

# Sustainable Development and Transportation: A Taiwan Perspective\*

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## Abstract

In response to *The Rio Agenda 21* and *The Kyoto Protocol*, Taiwan government has formulated important policies and set up implementation guidelines for national sustainable development over the past few years. This paper presents the policies and strategies that Taiwan has endeavored to pursue environmental, social, and economic sustainability. In transportation sector, some important undertakings for sustainability are also examined. To be sustainable, overall transportation systems including infrastructures, vehicles, operation and maintenance must not endanger the public health or ecosystems while meeting the mobility needs. They must at least comply with two basic principles: use of renewable resources at below their rates of regeneration and use of non-renewable resources at below the rates of development of renewable substitutes.

**Key words:** sustainable development, sustainable transportation, Taiwan.

## 1. The Challenges

Rapid technological development has caused rapid changes in socioeconomic activities in the human society since the middle of 20<sup>th</sup> Century. Mass production, mass consumption, and mass disposal of wastes have also characterized human lifestyle as a result of greater material sufficiency. The environmental damages caused by production processes have gone beyond nature's ability to repair itself, leading to a polluted environment, sharp reduction of natural resources and threatening the sustainable development of human beings. The huge amount of production and consumption process has also derived a drastic increase in the demand for transporting people and goods. Unfortunately, the transport systems of international, intercity, urban and suburb of all motorized vehicles (aircrafts, containers, buses, trucks, cars, motorcycles, moving equipment, etc.) have relied heavily on the fossil fuel resource. One of the grimmest negative impacts of such fossil-based transport is perhaps the pollutants resulted from direct emissions of transportation infrastructure construction (airports, seaports, bridges, tunnels, highways, railways, terminals, etc.) and vehicle operations as well as indirect emissions of vehicle manufacturing, fuel extraction and processing, manufacturing of construction materials and machinery.

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Transportation emissions should take the major responsibility for deteriorating environment at local level due to high emission concentrations, at regional level due to acidification and photochemical oxidants, and at global level due to indirect and direct greenhouse effect and stratospheric ozone depletion. The major transport emissions causing impacts to our living environment at local and regional levels, in terms of human illness (mortality and morbidity) and material damages, include particulate matter (PM), ozone or volatile organic components (VOCs), carcinogenic toxics, carbon monoxide (CO), and sulphur dioxide (SO<sub>2</sub>). PM, a heterogeneous mix of solid or liquid compounds, are regarded as the most damaging air pollutant to human health (McCubbin and Delucchi, 1999). PM with diameters between 2.5 and 10 micrometers do have significant positively correlated to mortality (Pope et al, 1992; Schwartz and Dockery, 1992a, 1992b) and respiratory illness such as chronic coughs, chronic phlegm, wheezing, chest illness, and bronchitis (Chapman et al, 1985; Dockery et al, 1989). PM also cause material damage, significantly related to household expenditures in laundry, cleaning and utilities (Manuel et al, 1982).

Ozone is not directly emitted by vehicles but is formed through chemical reaction among NO<sub>x</sub>, VOCs and some other compounds in the atmosphere. The linkage between ozone and mortality is statistically significant (Kinney and Ozkaynak, 1991; Moolgavkar et al, 1995). The health effects include eye irritation, asthma attacks and other acute lower and upper respiratory symptoms, in particular, Holguin et al (1985) and Stock et al (1988) found a positive correlation between asthma symptoms and ozone concentration.

Although other toxic air pollutants are also emitted from vehicles, carcinogenic air toxins are most evident. The link between carcinogenic air toxins and the increase in cancer cases is mainly through inhalation with subsequent absorption into the body through lungs. CO binds with haemoglobin in the blood to form carboxyhaemoglobin, and reduces the oxygen carrying capacity of the blood and limits the release of oxygen from circulating haemoglobin (McCubbin and Delucchi, 1999). Studies have shown that the concentration of CO is linked to cardiovascular problems (Schwartz, 1997; Morris et al, 1995). The damage due to SO<sub>2</sub> comes mainly from materials soiling. SO<sub>2</sub> atmospheric emissions form sulphuric acid – acid rain. In particular, SO<sub>2</sub> exposure is correlated with the corrosion of exposed metal surfaces, specifically galvanized steel (Baedecker et al, 1990).

Transportation emissions causing negative impacts to our living environment at global level mainly include global warming and stratospheric ozone depletion. Scientists reported that the 1990s appeared to have been the warmest decade of the last Millennium and 1998 was the warmest year. The average temperature of the earth's surface has risen by 0.6 degrees C since the late 1800s and another 1.4 to 5.8 degrees C is expected to increase by the year 2100. The mounting temperatures have caused glaciers and ice caps melted and discharged more water into the oceans; as a result, the ocean volume expands. On average, the sea level has already risen more than 10 cm during the last century and it is estimated to increase by another 9 to 88 cm at the end of this century. Consequently, the sea is very likely to overflow the highly populated coastlines of some current countries or even cause the disappearance of some island nations entirely. It would ultimately cause foul freshwater supplies for billions of people and spur mass migrations. The current transport systems have also increased the amount of greenhouse gases in the atmosphere, especially carbon

dioxide, methane and nitrous oxide. Such gases occur naturally and are critical for life on earth; they keep some of the sun's warmth from reflecting back into space, and without them the world would be a cold and barren place. But in augmented and increasing quantities, these gases are pushing the global temperature to artificially high levels and changing the climate. Scientists have seriously warned that the ever-increasing global warming trend could ultimately lead to extinctions. The climate change could disrupt the land and collapse the food supply chain on earth. If the temperature increase is more than a few degrees C, then numerous plant and animal species, already weakened by pollution and loss of habitat, are not expected to survive the next 100 years. Agricultural yields are expected to drop in most tropical, sub-tropical and temperate regions. Drying of continental interiors is also foreseeable. Although other human economic activities such as cutting of forests and certain farming methods are also deteriorating the environments and altering the climate, burning of ever-greater quantities of petroleum in the transport sector has been the main cause of global warming and thus should take the major responsibility for climate change.

In addition, other environmental issues concerning transportation include the depletion of a non-renewable finite fossil resource, the opportunity costs of land for transportation usage, and noise and vibrations due to motor vehicle usage. Moreover, further deterioration can also be seen in the rapid reduction in natural habitats and number of species and recyclable resources such as fresh water, forests, topsoil, ocean fishes, and the poorer quality of drinking water. Other non-environmental impacts of transportation include the huge financial burdens in maintaining and operating the transport infrastructures and vehicle operations, the ubiquitous recurrent and non-recurrent congestions in various transport networks, the excessive injuries and fatalities due to motor vehicle accidents, the urban sprawl problems stimulated by motor vehicle transport, and the undesirable social disruption and poverty. All of the above-mentioned factors have lessened the potential for future generations to meet their transport needs. Hence, our current petroleum-based transport systems are not sustainable (Black, 1996).

## **2. Needs for Sustainable Development**

Sustainable development has become the main theme of a number of international and world conferences, such as the establishment of the Intergovernmental Panel on Climate Change in 1988, the UN Earth Summit in 1992, the European Conference of Ministers of Transport in 1995, and the Kyoto Convention on Climate Change in 1997. The need for sustainable development has been expressed in the early seventies with the publication of articles such as *A Blueprint for Survival* quoted in Haq (1997). Several academic works such as Cervero (1998), Nijkamp et al (1998), Newman and Kenworthy (1999) have also addressed the sustainable development issues.

