Energy-Saving and Carbon Reduction Effects of Long-Term Green Transportation Policy in Taiwan: International Comparisons and the East Asian Perspective

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ABSTRACT

Energy-saving and carbon reduction in the transportation industry are becoming important research issues in East Asia. Among various international policy-effect evaluation frameworks, the current study first reviews taxation, pricing, and demand elasticity among car users. Second, it reviews the thinking behind the operation of rail systems, as well as the policies therein, and evaluations of their efficiency and sustainability. In the United States, developments in train systems that took place between 1955 and 1975—including the thruport design for freight distribution—marked the first wave of this trend. Between the mid-1990s and 2006 in East Asia, the growth of railway patronage numbers as a proportion of public transportation highlights the importance of integrating land-use plans and low-carbon transportation systems in working towards the creation of sustainable cities. Finally, energy-saving policies within the transportation industry need to be evaluated in terms of national socioeconomic background (i.e., calculations of Taiwan's carbon emissions reductions as a result of implementing high-speed rail, both during the feasibility study stage [before 1994] and the system's business operations [after 2007]). Lessons drawn from past experiences are summarized, and East Asian perspectives (especially those of the Association of Southeast Asian Nations) are suggested.

Keywords: Energy-saving, carbon reduction, taxation, pricing, land transportation, East Asia
JEL Classifications: N70, R48, O57

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1 Introduction

Transportation activity, a key component of economic development and human welfare, increases worldwide as economies grow. The use of forms of transportation that expend high levels of energy is inevitable in the early stages of economic development (i.e., during the take-off and high-growth phases). Links between transport and the economy are strong, and the increased use of transport and worsening environmental deterioration are interwoven. For most policymakers and stakeholders, the most pressing problems associated with this increase in transport activity are traffic fatalities and injuries, congestion, air pollution, and petroleum dependence.

Once its economy enters a mature stage, an advanced country may begin to see a relative decoupling of both passenger and freight transport growth from gross domestic product (GDP) growth. Among Organization for Economic Co-operation and Development (OECD) countries since 1960, income growth, technological and infrastructure improvements, and greater amounts of leisure time have allowed people to travel more frequently and at further distances. Policy paid attention to saving transportation-related energy and reducing carbon dioxide (CO_2) emissions may change. The decoupling of transportation pollution from GDP growth is greatly assisted by economic development, along with carefully integrated transportation and land-use planning.

Propelling worldwide growth in transportation-related energy consumption, primarily, is the use of light-duty vehicles (LDVs), freight trucks, and air travel. *Mobility 2030* estimates that these transport modes will account for 38%, 27%, and 23%, respectively, of the total 100-exajoule forecasted growth in transportation energy between 2000 and 2050. This study mainly reviews LDVs and freight-related energy-saving issues.[2] Furthermore, energy cost-saving[3] policies

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[2] Due to the necessarily strict standards and practices vis-à-vis aircraft, as well as matters relating to safety supervision, security audits, and aviation security management, most air travel transportation policies have been under the auspices of the International Civil Aviation Organization.

[3] Transport economists may have an interest in the basic terminology pertaining to energy-saving in transportation; these terms include “transportation intensity,” “energy intensity,” and “emission reduction.” Policy implementation and its effects can differ markedly between the sphere of personal vehicles and that of public transportation. In general, personal vehicles lead to three “highs”: high transportation intensity, high energy intensity, and high emissions. Introducing a good public transportation capacity plan (i.e., a low, median, or high-capacity urban transit system) can increase transportation intensity and reduce both energy consumption and emissions. Nonetheless, if urban settlement is greatly dispersed, in that region, highly energy-efficient personal vehicles could be a superior transportation mode to public ones. Second, the aggregate energy intensity of travel or freight transport is shaped by the relative importance of various transport modes and their energy intensities, which are determined by considering both vehicle fuel intensity (energy per kilometer) and vehicle capacity. An increase in the latter leads to a decline in modal energy intensity. Third, the quality of the transport infrastructure affects both mode choice and energy intensity; however, a detailed examination of this is beyond the scope of this study.

and a shift from the use of private cars or aircraft to rail transport for both the metropolitan and inter-city movement of people and goods will be a future trend in developing countries. This study examines how this shift has begun in terms of national policy experiences and development history, while later examining the case of Taiwan.

Among the important findings on transportation energy use in eight OECD countries,[4] less-developed countries (LDCs), and the former East European block from 1970 to 1988, we can draw five especially salient points.

