

6.5.1 Private Transit Concessions

The public sector is increasingly incapable of providing adequate financing for urban transport infrastructure. Further, the relatively inefficient provision and operation of the public transport services by public entities has resulted in increasing reliance on the private sector to provide these facilities and services. At least 80% of all urban bus services around the world are privately owned and operated. Increasingly cities are arranging concessions or other arrangements for the private provision of urban transport infrastructure including roads, light rail, and subways. Cities are becoming facilitators of public transport provision and moving away from ownership and operation.[192]

Private provision and ownership of infrastructure assets may be the best possible route in some developing markets. However, private sector participants such as investors, contractors, and technology providers face a number of daunting challenges in attempting to engage the developing-world's infrastructure markets. Namely, the current regulatory, economic, and cultural contexts are ill equipped to suit traditional 'Western' private investment. Special consideration must be made when structuring municipal concession contracts to provide adequate returns and acceptable risk levels to potential investors. Likewise, unique guarantees and agreements will have to be devised to suit municipal governments and users alike. Creative funding mechanisms may also be required, such as private land-development revenues, potential property taxes, and realized savings resulting from reduced government expenditure on road infrastructure, to guarantee economic feasibility. Financial returns must be distinguished from economic impact, but capturing economic benefits generated by transportation investments influences the financeability of projects.

Where the private sector is underdeveloped or constrained by regulation, the issues of financial sustainability do not evaporate. It is increasingly evident that public entities can

[192] The World Bank Group. (2001) Urban Transport: An Overview. <http://www.worldbank.org>

benefit from the introduction of market forces and discipline into their operations. Corporatization, public-private partnerships, and short-term operation and maintenance (O&M) contracts are some of the vehicles that help to increase efficiency and accountability in publicly administered systems. Each of these strategies solves certain problems while creating new challenges, determining which to use must be done on a case-by-case basis. O&M contracts are ideal for situations where access to capital is not the primary constraint but where inefficiency is endemic. In these situations, O&M contracts may be used to extract operational efficiencies. Driven by the profit motive, private enterprises will generally outperform entrenched public-service bureaucracies. Thus, the issues related to financial sustainability can and should influence policy makers, investors, developers, and regulators alike.

In 1995, the city of São Paolo sought to revamp its aging and inefficient public bus system through privatization[193]. São Paolo's buses were characterized by obsolete ticket collection systems and poor access for bus passengers. The service schedule was unreliable and average bus speeds were 13 km/h. São Paolo decided to pursue a privatization plan to reap the benefits of private sector ownership and operation. Bid documents for ten bus corridors were issued, defining the rules for implementation and operation of trunk-line services. All the costs associated with implementing the service, including improvements to street systems and facilities, were to be borne by the winning consortium. This innovative project demonstrated that private companies were prepared to delve into public transport finance at an unprecedented scale. Regulatory and controlling power remained in government hands with the public authorities controlling tariffs and monitoring the level of service offered against the pre-agreed targets. Although municipal authorities did attract private investors with carefully designed concessionaire compensation packages, the program failed because investors had problems securing financing. One hypothesis is that the capital markets perceived that the risks involved outweighed the potential profits.[194]

[193] Rebelo & Benvenuto. (1995). Concessions of Bus-ways to the Private Sector: The São Paulo Metropolitan Region Experience. The World Bank Group. Washington DC.
[194] Rebelo & Benvenuto. (1997). Lessons from São Paulo's Metropolitan Bus-way Concessions Program. The World Bank Group. Washington DC.

6.6 Land-Use Planning Strategies

The land-use planning (LUP) strategies are different from the policies just described and warrant a separate classification in the grouping of potential transportation management devices in this chapter. The predominant three are discussed herein. These strategies affect both the supply of and demand for road-space. LUPs may be either dictated or induced through market-incentives. Transit Oriented Development sits at the intersection of both continuums. TOD must be driven by a rational land-use and mass-transit policy, thus having Command & Control characteristics, but is simultaneously dependant upon individual choices made by city inhabitants and real-estate developers that are dictated by market forces. TOD complements and is often a prerequisite for mass transit development. Concurrently, TOD can contribute to a lower demand for private vehicle use as the proximity of residential areas to mass transit reduces the cost effectiveness of private automobile use. Another tool, high density development (HDD) involves concentrating population within a city to reduce the demand for private vehicles. On the other hand, urban growth boundaries regulate city expansion by establishing geographical border limits that either discourage or restrict exterior growth.

6.6.1 Transit Oriented Development [195]

Transit Oriented Development refers to a group land-use planning strategies geared toward the creation of residential and commercial areas designed to maximize access by public transit. In essence, it is a transportation management tool. TOD is intended to increase accessibility and travel choice through land use clustering and public transportation improvements. This strategy makes it possible to reduce the frequency and distance of car trips, and enables reduced car ownership. TOD also reduces total transportation costs and helps to create a livable community, in addition to supporting other TDM objectives like greater pedestrian access. By focusing commercial and residential development around mass transit systems, TOD facilitates association with adjacent land uses.

[195] Litman, Todd. (2000). Transit Oriented Development: Using Public Transit to Create More Accessible and Livable Neighborhoods. Victoria Transport Policy Institute. British Columbia.

The TOD model includes regional and local planning. The backbone of the TOD is the regional Trunk Line that can be heavy rail, light rail, or express bus. Along the Trunk Line are a series of Urban TODs, which are developed at high commercial and residential densities. Neighborhood TODs are composed of residential uses and local serving-shopping, and linked to the urban transit stations via feeder bus lines.[196] It is not enough for a development to be adjacent to transit; it must be shaped by transit, in terms of parking, density, and building orientation.