The World Commission on Environment and Development (1987) published *Our Common Future*. In this report, sustainable development was defined as: "...development which meets present needs without compromising the ability of future generations to achieve their own needs and aspiration." This definition contains the concern for natural resources and the well being of human society as well as the recognition of the uncertainties encompassed by the time dimension and future resources, technologies and human values. In word, sustainable development is the

achievement of continued economic development and social activities without detriment to the environmental and natural resources. It has to do with long-term goals and impacts to future generations and to other regions or activities.

In June 1992, the Commission on Environment and Development of the United Nation held Earth Summit in Rio, Brazil. More than a hundred leaders from countries around the world attended that summit. After debates and discussions on sustainable development of the environment, they agreed to endorse the idea of sustainable development and passed *The Rio Environment and Development Declaration* and *The Agenda 21*, signed *The Framework Convention on Climate Change* and *The Convention of Biodiversity*, which demonstrated the new thinking and efforts of mankind to pursue sustainable development. *The Agenda 21* calls for signatories to establish and implement sustainable development strategies and to promote international cooperation to increase welfare of all peoples.

The 1997 Kyoto Convention on Climate Change took further steps in achieving an international and legally binding agreement—called *The Kyoto Protocol*, which has more power to reduce greenhouse gases emissions worldwide. In its Article 2, the objective is clearly stated: “The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.”

In August 2002, the United Nations invited world’s leaders to attend the Sustainable Development World Summit in Johannesburg, South Africa, aimed at implementation of sustainable development. This summit held discussions on sustainable development topics, such as water resources, energy, health, elimination of poverty, agricultural resources and biodiversity under the trend of globalization. The participants produced the World Summit of Sustainable Development Action Plans, and Johannesburg Declaration on the Sustainable Development of the United Nations World Summit, and promised that they would endeavor to achieve the goal of worldwide sustainable development.

On 18 November 2004, the 90-day countdown to *The Kyoto Protocol’s* entry into force was triggered by the receipt of the Russian Federation’s instrument of ratification with the United Nations Secretary-General. Entering into force on 16 February 2005, *The Kyoto Protocol* has broken new ground by defining three innovative “flexibility mechanisms” to lower the overall costs of achieving its emissions targets. These mechanisms enable Parties to access cost-effective opportunities to reduce emissions or to remove carbon from the atmosphere in other countries. While the cost of limiting emissions varies considerably from region to region, the benefit for the atmosphere is the same, wherever the action is taken.

### **3. Transportation: A Way to Sustainability**

Sustainable transportation is the expression of sustainable development in

transportation sector. The Organization of Economic Cooperation and Development (OECD, 1996) defined environmental sustainable transport (EST) as “transportation that does not endanger public health or ecosystems and meets mobility needs consistent with (a) use of renewable resources at below their rates of regeneration and (b) use of non-renewable resources at below the rates of development of renewable substitutes.” Black (1996) defined sustainable transportation as “...satisfying current transport and mobility needs without compromising the ability of future generations to meet these needs.”

After the 1992 Earth Summit, the United Nations Commission on Sustainable Development (UNCSD) was established to enforce, assist and monitor countries around the world to carry out sustainable development work. In response to *The Agenda 21*, many countries have issued statements or reports identifying the steps to make transportation more in line with sustainable development. For instance, the first North American response was prepared by Canada. Its 1993 report on *The State of Canada's Environment* addresses several areas on the sustainability question (Redpath, 1993). *Sustainable Development: the UK Strategy* (Department of Environment, 1994) is another example of such document; although it is not a transport report, transport did receive some attention in it.

In the United States, the White House issued *The Climate Change Action Plan* (Clinton and Gore, 1993), proposed a reduction in greenhouse gas emissions to 1990 level by the year 2000. Four federal programs were put in place: (1) Employees would be able to opt for the value of a parking place in dollars as income and arrange for their own transport (vans, buses, carpools) to work. (2) States would have to develop transportation system efficiency strategies ranging from market techniques to encourage people to drive less, parking charges, emissions-based fees, and transit subsidies. (3) Promotion of a greater use of telecommuting in order to decrease travel. (4) Federal DOT was to establish a system for labeling the fuel economy of different tires.

The President's Council on Sustainable Development (1996) further issued a statement, entitled *Sustainable America*, in which four sets of steps that would make transportation more sustainable were identified: (1) Improve community design to contain sprawl better, expand transit options, and make efficient use of land within a community. Locate homes for people of all incomes, places of work, schools, businesses, shops and transit in close proximity and in harmony with civic spaces. (2) Shift tax policies and reform subsidies to significantly improve economic and environmental performance and equity in the transportation sector. (3) Make greater use of market incentives, in addition to changes in tax and subsidy policies, to achieve environmental objectives. (4) Accelerate technology developments and encourage public-private collaboration to move industrial sectors closer to economic, environmental and equity goals.

In response to the concerns of governments that transportation has been posing the severe challenges for sustainable development, OECD organized a conference on *Towards Sustainable Transportation* at Vancouver, Canada in 1996. To make our current transport systems sustainable, OECD suggested some specific changes, including significant reduction in car ownership and use, and shifts to more efficient vehicles; reduced long-distance passenger and freight travel, particularly air travel,

and increased non-motorized short-distance travel; energy-efficient, electric powered, high-speed rail; energy-efficient, less polluting shipping; more accessible development patterns; increased use of telecommunications to substitute for physical travel; and more efficient production to reduce long-distance freight transport.

Different countries or world organizations used various indicators or criteria to measure sustainable transportation. For instance, US Department of Transportation suggested the following indicators: (1) Emissions: tons of mobile source emissions from on-road motor vehicles. (2) Greenhouse gas emissions: metric tons of carbon equivalent emissions from transportation sources. (3) Wetlands protection: acres of wetlands replaced for every acre affected by Federal-aid highway projects. (4) Livable communities/transit services: percent urban population living within 1-mile of transit stop with service of 15 minutes or less. (5) Airport noise exposure: number in US exposed to significant aircraft noise level. (6) Maritime oil spills: gallons of oil spilled per million gallons shipped by maritime sources. (7) Fisheries protection: compliance with Federal fisheries regulations. (8) Toxic materials: tons of hazardous liquid materials spilled per million ton-miles shipped; and gallons of hazardous liquid spilled per serious transportation incident. (9) Hazardous waste: percent DOT facilities categorized as No Further Remedial Action Planned under Superfund Act. (10) Environmental justice: environmental justice cases unresolved over one year.

In contrast, OECD used six criteria to measure the attainment of environmental sustainable transport in 2030 as follows: (1) Transport-related emissions of NO<sub>x</sub> have been reduced to the extent that the objectives for ambient nitrogen dioxide and for ozone level as well as for nitrogen deposition are achieved. (2) Emissions of VOCs have been reduced to the extent that excess ozone levels are avoided, and emissions of carcinogenic VOCs from all movement of all vehicles have been reduced to meet acceptable risk levels. (3) Climate change is being prevented by achieving per-capita CO<sub>2</sub> emissions from fossil fuel use for transportation consistent with the global protection goals for the atmosphere. (4) Emissions of particulates have been reduced to the extent that harmful ambient air levels are avoided. (5) Land surface in urban areas is used for movement, maintenance, and storage of motorized vehicles, including public transport vehicles such that the objectives for ecosystem protection are met. (6) Noise caused by transportation should not result in outdoor noise levels that present a health concern or serious nuisance.