1. *Historical background*: In 1988, around 64% of the world's total transportation energy use was by OECD countries, reflecting their high levels of automobile ownership and use. The shares of LDCs and the former East European block were only 22% and 14%, respectively. Since 1970, however, growth in terms of this energy-use ratio has been much faster among LDCs (5.1% per year) than among OECD countries (2.4%) and the former East European block (2.0%). The real price of gasoline in 1988 in most countries was close to its 1970–73 level, and the trend in Europe toward larger cars began in the 1960s.
2. The *energy intensity* of rail travel declined slightly in Western Europe in the early 1970s, but has changed little since then. Rail energy intensity in Japan is much lower than elsewhere, given the high ridership levels there. Rail energy intensity is several times higher in the United States than in Europe and Japan, due in part to the relatively large share of urban and commuter rail in total rail travel (i.e., lower load factors during nonpeak hours).
3. Whereas in 1973 *automobile energy use* per kilometer was twice as high in the United States as in Europe-6, by 1988 it was only about 50% higher; part of the difference between the United States and Europe-6 is due to the popularity of light trucks in the former.
4. *Modal structure in freight*: While there was only a slight shift in freight (tons per kilometer) from rail to trucks and ships in the United States (probably due to the successful implementation of the thruport design, which will be discussed in Section 3), Japan and Europe-6 each saw a major shift from rail use to truck use. During 1970–1988, the share of freight activity in trucks increased from 35% to 51% in Japan, and from 54% to 63% in Europe-6; the share of rail declined from 14% to 5% and from 28% to 18%, in Japan and Europe-6, respectively. The growing use of "just-in-time" delivery in manufacturing has favored trucks.

[4]See Schipper, Steiner, and Meyers (1992). In the current study, "OECD-8" refers to the United States, Japan, West Germany, United Kingdom, France, Italy, Sweden, and Norway. The last six of these countries comprised the "Europe-6" at that time.

5. In breaking down changes in *aggregate freight energy intensity* between 1973 and 1988, we find that that of the United States increased 4%; compare this to the 12% increase in each of Japan and Europe-6. A structural change toward truck use contributed strongly to the increase in Japan, and more than offset the decline in energy intensity.

Worldwide, transport is predominantly fueled by a single fossil resource—namely, petroleum, which supplies 95% of the total energy used in transport worldwide. In 2004, transport was responsible for 23% of the world's energy-related greenhouse gas (GHG) emissions, with about three-quarters of it coming from road vehicles. Between 1997 and 2007, transport's GHG emissions have increased at a faster rate than that of any other energy-using sector (Ribeiro et al., 2007).

Second, according to an Intergovernmental Panel on Climate Change (IPCC) report (Ribeiro et al., 2007), mitigation technologies and strategies within the transportation sector can be classified in terms of four travel modes: road (or ground) transportation,[5] rail, aviation, and shipping. According to the International Energy Agency (IEA)/OECD 2009 report, the four most important modes, in terms of their expected contribution to CO_2 in the 2050 baseline scenario, are LDVs (43%), trucks (21%), aviation (20%), and shipping (8%). Rail and other new modes account for only 8%. The first two transportation modes—which together constitute "surface transport"—generate 64% of all emissions. If a government can implement related policies effectively, the contribution to reducing domestic GHG emissions and saving energy can be large. However, cooperation with private sectors, and/or subsidies offered to them, are also important to promoting long-term technical progress and sustainable transportation systems.

The remainder of this paper is organized as follows. Section 1 provides an overview of the international history of implementing energy-saving polices and measures in the transportation sector, and Section 2 compares South Korea's experience with energy pricing and demand elasticity to that of Taiwan, from 1973 to 1992. Section 3 is a review of the historical implementation and effects of rail transportation sustainability, including both the thruport design[6] (a facility design that facilitates the handling of high-volume transmodal rail shipments) and trends in railway use in East Asia between the mid-1990s and 2006. Finally, Section 4 offers policy formulation ideas and plans for modern

[5]Some transportation modal research—such as that from the IEA and the OECD—classifies road transportation into (1) LDVs and (2) trucks and freight movement.

[6]A thruport is defined as a seamless transfer of freight that reduces handling and the number of movements required to perform a transmodal container or trailer operation. An analogy can be made with air–ocean transport hubs that consolidate and redistribute passenger and freight traffic.

rail transport in Taiwan (i.e., Taipei Metro transit and high-speed rail [HSR]). Key lessons from these experiences may assist in the formulation of global policy and action plans that promote sustainable transport cooperation between developed and developing countries.

2 Transportation policy framework and energy-saving policies/measures: international experiences

Five types of policies and measures help save energy and reduce GHG emissions, en route to securing sustainable surface transport. These include (1) land-use and transport planning, (2) appropriate taxation and pricing, (3) regulatory and operational measures, (4) fuel economy standards in road transport, and (5) transport demand management (Ribeiro et al., 2007). Few papers have been published that provide a consistent environmental perspective on these five types of initiatives. For example, the research reported here undertakes adequate international comparisons only for types (1), (2), the second part of (3), (4), and (5).