A TOD strategy may also include the expansion of transit systems into poorly served suburbs, including cross-urban and orbital rail lines, and the creation of new urban villages around them. In this manner, Transit Oriented Development strategies also help to increase mobility in economically disadvantaged communities. In addition, the economic impacts of a TOD can be numerous and include increased real estate values, reduced infrastructure spending, reduced transportation externalities, and economic development stimulation.

When governments are effective in controlling land use, especially when they are important providers of housing, TOD strategies can fundamentally change city structures. In Hong Kong and Singapore, the city administrations practice rigorous land-use and transport planning, and have adopted policies to enlarge the metro's catchment area by concentrating high-density public housing and commercial development close to metro stations. In these cities, the impact of a TOD strategy is clear. In these examples, "true" TOD has been achieved by a combination of public sector land ownership, housing and infrastructure provision, major development over stations and depots, and private sector development. However, when these conditions do not apply, which is the case in many developing cities, TOD strategies are less effective. Often, expected developments at and near stations did not occur.

[196] Peter Calthorpe Associates, (1990). Transit-Oriented Development Design Guidelines for the County of Sacramento.

6.6.2 High-Density Development

Low-density development encourages automobile dependency, which requires more land for roads and parking than other forms of transportation. Automobile dependency, necessitated by low-density development, encourages urban sprawl. Urban sprawl increases a number of economic and environmental costs, and increases future transportation costs.

While lower density land development provides some benefits to some individuals, many of the external costs are borne by society as a whole. Because of the many negative externalities of low-density development, many developing cities have pursued development strategies meant to foster high-density (HDD). These strategies go hand in hand with TOD, as the major benefits to be reaped from HDD are reliant on the availability of viable transit. Land-use-planning focused on attaining higher densities, together with well-integrated transit development can substantially reduce travel demand. The connection between HDD and reduced travel demand is well established.[197] For example, a recent study by the Regional Planning Association demonstrated that cities with rail transit induced high-density commercial development because they represented a long-term commitment through an investment in fixed facilities.[198] Other studies have concluded that well planned mass transit systems can induce concentrated housing around transit axes and stations, thereby reducing reliance on cars. "Total travel demand in regions that have successfully integrated HDD and transit may be lower than in other areas by factors of four to eight."[199] Finally, where urban sprawl increases municipal service costs, municipalities can share the costs of expanding transit services with the developers who benefit from access to their projects.

Efficient public transport is essential to the continuing growth of large cities' central areas. Bus systems, however well organized, have a maximum capacity of 20,000 people

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[197] Newman and Kenworthy. (1989). Sustainability and Cities: Overcoming Automobile Dependence. Brookfield, VT. Gower.

[198] Regional Planning Association. (1997). Building Transit Friendly Communities. New York. <http://www.rpa.org>

[199] Holtzclaw. (1994). Using Residential Patterns and Transit to Decrease Auto Dependence and Costs. NRDC. San Francisco.

per hour per direction, which when reached on the major arteries can limit the continued growth of the center. Consequently, either the natural growth of the center is forced to the perimeter, or a high-capacity metro is built to alleviate the public transport bottleneck. The role of the metro is permissive, it allows dynamic central growth to continue allowing the city to function with a strong center, but it does not create the underlying growth. In the absence of strong land-use planning regulations, which require considerable institutional strength, the effect of a metro is less certain. This is partly because metros are nearly always located in the densest part of big cities, where land ownership is fragmented. Where land assembly is difficult and requires government action, developing city-governments have often failed to direct development constructively. However, in either case, the long-term impact of a metro network is generally to create a more concentrated city structure, which contrasts strongly with the geographical sprawl, which characterizes many developing cities.[200] It can be concluded that high-density developments along the transit alignment do not just happen. HDD and TOD require strong government action either by the municipal government acting as the developer or by strategic land assembly.

Hong Kong and Singapore are cities that have successfully implemented high-density development policies as mentioned previously in the transit oriented development description.

6.6.3 Urban Growth Boundaries

Urban Growth Boundaries (UGBs) are tools for growth management that establish lines around metropolitan areas, outside of which growth is discouraged or prohibited. "Development outside the ring is discouraged through down-zoning, tax incentives not to develop and prohibitions on providing services. Development inside the boundary is encouraged by expedited approval processes and up zoning. Thus, an urban growth boundary protects open space on the outside, and encourages increased density on the

[200] Litman, Todd (1999). Land Use Impact Costs of Transportation. Victoria Transport Policy Institute. British Columbia.

inside." [201] UGBs exist in several forms, Urban Services Boundary (USBs) and Greenbelts are other methods that, in essence, do the same thing. The UGB concept was first applied in Lexington, Kentucky in 1958, when the Urban Services Area was delineated as the basis for the Fayette County land use plan. Growth boundaries have since been adopted in only a handful of places.[202]

Portland's UGB was created as part of the statewide land-use-planning program in Oregon in the early 1970s. It encompasses an adequate supply of buildable land that can be efficiently provided with urban services for twenty years. The primary objectives of the Portland UGB are to promote the efficient planning and use of urban land; to improve the efficiency of public facilities and services; and to preserve prime farmland and forestlands outside the boundary. Portland's UGB has hemmed in development, fostered higher density development, and encouraged redevelopment of blighted urban areas. The average housing density in Portland increased from five homes per acre to eight homes per acre. Multifamily housing units account for half of all new building permits. High rates of in-fill and redevelopment were associated with low overall levels of housing production.[203]

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[201] Franciosi, Robert. (1998). A Tale of Two Cities: Phoenix, Portland, Growth and Growth Control. The Goldwater Institute. Phoenix.