To plan for sustainable transportation development, Shiftan et al (2003) proposed the following three goals: (1) Environmental goals, including reductions in air pollution and noise from road vehicles, preservation of open land, and protection of wild life and natural habitats. (2) Economic goals, including energy savings, minimizing the costs of transportation infrastructure, and travel time saving. (3) Social goals, including improvement of accessibility to employment, cultural activities and open land areas, maximization of the availability of public transport to the population, and increasing road safety by decreasing the number of road accidents and their severity.

Transportation development is mainly influenced by five factors, including spatial and land use planning, government policy, economic forces, technology, and social and behavioral trends (e.g., Nijkamp, et al 1998; Masser, et al 1992, 1993; Nijkamp, 1999). The land use patterns certainly affect the trip characteristics including trip length, trip distribution, trip volumes, and trip purposes. The influence is long term because of the

long-life span of buildings and infrastructures. Government policy is strongly involved in transportation development due to the need for long range planning, huge financial investment involved, and correction for negative external effects. However, the policies are always sensitive to political priorities. Economic forces normally drive the large-scale transportation projects such as airports, seaports, high speed rails, urban metros, and freeways. Due to the huge financial and investment capital needed, long time span of projects and slow rate of returns, large-scale transportation projects have long term effects on future generations. Technology can help reduce or change the transportation energy consumption, improve the waste treatments, and thus reduce the emission pollution, as well as offer substitutes to physical travel by communications. However, technology development in transportation is relatively slow due mainly to huge costs and long period for research and development, long life span of projects and mobile equipment. Finally, individual behavior is a combination of habits, practical and emotional considerations. Thus, social values and norms may greatly affect individuals' choice for transportation. The above-mentioned factors will evolve over time and will affect both the others and the transportation systems, including mobile technology, infrastructure design, travel behavior, the level of motorization, and policy measures. Thus, these factors will determine whether the progress in transportation is sustainable.

Other academic works have also proposed sustainable transportation strategies or actions. For instance, Hughes (1993) identified several actions that could be taken to reduce emissions from personal travel: motor vehicle fuel economy labeling, fuel economy feebates or rebates, programs for the development of alternative fuels, speed limits for motor vehicles, employee travel schemes, environmental impact assessments for transport projects, increased spending on transit, redistribution of transport taxes to more energy-efficient modes, accessibility taxes, area licensing or road fees, land use planning, and carbon taxes to lessen motor vehicle use. Shiftan et al (2003) proposed five strategies for sustainable transportation as follows. (1) Spatial strategies, such as defining car-restricted pedestrian-friendly zones in city centers, high density land uses or development along main public transport corridors, near major public transport stations or around the CBD area, and mixed land use development. (2) Economic strategies, such as heavy taxes on more than one vehicle per household, high parking fees or congestion pricing in the CBD area, heavy subsidization of public transport in order to decrease fares, privatization of public transport, and consideration of external costs in the evaluation of new projects. (3) Social strategies, such as public information as an aid to trip planning (time tables, different means of travel, fastest path from-to destination), information about the negative external effects of transportation on the environment and about how telecommuting can reduce the number of trips, and educational programs to increase public transport ridership and car pooling. (4) Technological strategies, such as incentives for buying zero emission vehicles, intensive development of ITS systems, a high quality public transport system based on buses, LRT and subway in the core area, and the development of communication infrastructure and local centers for telecommuting. (5) Governmental strategies, such as operating public transport daily and 24 hours a day, reducing the development of new roads, limiting parking spaces in ones that are well served by public transport, granting a business license on the basis of the provision of adequate public transport for employees.

#### **4. Taiwan's Responses to Sustainable Development**

#### 4.1 The initiatives

Over the recent three decades, Taiwan has enjoyed the blossom of economic growth with annual growth of gross domestic product (GDP) averaged about 8%. For instance, the per capita GDP was US \$12,588 in 2002, rising from the 20<sup>th</sup> world position in 1990 to the 17<sup>th</sup> (DGBAS, 2002). During the same period, the average economic growth rate was 6.4%, which was much higher than the world's average (2.7%). A political miracle was also created with a thriving democratic system in which Taiwan's citizens actively participate. However, in the process of economic development, we have experienced our share of ecological degradation, including pollution, dwindling of biological species, the decline of renewable energy, such as forests and fresh water. Such occurrence has inhibited sustainable development from being passed down to future generations. Thus, pursuing sustainable development has become a major goal for Taiwan in the 21<sup>st</sup> century.

In response to *The Rio Agenda 21*, Taiwan government has endeavored to carry out sustainable development based on the principles of equality between generations, social justice, equal emphasis on the environment and development, knowledge-based economy, human rights protection, education promotion, respect for aboriginal traditions, international participation. In August 1997, the Executive Yuan set up the National Council for Sustainable Development (NCSD). In May 2000, the NCSD drafted *The Agenda 21 of Taiwan: the Guidelines for the National Sustainable Development Strategy*, compiling the important documents on Taiwan's national sustainable development. Recognizing the importance of implementation, the NCSD started from June 2002 to offer proposals to the sustainable development action plan with reference to the special circumstances and conditions. These proposals enhance and enforce the government to build up the sustainable development structure, which included the undertaking, items, purposes, action details, laws and regulations, host agencies, affiliated agencies and the deadline for completion. In December 2002, *the Environmental Basic Law* was promulgated. Article 29 of this law states that the Executive Yuan should establish the National Council for Sustainable Development to respond to the relevant policy making and decisions of sustainable development in Taiwan, and pass to the relevant agencies for execution.

*The Guidelines for the National Sustainable Development Strategy* follows the following basic principles to achieve the vision of sustainable development. (1) Generation fairness: This generation has the responsibility to maintain and secure enough resources that can provide for the needs of future generations. (2) Environmental loading: Social and economic development should not cause overloading to the environment. (3) Balanced consideration: Environmental protection and economic development should be considered on an equal basis. (4) Prior precaution: Before commencement of any activities which can possibly cause significant and unavoidable damage toward the environment, environmental impact assessments should be implemented and efficient prevention measures adopted in advance, in order to minimize the damages. (5) Social justice: Distribution of environmental, social and economic resources should meet the fair and equity principles. (6) Public participation: Decision making for sustainable development actions should be predicated on comments and expectations from people at every socio-economic level. The sustainable development policies should be formed after



sufficient public participation and considerations. (7) Cost internalization: Based on the principles that the polluter has the responsibility to solve pollution problems and polluter/beneficiary pays, business sectors and society should internalize the external cost and reflect production cost rationally, through market mechanisms and economic tools. (8) Science and technology emphasis: The sustainable development strategies should be mapped out and the risks of these policies should be evaluated, based on the spirit and methodology of science. Technology innovation should be considered as the driving force for environmental protection and economic development. (9) System integration: Integrated consideration of eco-system should be taken before setting sustainable development strategy. Promotion of sustainable development policies also should be integrated into public and private sectors' efforts. (10) Global participation: To be a member of the international community, Taiwan should follow international moves, provide support to other developing nations, and set sustainable development as a priority.