2.1 Integrated land-use and transport planning (road networks for achieving land-use efficiency)

The optimal urban structure allows residents to move around easily while expending minimal energy. Before 1980, the percentage of trips undertaken by walking, cycling, and taking public transport was 50% or higher in most Asian, African, and Latin American cities; that number in Chinese cities was especially high, at 65%. This was largely because low incomes in these regions prohibited car ownership. However, if we compare these numbers to those in developed countries, we find that Japan and Western Europe had moderate percentages, around 32%. The numbers from the United States, Canada, and Australia/New Zealand were the three lowest, worldwide. The coordination of land-use and transport planning is crucial to maintaining high shares of nonmotorized and public motorized transport use. The use of investment appraisals is important to integrated land-use and transportation planning (Nijkamp, Ubbels, and Verhoef, 2003).

There are many examples of successfully integrated land-use and transport planning; however, there is little published evidence citing the effectiveness of policies in shifting passengers from cars to buses and rails. A Japanese study of four domestic rails and monorails showed that 10–30% of passengers on these modes had shifted from using personal automobiles, and a majority of passengers had switched from alternative bus and rail routes (JMLIT and IHE, 2004).

2.2 Evidence of effective taxation, pricing, and energy-saving policies

2.2.1 Taxation and pricing policies in developing and developed countries

In general, single-policy initiatives tend to have a rather modest effect on the motorization process. The various pricing and regulatory instruments that have been enacted in various countries are summarized in Table 1. Personal vehicles and road freight are the main targets of taxes and pricing measures in the transport sector, in developing and developed countries alike. Germany, Belgium, Austria, the United Kingdom, Ireland, and Singapore are well known for enacting multiple measures.

Table 1. Taxes and pricing in the transport sector in developing and developed countries.

Instrument	Developing countries	Developed countries
Tax incentives to promote use of natural gas	Pakistan, Argentina, Colombia, Russia	Italy, Germany, Australia, Ireland, Canada, UK, Belgium
Incentives to promote natural gas vehicles	Malaysia, Egypt	Belgium, UK, USA, Australia, Ireland
Annual road tax, differentiated by vintage	Singapore and India (fixed span and scrapping)	Germany
Emission trading	Chile	
Congestion pricing, including area licensing scheme, vehicle registration fees, and annual circulation tax	Chile, Singapore	Norway, Belgium
Vehicle taxes based on emissions-tax deductions on cleaner cars (e.g., battery-operated or alternative-fuel vehicles)	Korea	Austria, UK, Belgium, Germany, Japan, the Netherlands, Sweden
Carbon tax by size of engine	Zimbabwe	UK
Cross-subsidization of cleaner fuels (ethanol blending through gasoline tax—imposition of lower surcharge, or excise duty exemption)	India	

Source: Ribeiro et al. (2007), Table 5.14.

2.2.2 Evidence of effective transportation energy-saving policies

In the transportation sector, energy-saving policies have been effective in many countries (Table 2). Currently, there is a lack of data pertaining to GHG savings as a result of other measures (e.g., licensing and parking charges). The area most well known for its licensing and parking charge scheme is Singapore.

There are some other significant findings in the literature. Transportation price elasticity has been around –0.25 (i.e., 2.5% reduction in fuel for every 10% increase in price) (Goodwin, 2004). Price elasticity in the United States dropped to about –0.11 in the late 1990s (Small and Van Dender, 2007) and fell to about –0.04 in 2001–2006 (Hughes, Christopher, and Sperling, 2008). Residents in the United States appear to be so dependent on private vehicles that they have little choice but to accept and adapt to higher energy prices.

Table 2. Potential energy and GHG savings from pricing, taxes, and charges for road transport.

Tax/pricing measure	Potential energy/GHG savings or transport improvements	Reference Sources
Optimal road pricing based on congestion pricing (London, UK)	20% reduction in CO_2 emissions as a result of 18% reduction in traffic	Transport for London (2005)
Congestion pricing for the Namsan Tunnels (Seoul, Korea)	34% reduction in peak passenger traffic volume; traffic flow increased from 20 to 30 km/hr	World Bank (2002)
Fuel pricing and taxation	15–20% for vehicle operators	Martin et al. (1995)
Area licensing scheme (Singapore)	1.043 GJ/day energy savings; vehicular traffic reduced by 50%; private traffic reduced by 75%; travel speed increased from 20 to 33 km/hr	FWA (2002)
Urban gasoline tax (Singapore)	1.4 Mton by 2010; 2.6 Mton by 2020	Transportation in Canada: www.tc.gc.Ca/pol/en/Report/anre1999/tc9905be.htm
Congestion charge trial in Stockholm (2005–2006)	13% reduction of CO_2	http://www.stockholmsforsoket.se/template/page.aspz?id = 2453

Source: Ribeiro et al. (2007).