[202] National Association of Homebuilders Web-site. (2001). Urban Growth Boundaries Portland Style: A Response. <http://www.nahb.net/growth_issues/growth_management/growth_portland.html>

[203] Knaap, G. (2000). The Urban Growth Boundary in Metropolitan Portland, Oregon: Research, Rhetoric, and Reality. University of Illinois. Urbana-Champaign.

6.7 Intelligent Transportation Systems

The United States Federal Highway Administration defines ITS as systems that "apply well-established technologies in communications, control, electronics, and computer hardware and software to improve surface transportation performance"[204]. ITS can increase effective road capacity, improve vehicle safety, increase the efficiency of public transit, and reduce environmental impacts, all without conventional infrastructure building. Advances in technology have led to the exploration of applications of electronics to transportation. As a result, a broad range of intelligent transportation system technologies are available, though many of these are not widely implemented.

While many transportation professionals support increased research and development into ITS, certain environmentalists oppose the concept on the basis that it contributes to unsustainable lifestyles by making driving more attractive. ITS can have significant benefits on reducing congestion and air pollution with measurable impacts in improving urban mobility. In order to prevent the possibility of these devices contributing to unsustainable conditions, ITS must be installed in cities at the same time that demand management policies are implemented. Intelligent transportation systems have great potential to increase the capacity and efficiency of the existing infrastructure supply.

Numerous ITS technologies have been developed in the last several decades, yet it remains difficult for regions to implement these congestion-reducing measures. The problem appears to be institutional rather than technological. Institutional capability is a crucial component for success in using ITS to manage urban transportation systems. In addition to organizing public institutions, planners must consider the roles of the private sector, individual citizens, legal issues, and financial considerations. No single issue may necessarily derail a proposed ITS project; however, the accumulation of many small problems can lead to project delays, cost overruns, ineffective deployment, or user dissatisfaction. A deployment framework must be formulated by agencies that are

[204] US DOT. (2000). Federal Highway Administration. What Have We Learned About Intelligent Transportation Systems? Washington, DC: Federal Highway Administration, 2000.

planning on the deployment of ITS for their regions. Before developing this framework, however, it is first important to understand the range of technologies available.

6.7.1 Intelligent Infrastructure Technologies

Intelligent infrastructure technologies require geographically widespread networks for information processing and sensing. The hardware is largely based within road or transportation infrastructure itself. Examples include sensors imbedded in the roadway or receivers placed at the sides of roads. Many different intelligent infrastructure technologies are comprised of the same hardware components. Among these are variable message signs, video imaging technology, and central control centers. While the technologies are listed separately, they have commonalities that can be leveraged during actual implementation. The incident management control center, for instance, could be used to manage advanced traveler information systems as well.

Federal, state, and local governments, not the private sector, are typically the champions for intelligent infrastructure investment. There are several reasons for this observance. First, ITS often carries high capital costs that may not be economically attractive for private ventures, but are socially attractive for the public at large. Second, infrastructure technologies require the use of equipment owned by the public sector, to which private companies may not have access. For example, a private sector initiative into electronic fare payment requires an overhaul of public fare collection equipment. Finally, intelligent infrastructure technologies should be managed in the public's best interest, and the government is the logical stakeholder for this role. It should be noted, however, that while the government normally champions ITS infrastructure, it often does so through private sector channels. One example is the government granting electronic toll road concessions to private operators. In this case, the private sector is responsible for the deployment of electronic toll collection technology. The government, however, is still needed to organize the effort and ensure the technical interoperability of the various concessionaires.

6.7.1.1 Advanced Traffic Management Systems

The first set of intelligent infrastructure technologies relates to Advanced Traffic Management Systems (ATMS). These computer systems help manage arterial and freeway traffic by adjusting the flow of vehicles on roadways through traffic signals and fast response to blockages. Examples of ATMS are smart traffic signal control, ramp metering, automated red light enforcement, and incident management.

The first two technologies listed, smart traffic signal control and ramp metering, accomplish this by using signals to limit the number of vehicles passing through in a single light cycle. In addition, these signals may be coordinated so that cars going at a certain speed do not need to stop. They use sophisticated computer algorithms to determine the optimum cycle times for maximum road efficiency. The third technology, automated red light enforcement, reduces accidents by catching all drivers who violate the red light signal at intersections. The final technology in this section is incident management. Incident management systems detect flow problems, such as vehicle breakdowns, and notify the appropriate personnel to clear the blockage as rapidly as possible. Detecting problems early can help control non-recurring congestion.

6.7.1.2 Advanced Traveler Information Systems

A second set of intelligent infrastructure technologies is Advanced Traveler Information Systems (ATIS). ATIS provide current and accurate traffic information to help drivers choose better routes. The information can be disseminated through a variety of media, including television, the Internet, and cellular phones. The concept ties closely with networked in-vehicle navigation assistance devices discussed later.

Because ATIS relies on accurate and reliable traffic data, agencies must first deploy ATMS technologies before implementing ATIS. Information collected through the ATMS network is then disseminated through ATIS channels. The data is often processed by third parties, typically private companies, to make the information useful to drivers.

A subset of advanced traveler information systems is parking guidance systems. Parking guidance systems reduce congestion by helping drivers find open parking spaces. In Cologne, Germany, a central computing system counts the number of cars entering and leaving each parking zone. The information is displayed real-time on variable message signs located on major roads into the city, as well as on the Internet[205].