Nine integrated strategies have been considered in *The Guidelines for the National Sustainable Development Strategy*. (1) Creation of good environmental quality: Strengthen the management and monitoring of nature resources, including air, water, land, wildlife, marine areas and forests; build up an environment with a rich ecosystem and unique culture by conserving and fair allocation of natural resources; plan and implement landscaping and public facilities in a systematic manner. (2) Creation of eco-balanced urban environment: Create an eco-balanced urban environment by considering the carrying capacity of the environment and the control of environmental loadings; prevent heat-island effect by promoting greening of urban environment measures. Promote the establishment of waste, air emission and water pollution treatment facilities, sewage and runoff separation and reclamation systems; implement urban water balance, soil and wastewater pollution cleanup tasks. Strengthen risk assessment of health and to adopt disaster prevention and emergency response measures; thereby providing citizens with a safe, healthy, and abundant living environment. (3) Promotion of social welfare policies: Eliminate the gap between the poor and the rich people by promoting social welfare policies; and achieve the goals of social balance and justice by strengthening welfare initiatives for aboriginals and minority groups. (4) Adjustment of lifestyle and personal behavior modes: Promote a new way of lifestyle, emphasizing resource conservation in order to replace the lavish behavior; buildup a society accustomed to resource recycling; implement waste and resource recycle/reuse systems; and establish a plain and conservative livelihood. (5) Promotion of risk management and proactive planning for economic development: Build up capacity of proactive planning; take ecology and biodiversity conservation into consideration ahead of promoting economic development; set aside environmental sensitivity areas, wildlife habitats, and undeveloped lands moderately, in order to keep ecosystems in balance. (6) Adjustment of energy polices and industrial structure and building a cleaner production mechanism: Diversify the modes of energy usage; promote energy efficiency; research and develop clean energy sources; and stabilize the energy demand and provision. Increase use of renewable energies; promote low emissions and energy conserving transportation systems to control carbon dioxide emissions. Reduce energy consumption; adjust industrial structure; and strengthen cleaner production mechanisms, in order to prevent ecological destruction, global warming and climactic changes. (7) Promotion of educational reform: Give everyone the access to school and social education and to fulfill the goal of personal self-development.

Provide basic living skills in primary education and emphasize on building basic scientific knowledge and social concerns in higher education. Access to public information is also necessary. Social education needs to promote lifelong learning opportunities in order to uncover citizen's natural talents and to buildup a computerized society. (8) Promotion of public policy participation: Policy decisions should be formed based on public consensus and support. We must respect comments from minorities, promote broad public participation in public and global environmental affairs, and accept public input. (9) Adjustment of organizational structure and proceeding with governmental reconstruction: Adjust governmental organization structure; establish Environmental Resource Ministry by integrating various ecological conservation, resource development, and environmental protection institutes. Proceed with government restructuring plan and implementation of a "focused, capable and perfect" policy package.

In addition to setting up the above basic principles and strategies for national sustainable development, the NCSD are to evaluate major issues relevant to national sustainable development; to coordinate and promote sustainable utilization of water and land resources and sustainable establishment of urban and rural green life, and promote the harmonious coexistence between human activities and the natural environment; to coordinate and promote biodiversity conservation and health risk management, so as to ensure human health and ecological balance; to coordinate and promote green technology and sustainable industry, so as to reach the dual goal of high environment quality and sustainable economic development; to spread the concept of sustainable development, promote the partnership between the government and communities, and carry out the overall task of sustainable development; and to promote sustainable development cooperation, actively participate in international environmental and sustainable development affairs, and take up the duties of a responsible member of the global village.

In order to set up an effective means of evaluating the sustainability of the island's national development, the NCSD has been extremely proactive in promoting efforts towards the development of a set of national sustainable development indicators (SDIs) and in putting into place the relevant mechanisms for recording, measuring, announcing and reviewing these indicators. Initially, a total of 112 indicators were proposed. After considering the feasibility and stability of data collection, the significance of correlation with public policy, the possibility of international collaboration, and other factors, a set of 42 meaningful and representative indicators were selected. These 42 SDIs include six core dimensions (ecological resources, environmental quality, social pressure, economic pressure, institutional response, and urban sustainable development) and are divided into two categories (island Taiwan indicators and urban Taiwan indicators).

Based on the "think globally, act locally" principle, the NCSD has set up twenty-two basic action guidelines for sustainable development. These specific guidelines can be divided into five fields: (1) sustainable environment, including atmosphere, water resources, terrestrial resources, marine resources, biodiversity, environmental management, (2) sustainable society, including population and health, residential environment, social welfare, preservation of cultural heritage, disaster prevention and response, (3) sustainable economic, including economic development, industry development, transportation development, energy strategy, resource recovery, (4)

development motivation, including educational development, science and technology development, informationized society, and (5) promotion mechanisms, including public participation, governmental restructure, and international cooperation (NCSD, 2000). The guidelines will be revised periodically in accordance with the changes of environmental, social and economic conditions.

#### **4.2 Some comments**

Taiwan is facing tougher and more urgent challenges than other nations in the pursuit of sustainable development because of the following reasons. Firstly, the ecosystem in Taiwan is very fragile with many unique characteristics. The habitats of diverse forms of flora and fauna have been harmed by decades of rapid economic development. Forests, coastal and marine areas, rivers and wetlands are all under threat. Secondly, the population density, numbers of motor vehicles, abundance of factories and primary energy consumption in Taiwan are all ranked among the highest in the world. These factors cause heavy environmental loadings to the environment. Though there is a current lack of public and private treatment facilities, the government deeply realizes the need to treat municipal wastes, wastewater and industrial wastes in an environmentally sound manner. Thirdly, with the limited space, dense population, and a shortage of natural resources in place, the natural resources in Taiwan are sometimes overused. The imbalance of water shortage and supply on the island has also caused groundwater levels to decrease. Fourthly, Taiwan is located on the eastern edge of the Asian continental shelf. Due to the complex nature of geology in this region, typhoons, flooding and earthquakes occur quite frequently. Finally, Taiwan relies heavily on international trading. Because the global business environments have become increasingly complex, the pressure for local businesses and resource consumption pattern to change has also increased tremendously.

In response to *The Agenda 21* and *The Kyoto Protocol*, Taiwan government must arouse public awareness of the importance of environmental protection, social safety, and open economy in achieving sustainability. Education is perhaps the most urgent work to form the public consensus. All producers and consumers must recognize the needs of sustainability and behave accordingly. For the environmental protection, people should understand the essential of co-existence and co-prosperity with other species while pursuing their living necessities. All public areas should improve their services and at the same time effective pollution control should be implemented. For social safety, an employment security system should enable workers who are willing and able to work to enjoy a certain protection to job security. All people should all enjoy social care under the national social security system in place. For the open economy, upon joining the WTO, the domestic economic development in Taiwan has geared toward preparing the business sectors for open competition.