2.3 Transport demand management: comparisons of energy-saving pricing policy and demand elasticity between Taiwan and Korea

Little research has examined transportation energy-saving pricing effectiveness in East Asia. GDP growth in South Korea (henceforth, Korea) and Taiwan both sharply accelerated in the 1960s. Generally, as a country develops, its energy intensity increases for a period of time, before decreasing slightly and then becoming stable (Nilsson, 1993). Between 1987 and 1992, Taiwan's energy intensity dropped from 0.285 to 0.265 toe/USD1,000 of real GDP; during the same period, Korea's energy intensity increased from 0.310 to 0.362. One significant examination of the demand for gasoline and diesel in the ground transportation sectors of Korea and Taiwan is that of Banaszak, Chakravorty, and Leung (1999), which used time-series data from 1973–1992 to compare the effects of their differential pricing policies and their stages of economic growth.

2.3.1 Economic and policy background (1973–1992)

Retail gasoline prices in Korea were among the highest in the region, surpassed only by those of Japan. Petroleum taxes in Korea at the end of the 1973–1992 period comprised the following: 1) a 5% import duty on crude and products, 2) a special excise tax (SET) levied on gasoline, diesel, and liquefied petroleum gasoline, and 3) a 10% value-added tax (VAT) on all goods. In February 1994, the SET for gasoline was increased from 150% to 180%, while that for diesel rose from 20% to 25%. Taiwan, in comparison, did not maintain a large gasoline–diesel price differential on account of taxation. Its special energy excise tax rate rose in 1994 from 75% to 85% for diesel, and a general VAT has been levied at the 5% rate since 1986. Although Taiwan began allowing the operation of private retail service stations in 1988, the sole supplier is a state-owned company; a privately owned refinery is under construction.[7] Additionally, unlike Korea and other major price regulators in the region, the Taiwan was slower to outline deregulation plans.

2.3.2 Comparisons of Korea and Taiwan

Compared to Taiwan, Korea has moderate coal resources; this, together with its rapidly expanding petrochemical industry, distinguishes it sharply from the case of Taiwan. Korea uses twice as much diesel as gasoline—a trend more common in developing economies—while Taiwan consumes an ever-greater share of gasoline in industrialization. Finally, Korean taxes on gasoline are three to four times higher than those on diesel, while Taiwanese consumers pay only twice as much tax on gasoline than on diesel.

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[7] This private petrochemical corporation began business operations in April 1992.

2.3.3 Goodwin's important findings

Goodwin's (1992) study drew fuel consumption data from the IEA Energy Statistics and Balances;[8] price, GDP, deflator, and population data were taken from the Asian Development Bank.[9] Goodwin's important conclusions were as follows: (1) income has at least a three or four-fold greater effect on aggregate transport fuel demand than on whether that fuel is gasoline or diesel, (2) price elasticity is lower in the higher-income country of Taiwan and higher in the lower-income country of Korea,[10] and (3) aggregate demand elasticity in Korea and Taiwan (save for short-run price elasticity in Taiwan) is larger in the short run and smaller in the long run than those estimated for seven other countries (Miklius, Leung, and Siddayao, 1986). Goodwin (1992) projected smaller long-run income elasticity for Bangladesh, India, Indonesia, Philippines, Thailand, and Sri Lanka.

2.4 Fuel economy standards: fundamental measures via manufacturing research and development on vehicles and fuels (private sectors or public–private partnerships)

Countries and multinational corporations, each of which are players in an enormous motor and ship manufacturing and research and development (R&D) world market, can support both the governments of developed countries and LDCs and the private sector with technology, design, and fuel economy measures to help reduce global GHG emissions from vehicles. We can likely consider the World Trade Organization, World Bank, and World Intellectual Property Organization as post-Rio+20 platforms by which to negotiate a single holistic approach that encourages public–private partnerships, industry by industry, with the endpoint of establishing sustainable global low-carbon, low-energy transportation trade rules in the future. In line with the technology framework proposed by the IPCC (Ribeiro et al., 2007)—which involves knowledge-sharing and investment—an integrated action plan ought to include the following elements.

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[8]These data were obtained on diskette.

[9]Data were drawn from the energy indicators of the developing member countries of the Asian Development Bank. Estimations were performed by using the iterative nonlinear three-stage least squares procedure available in the SHAZAM software package (version 6.2).