6.7.1.3 Electronic Payment Systems

Electronic payment systems are another group within infrastructure-based technologies. Unlike the systems presented above, this ITS category groups together similar technology rather than its applications. As a result, similar electronic payment system concepts are found in several infrastructure technologies. Two systems are electronic toll collection, with relatively fixed charges, and electronic road pricing, also known as congestion pricing, with varied charges according to road congestion.

On toll roads, congestion often backs up for miles before a toll plaza, while cars queue for manual payment. Using electronic payment systems increases throughput significantly, because vehicles no longer have to come to a complete stop to offer payment. In addition, electronic payment eliminates the need for human operators to make change and collect tickets, which are both time-intensive processes.

Two applications of electronic payment technology are smart cards and wireless transmitters. Smart cards can have either contactless or contact interfaces. They function as debit cards and can be "refilled" at physical stations or sometimes online. Some examples of physical stations are ATM's, convenience stores, and post offices. Wireless transmitters are usually affixed to the windshield of a vehicle. These communicate with roadside receivers, which then access a central computer for charging and billing.

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[205] Chen, Kan and John C. Miles, ed. (1999). ITS Handbook 2000: Recommendations from the World Road Association (PIARC). Boston, MA: Artech House.

6.7.1.4 Advanced Public Transportation Systems

The final set of intelligent infrastructure technologies is Advanced Public Transportation Systems (APTS). APTS applies ITS concepts to the specific area of public transportation to make these modes of travel more attractive. For example, the concept of electronic payment applied to public transit is electronic fare payment. Similarly, the concept of ATIS applied to public transit is automated passenger information. A third technology utilized by APTS, automated vehicle location, is also applicable for fleet operations.

6.7.2 Intelligent Vehicle Technologies

This section outlines ITS technologies that are primarily located within, or as part of, individual vehicles. Intelligent vehicle technologies can be included within vehicles such as a car, motorcycle, or truck. They are typically either integrated into the vehicle itself or externally mounted onto the vehicle. Several of the key components to many intelligent vehicle technologies are Global Positioning Systems (GPS), electronic sensors, wireless communications, and sophisticated computer control algorithms. While advanced vehicle control systems and drive-by-wire, discussed later, do not directly affect traffic congestion from a systems perspective, they can make an impact by reducing the number of accidents and by mitigating some of the negative effects of congestion. For example, many AVCS technologies improve vehicle safety, thus lowering accident risk and reducing the congestion associated with vehicle accidents. Similarly, these technologies can reduce tailpipe emissions through greater efficiency, which lower the negative environmental impact of congestion.

Unlike the infrastructure-based technologies, vehicle-based technologies are most often developed and marketed by the private sector, primarily the automobile industry. Many of these technologies are sold as separately priced options on cars. There may conceivable areas of overlap with infrastructure-based technologies, whereby single devices can serve multiple functions or data can be collected for multiple uses.

6.7.2.1 Advanced Vehicle Control Systems (AVCS)

One set of vehicle-based technologies is sometimes referred to as Advanced Vehicle Control Systems (AVCS). These systems improve driver behavior in risky situations by changing vehicle speed and direction, either automatically or through visual and auditory warnings. Examples of AVCS are intelligent cruise control, vision enhancement systems, collision avoidance technology, intelligent stability and handling systems, and drowsy driver sensors. While these systems do not control traffic congestion directly, they aim to indirectly control congestion by reducing the number of accidents caused by vehicles on the road.

6.7.2.2 Drive-by-wire

There is also an entirely new approach to vehicle control systems called drive-by-wire. As a complete overhaul of automotive mechanical limitations, drive-by-wire has many implications for changing vehicle form and function. It is a relatively new vehicle concept that replaces mechanical systems in vehicles with highly advanced electronic controls. The term is derived from the "fly-by-wire" systems long used in the aviation industry. Under fly-by-wire, an airplane pilot uses computer controls and software, instead of steel cables and hydraulics, to control the turning, braking, and throttling functions of the airplane. Drive-by-wire is the same idea extended to the steering, braking, and acceleration of motor vehicles[206].

Current drive-by-wire technology in the marketplace replaces only the cable-operated vehicle throttle systems with electronic sensors and controls. The technology is already available on cars including the C5 Corvette, Mercedes E-class sedan, Acura NSX, and the Toyota Tundra. Although the systems rely on electronic instead of mechanical links, current models still include the conventional foot pedals for convenience. The designs of more futuristic advanced prototype vehicles, such as the Bertone Filo, have eliminated

[206] Brauer, Karl. Why Drive-By-Wire? Edmunds Car Buying Guide 25 Jan 2001. 15 November 2002 <http://www.edmunds.com/news/innovations/articles/43033/article.html>.

the steering column, all pedals, and the gearshift[207]. Eventually, drive-by-wire systems may be used for all four systems - braking, steering, accelerating, and gear shifting.

6.7.2.3 Navigation Assistance

Navigation assistance devices are information-based systems and are currently in the marketplace. These devices reduce travel time by helping drivers plan faster routes. The technology uses GPS positioning and map databases to guide vehicles. The systems are called "telematics" systems, because they blend telecommunications with informatics, the science of sending information.

The purpose of in-vehicle navigation devices is to help drivers optimize their travel paths by providing detailed information about routes. Some products also provide dynamic route guidance once a route has been selected. GPS technology involved requires signals from four satellites; therefore signals can be lost around tall buildings or under a bridge. The GPS is backed up by dead reckoning, which uses a gyroscope to calculate vehicle position from a known reference point[208]. The cumulative error with dead reckoning is occasionally corrected through radio beacons at known locations.