To increase national competitiveness, Taiwan must strengthen science and technology development, establish green production technology, stimulate high-tech manufacturing industry, and become an intelligent technology island. On one hand, marketing and trading should be fair. Both public and private sectors should provide services with the needs of customers in mind, and consumer's rights should be protected. On the other hand, with the help of the Internet, finance, insurance, telecommunication, transportation, legal services, and accounting services should be globalized.

The government should provide stronger incentive measures, including sufficient subsidy or tax reduction to reduce energy usage, emissions, and wastes in both production and consumption sectors. Meanwhile, setting up higher national standards of energy efficiency and vehicle emissions as well as imposing more rigorous control measures (e.g., external cost pricing, taxation, restriction, or prohibition) are absolutely necessitated in both production and consumption sectors so as to discourage inefficient energy consumption and high pollution and waste. Advanced research, development, and production of renewable or recyclable resource usage and low- or zero-polluted energy should be promoted with priority. Green construction, green building, green transportation, green production, and green consumption rely on actions, not just slogans!

## **5. Taiwan's Undertakings for Sustainable Transportation**

### **5.1 The facts**

Taiwan is an island of 394 kilometers long and 144 kilometers wide with a total area 36,188 square kilometers. Due to the long and narrow geography with barrier of the central mountains, the major intercity transportation systems are north-south direction and circle around the island. The most important urban transportation has concentrated in three metropolitan areas -- Taipei, Taichung, and Kaohsiung as well as in some urban areas including Keelung, Hsinchu, Chiayi, and Tainan. In 2003, the population has reached 22.61 millions and the number of motor vehicles is 18.50 millions -- two-thirds of which are motorcycles (12.367 millions) and the other one-third are motor vehicles (6.134 millions). In terms of private vehicle ownership, every 4.37 persons own a passenger car; while every 1.83 persons own a motorcycle, which is the highest in the world.

The number of private vehicles in Taiwan has drastically increased since 1990 while the number of public vehicles has slightly increased in the same period. Compared with year 1990, the number of passenger cars and motorcycles in 2002 grew by 120% and 67%, respectively; however, the number of buses grew only by 17%. Private vehicles in Taiwan made the majority of daily personal trips. According to the 1995 national household interviews and screenline traffic surveys, of the 34.66-million short-distance (within 50 kilometers) daily trips, about 81% were made by private vehicles and only 19% by public transportation. Of the 895-thousand long-distance (beyond 50 kilometers) daily trips, on the other hand, about 62% were made by private modes and 38% by public transportation (Institute of Transportation, 2002).

The intercity public transport mainly includes bus, railway, and domestic air. The passengers in the intercity public transport market have declined from 628.7 millions in 1993 to 464.7 millions in 2002. The decline is mainly contributed by the large decrease in bus passengers, as the railway and air passengers remain small changed. Nonetheless, bus is still the most important mode in Taiwan's intercity transport market today. Of the total intercity passengers in 2002, for instance, nearly 60% are made by bus, 37.7% by railway and only 2.3% by air. By ignoring the air transportation, the intercity passenger-kilometers have reduced by 14%, from 1993 to 2002, with 26% decrease by bus but 1% increase by railway. In contrast, the average trip length by bus is increased by 26% but the railway has a 9% decrease. In 2002, the

average trip lengths for railway and bus are 55.12 and 34.66 kilometers, respectively. These figures elucidate the fact that railway mainly serves medium- to long-distance passengers while bus mainly serves the short- to medium-distance trips. The intercity bus carriers in Taiwan provide both services on freeways and local highways. Freeway coach routes link the major cities in the western corridor mainly through Freeways No. 1 and 3, while local highway bus routes provide services between local cities and rural or mountain areas. Quite a number of the bus carriers run both freeway and local highway routes. By the end of 2001, there were a total of 54 intercity bus carriers running 1,900 routes with 6,602 buses. Compared with the local routes, the freeway routes have much longer mileage and are equipped with more luxurious fleet facilities.

The railway networks in Taiwan encircle the whole island. Taiwan Railway Administration (TRA), the sole public rail operator, currently operates 1,093 kilometers of rail lines, of which 589 kilometers are double-track. The lines in the western corridor are double-track, 25KV-electrified, and link the major urban centers with express passenger train services. Most of the lines in the eastern corridor are single-track and not electrified; however, they play a vital role in the intercity transportation because of less development in that area.

In urban public transport, it is dominated by bus and metro. The public transit system in Taipei metropolitan area is much better than any other cities in Taiwan. By the end of 2002, Taipei (including Taipei City and Taipei County) had 14 city bus carriers with a total of 3,369 buses running on 272 routes. Taipei was the earliest city in Taiwan that introduced the bus exclusive lane in 1990. Currently, there are 10 bus exclusive lanes reaching 50.28 kilometers, which have effectively raised the bus speed and reliability. According to a before-and-after survey conducted in 1997 (Chen, et al 2002), the average bus running speed has increased by 47% and 41%, respectively, during the morning and afternoon peak hours; Meanwhile, due to the reduction of the conflicts between buses and other vehicles, the average running speed for passenger cars has also increased by 8% and 7% during the same rush hours. Besides, the bus operators have benefited from an increase of frequency by 2.55%, an increase of patronage by 2.31%, and an increase of per kilometer fare-box revenue by 0.07%. Moreover, the number of bus-involved accidents per million bus-kilometers traveled has been decreased by 15.23% because of the simplification of mixed traffic.

The Taipei metro system amounts to 67.2 kilometers with 64 stations and carries about one million passengers per day currently. The number of bus passengers in Taipei has declined each year before the first rapid transit line was opened in 1996; however, it had a slight increase since then due to the successful integration with the metro, which includes the adjustment of parallel bus routes, the launching of feeder bus routes, and the discounted transfer fare. According to the latest survey by the Department of Transportation (2002), the market share of public transit in Taipei metropolitan area has reached 46% in 2002.

In Kaohsiung, the only one government-owned operator provides the city bus service. This carrier had 437 buses running on 64 routes and carried 109,558 daily passengers in 2002, which counted merely 6.2% of Taipei's daily bus passengers. In Taichung, there are three private bus carriers providing the city bus services. They operated on 46 routes and carried about 33,000 passengers per day in 2002, which was only 1.9%

of Taipei's daily bus passengers. These figures also reflect the fact that public transit is not so popularly used in Taiwan except for Taipei.

Taxicab, the most important paratransit in Taiwan, provides very convenient door-to-door service, either from roadside on-demand call or by phone reservation. By the end of 2002, the number of taxicabs in Taipei, Kaohsiung, and Taichung Cities were respectively 35,445, 8,541, and 4,756. In terms of its ratio to the citizens, each taxi in Taipei, on average, serves only about 75 citizens, which is much lower than the figures in Kaohsiung and Taichung. This also indicates that the taxi service capability in Taipei is extremely high, even a great deal higher than most of the large cities worldwide. In addition, according to the latest survey (Chou, 2002), a good number of previous taxi passengers have switched to use the Taipei metro system, which has contributed to the taxi average unoccupied rate as high as 59.83%.