[10]The economic race between Taiwan and Korea took a new turn in 2005, with Korea overtaking Taiwan in per-capita GDP for the first time. According to International Monetary Fund and World Bank statistics, in 2010, the per-capita GDP of Korea was USD20,591, and that of Taiwan was USD18,458. In terms of purchasing power parity, the figures for Korea and Taiwan in that year were USD29,836 and USD35,227, respectively.

1. Reducing vehicle loads (i.e., through the use of lightweight materials,[11] aerodynamic improvements, and mobile air conditioning systems)
2. Improving drive train efficiency and low-carbon electricity (i.e., through the use of advanced direct-injection gasoline/diesel engines and transmissions, hybrid drive trains, and low-carbon electricity in support of train-driving)
3. Use of alternative fuels (e.g., biofuels/bio-refinery, hydrogen/fuel cells, and electric vehicles)
4. Oil well-to-wheels analysis of technical GHG emission mitigation options
5. Modal shifts in road transport
6. Improving driving practices (eco-driving)

Among these six categories of transportation energy-saving technologies, East Asian countries should especially concentrate on "Improving drive train efficiency and low-carbon electricity" and "Use of alternative fuels" as the previous public-private partnership areas, given the very large volumes of ocean and air transportation between Association of Southeast Asian Nations (ASEAN) countries. However, for land transportation links between Asia and Europe, rail will still be the most energy-efficient low-carbon transportation mode. The main objectives of *AEC* (i.e., ASEAN Economic Community) *2015* are to promote inter-trade, facilitate transportation and communication, and enhance the competitive advantages of the region. Many ASEAN scientists are expecting Japan and Taiwan to focus more on energy technology R&D, to achieve the goal of a single-market production base (i.e., the free flow of goods, services, investment, and skilled labor) via PPPs for sustainable transport.

The policy implication in this, overall, is that it is extremely important for IPCC to make "Transport and its infrastructure" the first-priority task in pushing the world into a transportation energy-saving era.

2.5 Taiwan's sustainable-transportation choices

The Republic of China in Taiwan was ousted from the United Nations (UN) in 1971. It was not until 2007 that the transportation sector became highly effective in providing the nation with a rail-based public transportation system for metropolitan commuting and inter-city transportation. The Institute

[11] There are several ways to reduce vehicle weight: switch to high-strength steel, replace steel with lighter materials, and develop lighter-design concepts and new technologies. A 10% weight reduction in a vehicle's total weight can improve its fuel economy by 4–8%, depending on changes in the vehicle size and whether or not the engine itself is downsized. The average weight of a vehicle in the United States and Japan increased by 10–20% between roughly 2000 and 2010 (JAMA, 2002; Haight, 2003). However, not all OECD countries want to adopt such policies, for reasons of safety and customer preference.

of Transportation (IOT) began to think about the UN's climate change policies and thoroughly study the UN Framework Convention on Climate Change's (FCCC's) ideas on ecoTransport, ecoMobility, green transportation, green mobility, eSustainable transportation, and sustainable mobility, but only after COP13[12] and COP14 in 2007. The IOT (2010a) made a comprehensive comparative report on the transportation energy-saving and carbon reduction policies and measures of the countries in the European Union (EU), North America, Australia, and Asia.

The IOT compared 72 international policy measures in terms of three criteria: economic and financial feasibility, environmental protection effects, and social justice. The IOT classified these measures thus: (1) feasible and easily implemented, (2) feasible but with implementation thresholds, (3) highly difficult (i.e., revolutionary) and requiring policy decisions, and (4) unfeasible. Only six measures were considered unfeasible. Four items related to congestion pricing, including an area licensing scheme, vehicle registration fees, and congestion charges, none of which meet the social justice criteria. Two items (renewal of diesel engine and volunteer negotiation within the automobile industry) are unfeasible, mainly due to a limited domestic market for technology R&D.

The Taiwan government has set the vision of a "people-centered green transportation system"; it rejects the adoption of an area licensing scheme, vehicle registration fees, and congestion charges, because they would not meet the social justice criteria. This sets a good example with respect to national policy preference. It appears that, despite having lost its UN membership, Taiwan is still working hard to adopt sustainable measures.

In terms of policy implications, it is essential that each country develop an approach by which to establish a series of strategies that respond to the post-Kyoto framework. This approach can act as a blueprint for the "ability construction" (i.e., technical, social, and/or political) process.