6.7.2.4 Mayday Systems (Automatic Crash Notification)

Mayday systems are another vehicle information system that automatically notifies a call center in the event of a crash. Mayday devices, or SOS systems, enable direct verbal or data communication with emergency personnel. Their primary function is to automatically notify the call center in the event of a crash. This feature, which transmits the GPS location of the vehicle to the response center, is typically activated by airbag deployment or by a driver panic button. In the event of serious injuries, the intervention of the mayday device can reduce the critical response time necessary for medical help to arrive, since the devices are already integrated into the emergency response system.

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[207] McElroy, John. Bertone Uses Drive-by-Wire Technology to Fundamentally Change Vehicle Design. Autoline Detroit, 28 November 2001.

[208] Miller, Brian. Finding the Way: Navigation Devices and Public Safety. Government Technology March 1995.

6.7.2.5 Vehicle Mobile Computing

Finally, vehicle mobile computing is growing in popularity as a method by which drivers can better use the time that they are normally caught in traffic congestion. If delays can be used productively, then the negative efficiency effects of traffic congestion can be lessened, though the environmental effects remain. This concept is already being developed by providing e-mail and Internet access to special in-vehicle receptors or cellular phones.

To this end, cellular phone companies are creating new products that enable an office on the road. These phones include features such as data capability, interfaces with personal digital assistants, and compatibility with computers, printers, and fax machines. Wireless phone makers such as Nokia and Motorola hope that the widespread use of cellular phones can facilitate the introduction of office capabilities into the private vehicle.

7 *Conclusion*

Population and development pressures are increasingly exposing the flaws in the structure and governance of transportation networks. These systems are critical components of societal operation, yet they produce a host of negative consequences and are increasingly failing to perform the activities of mobility effectively. These failures must be mitigated and where possible resolved, but this transition requires a revolution in the existing infrastructure and a complete reevaluation of urban transportation priorities. Integrated transportation strategies that weigh the financial, environmental, and social repercussions of investment and policy action must be instituted by urban and national governments in the best interest of the human population.

The future of major cities and their economic prosperity depends heavily upon the manner in which transportation networks will be designed and controlled. Development must be managed from a more qualitative standpoint that values aspects of transportation including general accessibility and the effects on human health that are difficult to assess financially but nevertheless have considerable impact. The traditional role of governments in providing infrastructure through public investment and their continued responsibility for its management make policy legislation the key to change. Policies from both the demand and supply side of management must be utilized in transport, as well as land use controls and developing intelligent transportation systems. Whatever the combination of policies may be, it must be specifically tailored to existing conditions and be implemented with coordinated and supporting policies that encourage success.

It is also essential for governments of large and growing cities to challenge the negative implications for human health and environmental integrity, as distinct from controlling and satisfying travel demand. While the use of supply, demand, land use, and ITS tools can reduce the need for travel and increase the effective capacity of networks, environmental conditions must be addressed distinctly and in a way that does not diminish these other efforts. The safety of transport infrastructure, as determined by technical design and the proper provision for and integration of different modes, must be treated with greater care and emphasis than is currently the case, particularly in the

developing world where accident figures are climbing. Technical improvements of engines and fuels and substitutions thereof hold the keys to future reductions in air pollution in the developed world, but financially lesser nations continue to suffer from more severe environmental ramifications of transport in the absence of existing technological enhancements or regulations that have not been adopted. Of course, limited institutional sophistication often plays a role in preventing policies from being instituted because of poorly organized governments or inadequate capabilities for enforcement. In these instances, governments must shy away from bureaucracies and clearly define responsibility and authority for better strategy development and execution.

The adoption of sustainable solutions to urban transport and the composition of integrated and specifically tailored policies will only produce the desired effects if they are comprehensive in the scope of time. This requirement does not refer to the type of time considerations between generations as discussed with sustainability concepts, but rather as a measure of impacts of different policies. Technological advances and policy instruments have yield times that can be roughly estimated to determine when impacts can be expected. Therefore, investment in urban transport must account for the dynamic nature of these problems in terms of time.

Alcântara de Vasconcellos, Eduardo. (2004) Urban Transport and Tensions in Developing Countries. In: Benería, Lourdes and Savitri Bisnath (eds) Global Tensions. Routledge, New York.

Ashenden et al. (2003) Impacts of Vehicle Emissions on Vegetation. In: Brebbia, CA and LJ Sucharov (Eds) Urban Transport IX: Urban Transport and the Environment in the 21st Century. WIT Press, UK.

ATLAS Project. (2004). <http://europa.eu.int/comm/energy_transport/atlas >

Auer, Mathew. (2001). Policy Studies Journal, January 1. Volume 29: Issue 3.

Baarbé, HI. (2002) Emissions at Different Conditions of Traffic Flow. In: Benitez, F., CA Brebbia and LJ Sucharov (Eds) Urban Transport VIII: Urban Transport and the Environment in the 21st Century. WIT Press, UK.

Banister, David. (2002) Transport Planning. Spon Press, New York.

Better Traffic Policing Urged. Indian Express. Delhi, India. February 26, 1994.

Bickel, Peter and Rainer Friedrich. (2001) Environmental External Costs of Transport. Springer-Verlag. Berlin, Germany.

Black, William R. (2003). Transportation: A Geographical Analysis. The Guilford Press, New York.

Boston Globe. (2004) <http://www.boston.com/globe/metro/bigdig>

Brauer, Karl. Why Drive-By-Wire? Edmunds Car Buying Guide 25 Jan 2001. 15 November 2002
<http://www.edmunds.com/news/innovations/articles/43033/article.html>.