The lift-equipped handicapped van, also known as Fu-Kang minibus, is an important paratransit mode for the severe physically handicapped persons and their attendants in Taiwan. Taipei City Government has commissioned the Fu-Kang minibus fleets to the private operators since 1999. By the end of 2002, a total of 88 Fu-Kang minibuses were in operation and served about 20,000 trips per month. Each trip is charged by one third of the taxi fare and Taipei City Government subsidizes the remaining two thirds. In Kaohsiung and Taichung, the city governments directly operate the Fu-Kang minibus. Each trip is charged by one half of the taxi fare in Kaohsiung, while in Taichung the minibus is rent at NT\$ 2,000 on a daily basis.

## 5.2 Policy development

Like many developed countries, the transportation systems in Taiwan have caused serious impacts to the environmental, economic and social systems. The environmental impacts include air pollution, noise pollution, and marine pollution from road vehicles, aircrafts and vessels, destruction of open land, wild life and natural habitats. The economic impacts include ever-increasing consumption of petroleum fuel, deteriorating level of service due to congestion in transportation networks, huge financial burden in maintaining and operating the transportation infrastructures and services. The social impacts include inequitable accessibility and mobility to the handicapped and the people in less developed areas, human mortality and morbidity problems due to transportation accidents and petroleum-based emissions.

In response to *The Rio Agenda 21*, Taiwan government proposed strategies for developing sustainable transportation to ensure that environmental, economic and social considerations are factored into the transportation policy decision-makings. In maintaining the environmental sustainability, the government proclaimed to enhance the efficiency of transportation energy usage and to lower the air, noise, water pollution and greenhouse gas emissions by introducing low pollution and high energy efficiency transportation systems as well as by lowering the environmental impacts from transport activities. In upholding the economic sustainability, the government declared to promote the growth of economic development and to enhance the operating efficiency of transport services by stimulating more private participation in transport infrastructures, more liberalization and privatization in transport service industries, and expediting the operational processes in the inter-modal transport

systems. In keeping the social sustainability, the government proclaimed to ameliorate overall transportation quality as well as to consider the social equity by providing safe, healthy, and comfortable transportation environment while meeting the basic needs of transport for all people.

The development of public transport in Taiwan was perhaps the most prominent achievement of sustainable transportation. In order to break or reverse the direction of public-private transport vicious circle, giving the bus preferential treatment such as exclusive lanes in congested areas was proposed to enhance the bus operating efficiency and service reliability. Meanwhile, providing subsidies and tax exempt or reduction to the transit operators were also proposed to reduce the transit operating costs and the pressure of fare increase. Also proposed was raising the out-of-pocket expenses of private vehicle ownership and usage to reflect the external costs. Under such “carrot and stick” planning philosophy, the policy for developing the public transport in Taiwan was formulated. This rationale was clearly documented in the first *Transportation Policy White Book*, released by the MOTC in 1995. This document was the first transportation policy book in Taiwan, which definitely proclaimed to develop the public transport. To cope with the environmental change, the first *White Book* was revised in 2002. More explicit policies and strategies for the development of public transport were clearly outlined in the revised *White Book*.

Laying down the legislation was also the most fundamental task for developing the public transportation policy, too. The Public Transportation Development Act (PTDA) was promulgated in May 2002. Based on this law, the government shall subsidize the capital investment and operation deficit to those routes serving in the remote districts, such as offshore islands, mountain and rural areas. PTDA also requires the regulatory agencies to conduct periodical assessment on the operation of public transportation systems. In order to increase the attraction of public transit systems, PTDA pushes for constructing more bus exclusive lanes and public transit terminals and for integrating the tickets and schedules of different transit systems. Moreover, PTDA permits public transit carriers to charge full fare for any passenger. The discount concession for special passengers, such as the aged and the handicapped, previously cross-subsidized by the full-fare passengers now is directly subsidized by governments.

Providing higher quality of public transport services to attract more passengers from the private vehicles was considered as a general policy guideline in the *White Book*. Constructing new metro or light rail systems were also regarded as the important policy guideline. For example, the largest public transit project in Taiwan, a high-speed railway linking the major cities in the western corridor, is under construction. With the experience of rapidity, punctuality, and high capacity of Taipei metro, the government is also considering various types of rapid transit systems in different urbanized areas such as Taoyuan, Hsinchu and Taichung as well as a rapid transit line linking the CKS International Airport at Taoyuan to Taipei. To attract more people to use public transit, the government also endeavors to improve the transit service quality by implementing the integration of ticketing systems, schedules and transfer terminals, providing more exclusive lanes to bus transit, directly subsidizing the remote deficit routes, and keeping freeway coach market opened. With the successful demonstration of some pilot projects, the government intends to help the operators to introduce innovative intelligent transportation system (ITS) technologies to improve the efficiency and effectiveness of public transit systems operation.

### 5.3 Important deployments

Under the policy guides in the *White Book*, Taiwan government has exercised a series of public transport initiatives since 1995. Of these deployments, the so-called Five-year Enhancement of Mass Transportation Program and some innovative ITS applications are viewed as the most critical ones. Furthermore, the upgrading public transportation schemes in the National Development Plan, released in May 2002, have sketched the ongoing and near future deployments for the public transport in Taiwan.

#### The Enhancement of Mass Transportation Program:

In order to ameliorate the mass transportation services and to assist those operators with operational difficulties, the Five-year Enhancement of Mass Transportation Program, approved by Executive Yuan, had been implemented by MOTC from 1996 to 2001. In this program, the tax/fee exemption has improved the operators' financial crises, the direct subsidy has offered the essential money to keep the deficit routes in service, the periodical operational appraisal has ensured the transport service quality, the lift of entrance barrier has encouraged the competition in the freeway coach market, and the introduction of more exclusive lanes and innovative ITS demonstration projects have also improved the efficiency and effectiveness of bus operation. This program was viewed as the most important public transport action plan in Taiwan's public transport history (Chang, 2002).

One of the most important undertakings in the five-year enhancement program was the direct subsidy to deficit transit routes, started from July 1996. It was the first attempt in Taiwan's public transportation history. To the end of 2001, the subsidies to intercity and urban bus carriers amounted to NT\$ 3,958 and 2,330 millions, respectively. The direct subsidy has in effect kept many deficit routes in service, especially in the rural and mountain areas. In addition, to help reduce the operation costs, the government has exempted the fuel and license plate taxes since 1996. The taxes saved by all of the bus carriers approximately amounted to NT\$ 3 billions from 1996 to 2001. The government has also exempted the freeway tolls for the bus carriers since February 1997. To the end of 2001, the total tolls saved amounted to NT\$ 1.5 billions. These exemption measures have effectively benefited the bus carriers to resist their financial difficulties.

Another important undertaking related to the five-year enhancement program was the "open market" of freeway transit services. It was thought that the competition would invite higher quantity and quality of freeway transit services so as to attract more automobile users and to mitigate the serious freeway congestion and related environment impacts (Lan and Wang, 2002). MOTC opened the freeway market in 1995. By the end of the five-year enhancement program, the number of freeway coach carriers has considerably increased to 33 offering 140 routes. According to a recent survey (Institute of Transportation, 2000), the freeway market deregulation has essentially promoted the competition; as a consequence, the service quality and fleet capacity have been largely improved and the number of freeway passengers has drastically increased.