3 Transportation sustainability of rail systems

3.1 U.S. train development (1955–1975) and the thruport design for freight distribution

Transportation energy use has been one of the important research topics in transportation engineering. The United States consumed 71.08 quads (10^{15} BTUs) of energy in 1975; of that, roughly 19% was consumed by households

[12]The Conference of the Parties (COP) is the supreme decision-making body of the FCCC. All states that are parties to the Convention are represented at the COP, and it is there that they review Convention implementation and any legal instruments that the COP adopts. Any decisions may include institutional and administrative arrangements.

and the commercial sector, 27% by the industrial sector, 26% by the transportation sector, and 28% by the electricity-generation sector. Transportation energy use constituted, rather consistently, 25% of gross energy use from 1947 to 1975 (Staley, 1977). A further breakdown of transportation energy use by major transportation modes between 1955 and 1975 proves that new railway technology did make a difference with respect to energy use. In 1955, automobiles accounted for 4.2 quads or 43% of the total energy used in 1955, versus 9.1 quads (49%) in 1975. Air travel increased the most, accounting for 1.4% of the total transportation energy use in 1955 and 7.0% in 1975. All trucks consumed 17% in 1955, and 22% in 1975. Class I railroads, on the other hand, consumed 8.6% of all transportation energy used in 1955, but this number fell to 2.9% in 1975. These figures carry added meaning when one considers that class I railroads carried roughly 21% more freight while expending 38% less energy in 1975, relative to that in 1955. Mass transit consumed 1.3% of the total in 1955 and approximately 0.5% of the total in 1975 (Association of American Railroads, 2005).

Rail productivity has increased following the deregulation of rail transport in the early 1980s (Hensher and Waters, 1999). Comparatively, it has been found in North America that rail is 4.3 times more energy-efficient (455 ton-miles per gallon) than trucking, has 4.7 times the capacity (216 million tons per mainline per year), and is 1.8 times less costly (2.7¢ per ton-mile) than trucking (Brown and Hatch, 2002). Rodrigue (2008) points out that thruports are designed to accommodate fragmented markets, supply chains, and ownership, notably when this fragmentation takes place on a large scale. In the United States, these locations include Chicago, Minneapolis/St. Paul, Kansas City, St. Louis, Memphis, and Dallas/Fort Worth. Each transmodal hub can act as a gigantic funnel that collects the freight of all major gateways. A thruport terminal represents a complex operational agenda that optimizes movements while considering constraints such as the outbound destination of each container, the disposition of unit trains, and the stacking order. A few strategically located thruports can assist in removing millions of truck trailers from the roads each year. The potential impacts of a thruport system—namely, derived efficiencies and a substitution effect—on potential modal shifts and energy savings are significant.

3.2 The rise of high-speed rail systems (1964–present)

HSR is recognized as the most time and energy-saving public transportation mode worldwide; it also emits the least amount of carbon. The use of HSR began in 1964 with the world's first such line, the Japanese *Shinkansen*. Germany's InterCity Express and France's *Trains á grande vitesse* began operations in 1981 and 1984, respectively. Given the large expense related to investing in HSR, the learning effects for other emerging economies began two decades later. Korea inaugurated the first Korea Train eXpress in 2004. Taiwan planned its national HSR project in the early 1990s, but began business operations only in February 2007, due to the difficult build–operate–transfer (BOT) financial procedure involved. The People's Republic of China began its first Beijing–Tianjing HSR operations in 2008, and the Beijing–Shanghai line followed in December 2010. China now plans to have four "vertical" and four "horizontal" lines.

The U.S. government has been the most hesitant about constructing HSR, given the high anticipated construction costs and what will likely be low usage. Levinson et al. (1997) examined the full costs—defined as the sum of infrastructure costs, carrier costs, user money costs, user travel time costs, user delay costs, and social costs—and concluded that HSR is significantly more costly than expanding existing air services, and marginally more expensive than auto travel (Levinson et al., 1997). The authors doubted whether HSR could be constructed without considerable subsidy; they pointed out that in the early stages of transportation network design—where land use is denser and cities are closer together—the environment could be better suited to HSR projects. Second, the regulated transportation sectors in Japan and Europe precluded the degree of competition in the air travel sector that is seen in the United States. However, there is still one project for which the full cost of HSR has been estimated—namely, for the Los Angeles–San Francisco corridor in California.

3.3 East Asian railway patronage trends

Similar concepts can be applied to cross-border comparisons of transportation energy-saving, between Northeast and Southeast Asia. Asia is the continent with the densest populations and the most intensive land use. The rapid increase in railway patronage in terms of its share of public transportation systems, as seen in four major Asian cities (Table 3), suggests that it is reasonable to expect more high-density metro or inter-city rail routes in Asia in the future.

Table 3. Railway patronage as a proportion of public transportation in East Asia.

Hong Kong		Tokyo (2006)		Taipei		Seoul	
2001	2006	Metro R	Center	1996	2005	1996	2002
32%	43%	30%	70%	12%	34%	60%	65%

Source: Compiled by the author from various conference PowerPoint files. Seoul's definition is slightly different from those of the three other cities.