Brown, Lester R. (1991). Saving the Planet. The Worldwatch Institute.

Bull, Alberto (ed.) (2004). Traffic Congestion: The Problem and How to Deal with it. United Nations, Economic Commission for Latin America and the Caribbean. Santiago, Chile.

Bureau of Transportation Statistics - USDOT (1992). A Summary of Travel Trends. National Personal Transportation Survey. <http://www.fhwa.dot.gov/ohim/nptspage.htm>

Cheatham, Benjamin M. (2002). Sustainable Urban Transportation Development in Mega-cities: A Review of Policies, Regulations, and Technolgies, Master's thesis, MIT.

Chen, Kan and John C. Miles, ed. (1999). ITS Handbook 2000: Recommendations from the World Road Association (PIARC). Boston, MA: Artech House.

Cline, William R. (1992). The Economics of Global Warming, Washington, DC: Institute for International Economics. June.

Cohen et al., (2003). Mortality Impacts of Particulate Air Pollution in the Urban Environment, World Health Organization, Geneva.

Conversations with Professor Fred Moavenzadeh. (2001) MIT Department of Civil and Environmental Engineering. Cambridge.

Conversations with Professor Fred Moavenzadeh. (2004) MIT Department of Civil and Environmental Engineering. Cambridge.

Dales, JH. (1968). Pollution, Property and Prices. Toronto: University of Toronto Press. And Kneese, Allen V. and Charles L. Shultze. (1975). Pollution, Prices, and Public Policy. Washington DC: The Brookings Institution.

Dales, JH. (1968). Pollution, Property and Prices. Toronto: University of Toronto Press.

Demographia. (2004) <http://www.demographia.com/db-world-metro2000.htm>

Dornbusch, Rudiger and James M. Poterba. (1991). Global Warming. Cambridge, MA: MIT Press.

Downs, Anthony. (1992). Stuck in Traffic: Coping with Peak-Hour Traffic Congestion. Brookings Institution. Cambridge.

Economic and Social Commission for Asia and the Pacific. (2001). Review of Developments in Transport and Communications in the ESCAP Region 1996-2001. United Nations, New York.

Environmental Protection Agency. (2004).
<http://www.epa.gov/air/urbanair/lead/what.html>

Eskeland, Gunnar S and Tarhan Feyzioglu. (1995) Rationing Can Backfire: The Day Without a Car in Mexico. The World Bank Policy Research Working Paper 1554.

European Conference of Ministers of Transport. (1995). Urban Travel and Sustainable Development. OECD Publications, Paris.

Feitelson, Eran and Verhoef Erik. (2001) Transport and Environment: From Policy Measures to Sustainability and Back. In: Transport and Environment, Feitelson, Eran and Verhoef Erik (eds.). Edward Elgar Publishing, UK.

Franciosi, Robert. (1998). A Tale of Two Cities: Phoenix, Portland, Growth and Growth Control. The Goldwater Institute. Phoenix.

Gakenheimer, R. (1996) What to do with all those cars? MIT Center for Transportation Studies. Newsletter #39. Cambridge.

Garcia, Amando (Ed.) (2004). Environmental Urban Noise. WIT Press, UK.

Gillen, David. (2003) The Economics of Noise. In: Handbook of Transport and the Environment, Hensher, DA and KJ Button (eds.), Amsterdam.

Gomez-Ibanez & Small. (1994). Road Pricing for Congestion Management: A Survey of International Practice. Transportation Research Board. National Research Council. Washington DC.

Gozaresh. (2000). Get Your Masks Ready; Tehran's Poisonous Air is on the Way. Social and Economic Monthly. Tehran.

Greater London Authority. (2004). The Mayor's Annual Report 2004. <http://www.london.gov.uk/mayor/annual_report/docs/ann_rpt_2004.pdf>

Gustavo, Garza. (2000). 4.2 Ambitos de Expansion Territorial. El Colegio de Mexico. Referenced In: Lopez, Alejandro. (2001). Metropolitan Mexico City: Transportation Policies and Economic Development.

Gwilliam, Ken. (2002). Cities on the Move: A World Bank Urban Transport Strategy Review. World Bank, Washington D.C.

Hardin, Garrett. (1968). The Tragedy of the Commons, Science. 162, December 13, pp 1243-5.

Hensher, DA and KJ Button (eds.) (2003) Handbook of Transport and the Environment. Amsterdam.

Hill, Lewis. (1990). Resources, Resistances, and Economic Growth. International Journal of Social Economics. Volume 17, Issue 6, pp 60-66.

Holtzclaw. (1994). Using Residential Patterns and Transit to Decrease Auto Dependence and Costs. NRDC. San Francisco.

How Stuff Works. (2004) < http://auto.howstuffworks.com/catalytic-converter3.htm>

Humphrey, N. (2001). Reviewing the Status of HOV Lanes. TR News Number 214. Transportation Research Board. Washington DC.

Hyman, Eric L. (1981). The Valuation of Extramarket Benefits and Costs in Environmental Impact Assessment, EIA Review. Volume 2, Number 3, pp 226-64.

Intergovernmental Panel on Climate Change. (2000). Methodology and Technological Issues in Technology Transfer, Cambridge University Press, Cambridge.

Ison S. (1998). A concept in the right place at the wrong time: congestion metering in the city of Cambridge. Transport Policy No.5. London

Kenworthy, Jeff and Felix Laube. (1999). An International Sourcebook of Automobile Dependence in Cities, 1960-1990. Boulder, Colorado, University Press of Colorado.