#### ITS Applications:



In Taiwan, the first commercial electronic ticketing system was launched for the public transit, including bus and ferries in Kingmen Island in 2000. According to the survey (Huang, 2003), the number of cards issued has amounted to more than 50 thousands by the end of 2002, almost every resident in Kingmen Island owns an IC card. Until June 2002, the first contactless IC card, called Easycard, has started its commercial operation in Taipei metropolitan area. The Taipei Smart Card Corporation (TSCC), jointly founded by Taipei City Government, Taipei Rapid Transit Corporation, fourteen bus carriers, and some banks and private corporations, is responsible for providing the hardware and software of this ticketing system. Now Taipei Easycard can be used in all the metro lines and buses and 67 public car parks. According to TSCC, the number of Easycards issued has almost reached five millions at the end of January 2005. TSCC is planning to include other transport and non-transport services to expand its market penetrations.

In 1995, the Institute of Transportation of MOTC commissioned two real-time bus information system (RBIS) projects in Taipei and Hsinchu Cities. The systems, integrated by the vehicle location and wireless telecommunication technologies, can display real-time bus positions on the LED panels at each bus stop to notify the waiting passengers. Since the real-time information is transmitted by cable televisions, passengers at home can also check where the buses are. The information is also transmitted to the bus administrative office to facilitate the fleet supervision and dispatches. Later, Kaohsiung and Taichung Cities also began to implement the RBIS projects in 2001 and 2002, respectively. Another bus real-time information system in use is the “spoken LED units” that broadcast and display the current and next bus stops to notify the on-board passengers. It facilitates the occasional riders as well as the passengers with visually or hearing impaired. Taipei City Government started to finance the spoken LED units in 2002. Currently, all the buses in Taipei are equipped with such units.

To monitor the speeding and other aberrant driving behaviors that may jeopardize the safety for passengers, in the past, analog tachometer was installed, by regulation, on each bus. This conventional tachometer provided only very limited information for managerial purpose but it required tremendous man-hours to interpret the data. Recently, some bus carriers in Taiwan have attempted more advance devices, the digital tachometers, to supervise the aberrant behaviors for bus drivers. It has provided detailed en route data, from which some useful managerial indexes can be extracted and used for monitoring the drivers’ abnormal operation behaviors in a very efficient and effective manner (Lan and Kuo, 2004). In order to promote such digital tachometers, IOT began to document the technical requirements and functional specifications in 2002. It is anticipated that, after the proclamation of related documents, all buses in Taiwan will be enforced to equip with such advanced devices to promote safety and quality of services.

An innovative integration of GPS, geographic information system (GIS), and wireless telecommunication technologies on paratransit, such as taxicab and dial-a-ride handicapped vehicle, has been introduced in Taiwan recently. This technology can improve the vehicle dispatching efficiency due to the real-time vehicle positions collected by the GPS and displayed on the GIS. In March 2002, the first GPS taxi fleet in Taipei, known as Taiwan Taxi, started its commercial service, which is very

similar to the Singapore's Comfort Transportation Pte Ltd. By July 2003, Taiwan Taxi had about 1,600 taxicabs and it is expected to expand the fleet size in the near future.

### Ongoing Schemes:

The planning philosophy of Taiwan's sustainable transportation policies is based on the rationale that good public transport can not only mitigate the traffic congestion but also benefit the society at large. The National Development Plan, recently released by the Council for Economic Planning and Development in May 2002, is the most critical proposal to sketch the near future of Taiwan to the end of 2008. In this plan, one strategy for upgrading public transportation systems is the subsequent undertakings of the five-year enhancement program that was ended in June 2001. This upgrading strategy appends a predetermined budget of NT\$ six billions from 2004 to 2008, which contains the following public transit development schemes: (1) provide the local governments with budgets to plan the service integration among different public transit systems, (2) provide the budget to build public transit terminals, (3) provide the local governments with financial assistance to construct bus exclusive lanes, (4) provide the budget for implementing bus service appraisal every two years, (5) subsidize the bus carriers to invest in purchasing new buses, (6) subsidize the bus carriers to create electronic ticketing systems, and (7) continuously subsidize the operating deficits of bus routes serving in the remote areas.

To correct the previous undersupplied public transportation infrastructures, Taiwan government has approved to introduce more guideway transport systems. In Taipei, the initial metro network still has two more lines and two extensions under construction and one line at the detailed design stage. For the future expanded network, five more new lines and some extensions of existing lines with 67.7 kilometers will be constructed in the coming 10 years. Until then, the total length of Taipei metro will reach 134.9 kilometers. The initial network of Kaohsiung Rapid Transit System is 42.7 kilometers long with 38 stations. This metro system is a build-operate-transfer (BOT) project and is expected to provide high capacity and quality service for most commuting travels in Kaohsiung at the end of 2006. The high-speed rail, with 345 km connecting 14 major cities, is the largest transportation infrastructure as well as the first major public construction project with private investment in Taiwan. It is capable of carrying over 300,000 passengers per day and of reaching an operating speed as high as 300 kilometers per hour, which, as a result, would shorten the north-south journey time from Taipei to Kaohsiung to within 90 minutes. This project is still in progress under a BOT concession contract. It is scheduled to open for service in October 2005.

### **5.4 Suggestions**

Inadequate "sticks" for cars and motorcycles usage is mostly criticized. Reducing the heavy use of private vehicles has been set in the first *White Book* as one of the policy goals; however, the realization is yet accomplished. Accurately reflecting the private vehicle "external costs" by imposing higher taxes or raising parking fees is not satisfactorily put into practice in most jurisdictions mainly for political reasons. Other restrained tactics, such as requiring a parking space to be entitled to own a car or imposing congestion tolls on the private vehicles entering the CBD (similar to the Singapore's electronic road pricing), are just under study but with very controversial

debates. We urge the government to employ harsher “sticks” by imposing higher charges and necessary restrictions on private vehicles usage, especially in the areas where public transport systems are well provided.

Inadequate “carrots” for public transport is also criticized. While the subsidies in the five-year enhancement program have lessened the transit carriers’ financial difficulties, a recent survey (Lan, et al 2003) showed that nearly two thirds of the intercity bus carriers had operation deficits in 2001. We recommend the governments at different levels allocate enough budgets (e.g., from the air pollution fee or public parking revenue) to assist and subsidize the public transport systems including the related ITS applications. The worldwide concerns about the limited gasoline reserves and atmospheric greenhouse effect have aroused the transit-oriented development (TOD) for sustainable planning. The government should amalgamate the TOD concept into the land use and transportation planning. In metropolitan areas like Taoyuan, Taichung and Kaohsiung, the populations are more than one million but the public transit services are undersupplied, giving priority to build metro systems is recommended. In other urban areas that have not enough demands to support expensive metro, we recommend the governments introduce low-cost rapid transit systems, such as bus exclusive lanes, bus rapid transit, light rails or alike.