The four cities listed in Table 3 are the most competitive megacities in East Asia. The promotion of railway patronage for the purpose of saving energy and controlling pollution has not been easy. Tokyo has seen outstanding performance mainly because of its long-term public transportation development plan. In 2007, the metro Tokyo government inaugurated an additional 10-year plan called "Carbon-Minus Tokyo," which encourages car-pool driving and a 50–75% tax reduction scheme for low-carbon vehicles. Japan's second-largest city, Osaka, is evaluated in the Economist Intelligence Unit's *Green City Index (2011)* as the best (i.e., well above average) green transportation city in Asia. In addition, its public transportation network coverage rate is 0.62 km/km^2. Its full electrical train, transit, and city rail system fully serves the traffic demands of its citizens. Osaka's current transportation mode are 32% for train or transit, 27% for walking, 23% for bicycle, 15% for car, and only 2% for bus (Tung, 2011).

The proportion of railway patronage within Taiwan's overall public transportation structure is relatively low, due mainly to the late opening of the first mass rapid transit (MRT) line in Taipei in 1996. The full network for Taipei City was completed in 2005, and three extensions were quickly added to Taipei County (renamed New Taipei City after 2011).[13] As a result, railway patronage in Taiwan, as a proportion of public transportation, has been rising, from 12% in 1996 and 34% in 2005, to 42% in 2010.[14] The low ratio before 1996 reflects Taiwan's high level of car ownership, similar to that of Korea.

As for Seoul, its population growth rate was at its highest between 1960 and 2002. In central Seoul, the number of daily trips increased from 5.7 million in 1960 to 29.6 million in 2002. The rapid growth of car ownership in the 1980s and early 1990s reduced public transport's share of total travel trips in the city; as a result, the combined modal share of bus and metro fell from 75% in 1980 to a low of 60% in 1996. (Trips made by private cars increased from 4% in 1980 to 21% in 1996.) Indeed, 1996 saw a turning point: a combination of metro system expansion and car-restrictive policies implemented in the mid-1990s caused public transport's share of trips to increase from 60% in 1996 to 65% in 2002. Other successful and innovative policy measures included congestion tolls along two key tunnels during peak hours, parking fee increases, and reductions in the number of parking facilities. All these measures helped reduce the incentives to drive cars (Pucher, Hyungyong, and Song, 2005).

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[13] The newest extension line construction was initiated in November 2011 and is expected to be completed by 2018.

[14] The calculations of those ratios are based on: Numerator = passenger numbers of Taiwan Rail + HSR + Taipei MRT + Kaohsiung MRT. Denominator = numerator + domestic air + intra-city bus + inter-city bus. Detailed statistics and some English reports can be found at http://www.motc.gov.tw/mocwebGIP/wSite/lp?ctNode=541&CtUnit=313&BaseDSD=7&mp=1.

4 Evaluation of carbon-emission effects of long-term green transportation development policies/plans in Taiwan

As one of Asia's "four little dragons," Taiwan continues to see intensive traffic flows between itself and each of Taipei City, the ports, and the industrial zones. Rapid industrialization began to create inter-city traffic congestion in the 1960s. Construction of the first nationwide freeway began on August 14, 1971, and its first section, between San-Tsun and Chung-Li, was opened in 1974; the full route, from Taipei to Kaohsiung, became available in 1978. Such national infrastructure helped Taiwan's economy "boom." Nonetheless, energy consumption by private cars and trucks, along with the resulting air pollution, increased rapidly. Electronic toll controls were not introduced until February 2006, and the central government began to seriously plan a metropolitan MRT system in the late 1970s and an inter-city HSR in 1989.

4.1 Taipei Metro transit system[15]

Rapid traffic flow increases in the Taipei metropolitan area led to serious traffic jams and air pollution at many train and road nodes, especially during peak travel hours. The Ministry of Transportation and Communications invited a British rail consultant company in 1980–1981 to make a preliminary plan for an underground MRT construction project. Despite budget difficulties, construction began in July 1983, and the engineering works were completed in September 1989. The first Taipei Metro line initiated operations in 1996.

The policy implication of this is that the successful planning and construction experiences with respect to the underground rail construction and the Taipei MRT system gave the government the confidence it needed to proceed with constructing an inter-city HSR system, in the name of creating sustainable economic development. It is important that other LDCs initiate long-term sustainable energy-saving transportation plans that feature both metro-scale projects and nationwide projects. The development of various human resources—in the forms of planning experts and high-quality engineers that specialize in public works, electricity, rail/train management and maintenance (even though the construction is done by multinational corporations), and land-use development are to be fostered alongside these large-scale projects.