Kenworthy, Jeff and Felix Laube. Urban Transport Patterns in a Global Sample of Cities and their Linkages to Transport Infrastructure, Land Use, Economics and Environment. World Transport Policy and Practice, Eco-Logica Ltd. Volume 3, Number 3, 2002.

Kenworthy, Jeff and Peter Newman. (1989). Cities and Automobile Dependence: A Sourcebook. Gower Publishing Company Limited, England.

Knaap, G. (2000). The Urban Growth Boundary in Metropolitan Portland, Oregon: Research, Rhetoric, and Reality. University of Illinois. Urbana-Champaign.

Kojima, Masami and Magda Lovei. (2001) Urban Air Quality Management. Technical Paper No 508. World Bank, DC.

Kopits E, Cropper M. (2003) Traffic Fatalities and Economic Growth, World BankPress, Washington, DC.

Korver, Wim. (2001) Traffic and transport in the twenty-first century: market chances of new drive concepts for land-based transport. In: Transport and Environment, Feitelson, Eran and Verhoef Erik (eds.). Edward Elgar Publishing, UK.

Kumar, M. (2003) Environmental Management During Metro Railway Construction Especially in Highly Polluted and Densely Populated City. In: Brebbia, CA and LJ Sucharov (Eds) Urban Transport IX: Urban Transport and the Environment in the 21st Century. WIT Press, UK.

Kuranami, Winston, Kimura, Rose and Nakagawa (2000). Study on Urban Transport Development. PADECO Co. Ltd. World Bank Press. Washington DC.

Leautaud, Juan and Perez-Barnes, Cesar. (1997). Energy and Infrastructure for Mitigating Air Pollution in Mexico City. MIT, Cambridge.

Lee, Douglass. (1992) An Efficient Transportation and Land Use System. Volpe National Transportation Research Center, Cambridge. <http://ohm.volpe.dot.gov.

Litman T. (2000). Parking Pricing: Direct Charges for Using Parking Facilities. TDM Encyclopedia. Victoria Transport Policy Institute. British Columbia.

Litman, Todd (1999). Land Use Impact Costs of Transportation. Victoria Transport Policy Institute. British Columbia.

Litman, Todd. (2004). London Congestion Pricing: Implications for Other Cities. Victoria Transport Policy Institute.

Litman, Todd. (1996). Using Road Pricing Revenue: Economic Efficiency and Equity Considerations. Transportation Research Record.

Litman, Todd. (1998). Evaluating Criticism of Transportation Costing. Victoria Transportation Policy Institute. <http://www.vtpi.org>

Litman, Todd. (2000). TDM Encyclopedia. Victoria Transport Policy Institute. British Columbia.

Litman, Todd. (2000). Transit Oriented Development: Using Public Transit to Create More Accessible and Livable Neighborhoods. Victoria Transport Policy Institute. British Columbia.

Litman, Todd. (2001). Car-sharing Vehicle Rental Services That Substitute for Private Vehicle Ownership. VTPI On-Line Encyclopedia. British Columbia. <http://www.vtpi.org/tdm/tdm7.htm>

Lopez, Alejandro. (2001). Metropolitan Mexico City: Transportation Policies and Economic Development.

Lowe, Marcia D. (1990). Alternatives to the Automobile: Transport for Livable Cities. Paper 98. Worldwatch Institute, Washington, D.C.

Makler & Zegras. (1999). Regional Strategic Transportation Planning in Mexico City. Mexico City Project Seminars. MIT, Cambridge.

Marwick, P. & Mitchell and Co. (1985). West University Neighborhood Parking Pricing Demonstration Program in Eugene, Oregon. Final Report for the U.S. Department of Transportation. Houston.

McElroy, John. Bertone Uses Drive-by-Wire Technology to Fundamentally Change Vehicle Design. Autoline Detroit, 28 November 2001.

Menon A. et al. (1993). Singapore's Road Pricing System: Its Past, Present and Future. In ITE Journal. Volume 63, Number 12.

Metschies, Gerhard. (2001). Fuel Prices and Vehicle Taxation. GTZ, Eschborn, Germany.

Miller, Brian. Finding the Way: Navigation Devices and Public Safety. Government Technology

Molina, Luisa and Mario Molina (eds). (2002) Air Quality in the Mexico Megacity. Kluwer Academic Publishers, Boston.

National Association of Homebuilders Web-site. (2001). Urban Growth Boundaries Portland Style: A Response.
<http://www.nahb.net/growth_issues/growth_management/growth_portland.html>

Newman and Kenworthy. (1989). Sustainability and Cities: Overcoming Automobile Dependence. Brookfield, VT. Gower.

Nilles J. (1999). The Olympics, Jakarta Traffic, and Telework. Pacific Link Newspaper. Jakarta.

Nordhaus, William. (1992). Lethal Model 2: The Limits to Growth Revisited, Brookings Papers on Economic Activity. Volume 2, Washington, DC.

Norgaard, Richard. (1985). Environmental Economics: An Evolutionary Critique and A Plea for Pluralism, Journal of Environmental Economics and Management, Volume 12.

Pandey, K. D., Bolt, K., Deichmann, U., Hamilton, K., Ostro, B., Wheeler, D., (2004) (forthcoming), The Human Cost of Air Pollution: New Estimates for Developing Countries, World Bank Development Research Group Working Paper, Washington, DC.

Pearce, David W. and R. Kerry Turner. (1990). Economics of Natural Resources and the Environment. Baltimore: The Johns Hopkins University Press.

Pearce, David, Anil Markandya, and Edward B. Barbier. (1989). Blueprint for a Green Economy. London: Earthscan Publications Ltd.