The high-speed rail will certainly usher a new era of intercity transportation in Taiwan, which will inevitably attract a good number of passengers from the domestic airline, freeway coach and railway markets in the western corridor. To avoid waste of transport resources, the government should direct the domestic aviation to offshore islands and international markets (including the direct flights to Mainland) as soon as possible. Freeway coaches, particularly the long-distance routes, must be repositioned. The government should provide assistance to the intermodal service integration and build adequate public transit terminals for the ease of passenger transfers. Taiwan Railway Administration (TRA) must change its position to act as regional rapid transit systems in the northern, central, and southern regions by providing more frequent services for short-to-medium distance passengers. In addition, TRA must be reformed for financial sustainability reason. TRA has been suffering from a deficit since 1978, the year that the first freeway was opened to traffic. The annual deficit has increased over NT\$ 10 billions since 1998. We urge the government to designate a special grant or budget to completely offset the cumulative debts of TRA and to immediately cease the lifetime retired-allowance system. Privatization of TRA is perhaps the best way towards financial sustainability and operational efficiency.

Finally, the direct transport between Taiwan and Mainland has yet been resolved because of the long-existing political conflicts between both sides. Currently, the aircrafts on one side are not allowed to go to the other side, but the vessels carrying cargos from one side can reach the other side’s “off-shore” destinations via a third region, such as Hong Kong. This indirect transportation is not sustainable because it causes tremendous extra transportation times and costs, which lowers both sides’ economic efficiency and market competition. Both Taiwan and Mainland governments are urged to start the peace talks as soon as possible on such topics as trades, marriage, tourism, anti-criminals and cultural exchanges without changing the political status quo. Since all of these topics relate to direct transportation, we urge both sides starting with special security code systems that can identify the civil aircrafts and vessels along the designated routes.

## 6. Future Challenges

Some argued that sustainability exists when the 'full social costs' of an activity, including the intergenerational costs, are paid and that full costs must be based on the life-cycle approach. Not only should vehicles be sustainable when in use, their production and disposal as well as the production, maintenance and disposal of essential infrastructures should also be sustainable. However, the life-cycle costs of any of transport undertakings to future generations, including human illness and death, ecosystem damage, reduction in biodiversities, climate change, stratospheric ozone depletion, ground-level ozone formation, emissions of particulates, noise and vibration, land use changes, resource use, waste disposal, water pollutions and hydrological impacts, are not easy to calculate. The costing is rarely satisfactory even when current generations are considered.

The concept of full-cost pricing is useful both from equity and efficiency perspectives. People responsible for polluting activities should pay the cost of that activity. However, many of the sustainability indicators do not have market values. For instance, the air pollutants emitted from transportation are negative externalities in which markets are not taking care of (i.e., market failure). To correct it, Pigouvian tax, which is equal to the value of the 'marginal external cost' at the optimal output level, needs to be imposed on the polluters (Pigou, 1938). This concept is simple but the estimation is complicated.

Two main approaches are found in the external costing literature: hedonic-pricing method and damage-function method (or dose response approach), of them, the damage function appears to be more widely used (Zhang and Yuan, 2004). For instance, to find the optimal Pigouvian tax for air pollution, a damage function, which indicates how pollution damage varies with the level of pollution emitted in terms of monetary value, is needed. Despite that the estimation of external costs has had a significant progress during the past decade, most of the literature only focused on the short-term estimation (e.g., Small and Kazimi, 1995; Mayeres, et al 1996; Danielis and Chiabai, 1998). A long-term intergenerational costing or lifecycle costing of transportation externalities has remained unexplored so far.

Plan for sound sustainable transportation is not easy because it involves a high level of uncertainty regarding the impacts of a given transportation policy package on the future environmental, economic and social systems. The word 'sustainability' has broad and vague meanings and no universal definition has yet been found. Hanson (1998) argued that the question of exactly what sustainability means is vague and vexing, which relates to such matters as how long the impacts should be taken into account and what indicators should be used to represent the sustainability, and so on. If further considering the vagueness of sustainability definition, the lifecycle full-costs pricing would become even more difficult.

To deal with the vagueness, we may make use of fuzzy mathematical programming (FMP) models, which can be divided into three categories (Inuiguchi and Ramik, 2000): (1) flexible programming, which deals with vague objective or right-hand-side constraints; (2) possibilistic programming, which associates with ambiguous parameters; and (3) robust programming, which relates to vagueness and ambiguity

for both (1) and (2). Numerous related FMP models can be found in the literature and their solving techniques have been well developed. For instance, Hu and Fang (1998) proposed a max-min arithmetical method and induced a new variable to simplify the multi-objective programming problem transformed from FMP. Buckley (1995), Ramik and Rommelfanger (1996), Nakahara (1998), Parra et al (1999), and Sakawa and Nishizaki (2002) employed the possibility distribution to transform fuzzy numbers into crisp ones in order to simplify FMP as a linear programming problem. Rommelfanger (1996) proposed a method to transform the fuzzy constraint into a crisp constraint and a crisp objective function and then employed the max-min method to obtain the compromise solutions. Buckley and Feuring (2000) utilized Hamming distance to define fuzzy objective function and employed fuzzy numbers ranking method to represent the satisfaction of fuzzy constraints. Although FMP might be applicable, the determination of cortices or spreads of fuzzy numbers based on our current value systems can be too subjective and is perhaps not agreed by the future generations.

In his book, *City of Bits*, Mitchell (1995) sketched out a vision of the future based on many dichotomies as follows: spatial or anti-spatial, corporeal or in-corporeal, focused or fragmented, contiguous or connected, synchronous or asynchronous, narrowband or broadband, nervous system or bodynet, hands or telemanipulators, brains or artificial intelligence, façade or interface, bookstores or bitstores, work or network, at home or @home, face-to-face or interface, one the spot or on the net, street networks or worldwide web, neighborhoods or MUDs (multi-user dungeons), public space or public access, moving materials or processing bits, territory or topology. With new technologies, more and more of the instruments of human interactions and of production and consumption can be miniaturized, dematerialized, and cut loose from fixed locations. Although the ground-breaking technologies can revolutionize the future human lifestyles, civil engineering, the most ancient profession, is still playing the most fundamental role for sustainable development. In Chinese characters, “土木” represents civil engineering. The first character “土” means earth, environment, and resources; the second character “木” means forest, ecology, and hazard mitigation (Chern, 2004). According to the meanings of these two Chinese characters, civil engineering can be defined as sustainable development engineering. The core duty of civil engineers is thereby to construct and maintain infrastructures to create a safe, healthy, comfortable, and sustainable living environment and to build a pleasant world in harmonious with the nature.

To conclude, sustainable transport refers to the environmental, social and economic sustainability in transport sector, which contains three major parts: infrastructures, vehicles and facilities, operation and maintenance. In the construction and maintenance of transportation infrastructures, we need to advance the science and technology of “土木” and related professions so as to promote the preservation of the precious environment and prevention of the natural disasters. In the design and manufacturing of vehicles and facilities, we need to enhance the safety, comfort, and rapidity of vehicles or equipment and endeavor to the energy saving and emissions reduction. In operating and maintaining the transportation systems, we need to reduce new constructions by extending the service life of existent infrastructures. More importantly, we need to reduce the intensity and distance of transportation by reshaping the land-use patterns and better utilizing the substitutes. To be sustainable, the overall transportation undertakings must not endanger the public health or

ecosystems while meeting the mobility needs. They must comply with two basic principles: use of renewable resources at below their rates of regeneration and use of non-renewable resources at below the rates of development of renewable substitutes.

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