Peden M. et al., (2004) The World Report on Road Traffic Injury Prevention, World Heath Organization, Geneva.

Peter Calthorpe Associates, (1990). Transit-Oriented Development Design Guidelines for the County of Sacramento.

Porter, Michael. (1990). The Competitive Advantage of Nations. Harvard Business Review (March/April).

Rabinovitch, Jonas. Curitiba: towards sustainable urban development, Environment and Urbanization, Volume 4, Number 2, October 1992.

Rebelo & Benvenuto. (1995). Concessions of Bus-ways to the Private Sector: The São Paulo Metropolitan Region Experience. The World Bank Group. Washington DC.

Rebelo & Benvenuto. (1997). Lessons from São Paulo's Metropolitan Bus-way Concessions Program. The World Bank Group. Washington DC.

Regional Planning Association. (1997). Building Transit Friendly Communities. New York. <http://www.rpa.org>

Renner, Michael. (1988). Rethinking the Role of the Automobile. Paper 84. Worldwatch Institute, Washington, D.C.

Root, Amanda. (2003) Developing Sustainable Transport, Pergamon, Amsterdam.

Ruggiero, A. and A Senatore. (2003) On the role of engine tribology in the reduction of noise and emissions. In: Brebbia, CA and LJ Sucharov (Eds) Urban Transport IX: Urban Transport and the Environment in the 21st Century. WIT Press, UK.

Sayeg P. & Bray D. (1999) Prospects For Implementation of Electronic Road Pricing. Traffic Technology International. London

Schallaböck, K. and R Pertersen. (1998). Germany; in Round Table110. Traffic Congestion in Europe. EMCT, Paris.

Schmidheiny, Stephan. (1992). Changing Course. Cambridge, MA: MIT Press.

Setravi. (2000) Prgrama Integral de Transporte y Vialidad 1995-2000. Referenced In:

Soja, Edward W. (2004) Urban Tensions: Globalization, Economic Restructuring, and the Postmetropolitan Transition. In: Benería, Lourdes and Savitri Bisnath (eds) Global Tensions. Routledge, New York.

Solow, Robert. (1992). An Almost Practical Step Toward Sustainability, Resources for the Future.

Sustainable Transport (1996). The World Bank, Washington D.C.

Sveder & Nylander. (2001) Internalization of External Cost: An Assessment of Road Pricing in the Stockholm Region. Transek AB. Solana, Sweden.

Tay, R. (1996). Congestion Alleviation in Singapore: A Review of Demand Management. In C. Lim (Ed). Economic Policy Management in Singapore (pp 313-44). Singapore: Addison Wesley.

Teufel, D. (1989). The Future of Motorized Transport. Transportation the Environment and Sustainable Development. Die Zuykunft des Autoverkehrs. p. 184.

The Commons. (2000). Pico y Placa. Paris. <http://www.ecoplan.org/votebogota2000.org>

The Economist (1998). A Survey of Commuting, September 5. pp. 3-7, 10-18.

The World Bank Group. (2001) Urban Transport: An Overview. <http://www.worldbank.org>

Third World Network. (1999). Control of Private Vehicles in Urban Areas: The Vehicle Quota System and The Area Licensing Scheme. United Nations Development Programme - Special Unit for Technical Cooperation among Developing Countries. New York.

Trimet. (2004) http://www.trimet.org/newsandinfo.htm.

United Nations Center for Human Settlements. (1996). An Urbanizing World: Global Report on Human Settlements. Oxford: Oxford University Press.

United Nations Center for Human Settlements. (2001). The State of the World's Cities Report 2001. Oxford, Oxford University Press.

United Nations Development Programme (UNDP). (1991). Human Development Report. New York: Oxford University Press.

United Nations. (2003). World Urbanization Prospects: The 2003 Revision.

Urban Rail (2004). http://www.urbanrail.net/am/mexi/mex-history.htm

US DOT. (2000). Federal Highway Administration. What Have We Learned About Intelligent Transportation Systems? Washington, DC: Federal Highway Administration, 2000.

Vuchic, Vukan R. (1999) Transportation for Livable Cities. Center for Urban Policy Research.

Walsh, M.P. (1989). Motor vehicle emissions in Mexico: A strategy for progress. World Bank.

Weitzman, Martin L. (1991). What to Preserve? Discussion Papers 1574. Cambridge, MA: Harvard University Institute of Economic Research. (October).

Weitzman, Martin L. (1992). Comments and Discussion: Lethal Model 2: The Limits to Growth Revisited, Brookings Papers on Economic Activity. Volume 2, Washington, DC.

World Bank Group. (1998). Pollution Prevention and Abatement Handbook. July.

World Bank. (1992). World Development Report 1992: Development and the Environment. New York: Oxford University Press.

World Bank. (1994). World Development Report 1994: Infrastructure for Development. New York: Oxford University Press.

World Bank. (2001) World Development Indicators.

World Business Council for Sustainable Development. (2001). Mobility 2001: World Mobility at the End of the Twentieth Century and its Sustainability.

World Development Report 1999/2000: Entering the 21st Century. (1999) World Bank, Oxford University Press.

World Health Organization and UNEP. (1992). Urban Air Pollution in Megacities of the World. Oxford, Blackwell Publishers.

World Health Organization. (2004). Health Aspects of Pollution: Results from the WHO Project "Systematic Review of Health Aspects of Air Pollution in Europe. June.

World Resources Institute. (1992). The Going Rate: What It Really Costs to Drive.

WRI WRI, UNEP, UNDP, and World Bank. (1996). World Resources 1996-1997: The Urban Environment.