[15] Taiwan has another metropolitan transit rail system, albeit not yet completed, in Kaohsiung City. The Mass Rapid Transit Bureau, Kaohsiung City (KMR), commissioned THI Consultants Inc. in December 1998 and 2011 to undertake the transportation planning of the long-term MRT system network. To capture the data needed to forecast socioeconomic development and travel demand, the project completed in 2011–2013 a great deal of data collection, including that from home interview surveys, cordon surveys, screen-line surveys, speed surveys, and transit terminal passenger surveys.

4.2 Taiwan's high-speed rail system

Taiwan is a mountainous and populous country. Its population density in 2010 was 637 persons/km^2. Three-quarters of the land is mountainous, with one-half of that land having an elevation exceeding 1,000 m. For decades, effective land use has been an important mission among Taiwan's urban and regional planners. Close to 95% of Taiwan's industry and population are located in the 380-km West Taiwan corridor, between Keelung and Taipei in the north and Kaohsiung in the south.

When the central government began to aggressively undertake the Taiwan High-Speed Rail Feasibility Study in 1989, Taiwan's total population was 20 million. The socioeconomic forecast for future growth in inter-city transportation demand was based on the following assumptions. (1) The population was predicted to grow at a slower rate than in the past, to reach approximately 23.8 million by 2011. (2) The annual employment growth rate would reach 2.3% between 1989 and 2011, and the northern region would account for about 45% of Taiwan's labor force. (3) Family disposable income would continue to increase at an annual growth rate of 3.5% and reach TWD980,000 in 2011.[16] (4) Private car ownership in Taiwan would reach some 5.2 million vehicles in 2011 (assuming an annual growth rate of 6%).

Cars and buses together accounted for 85.3% of all trips, whereas car trips in 1989 had accounted for 43.8% of all trips (Table 4). Rail trips with a distance of at least 40 km were less prevalent (only 14%), and air trips were marginal (less than 1%). If we consider passenger-kilometers by mode and the average trip length, the freeway/highway system still accounts for 84% of total mileage, with high-class (air-conditioned) bus travel increasing the most, by 85%. Based on these socioeconomic survey data, IOT in concert with German HSR consultants prepared some forecasts of inter-city travel demand in 2011, by transportation mode (modal split). Those forecast results supported the feasibility or necessity of building HSR along the West Corridor (Chiu, 1989).

When one compares Taiwan's HSR to other existing transportation systems, one can see that its level of service offers significant improvements relative to other modes. Travel time along the freeway is 4.5 hours, versus 1.5 hours on HSR for the same distance. Other indicators—such as travel cost per passenger, ratio of traffic volume and capacity, urban development form (concentrated and high-density), areas of right of way (4,000 ha for freeway versus 1,137 ha for HSR), and energy consumption (freeway 3.5 times greater than that of

[16] See Chiu and Chen (1994), according to whom the actual family disposal income in Taiwan in 2010 was TWD889,000. However, Taiwan's PPP was relatively high in comparison to its peer countries. Taiwan's HSR runs fairly high passenger load rates, and began to make profit in the first half of 2011 (after a long BOT contract renegotiation in 2010, on the adjustment of reasonable infrastructure depreciation years).

Table 4. Inter-city travel demand by mode (1984 and 1989) (for person trips ≥40 km and passenger-kilometers per day).

Year		Car		Bus[1]		Rail		Air[2]		Total	
		Trips (1,000)	Passengers[3]	Trips (1,000)	Passengers	Trips (1,000)	Passengers	Trips (1,000)	Passengers	Trips (1,000)	Passengers
1984	Abs.	353.8	34.8	307.9	47.1	170.7	22.0	4.7	1.5	837.1	105.4
	%	42.3%	33.0%	36.8%	44.7%	20.4%	20.9%	0.6%	1.4%	100%	100%
1989	Abs.	544.4	50.2	516.7	87.1	174.8	24.1	6.2	2.0	1241.1	163.4
	%	43.8%	30.7%	41.5%	53.3%	14.1%	14.8%	0.5%	1.2%	100%	100%
Increase 1984–89	Δ%	54%	44%	68%	85%	2%	10%	32%	32%	48%	55%

(1) High-class (air-conditioned) buses only
(2) Excluding traffic to off-shore islands
(3) The unit for passengers is million kilometers per day
* Based on the "50" traffic zone system in Taiwan

HSR)—all highlight the environmental sustainability of HSRs, and how they contribute to a high quality of life (Mao and Chiu, 1991).

After decades of work expended in constructing the Taipei Metro and Taiwan HSR, the breakdown of Taiwan's CO_2 emission structure in 2013 was as follows: 48.97% from the industrial sector, 14.08% from the transportation sector, 12.93% from the commerce/service sector, 12.30% from homes, and 10.66% from the energy sector[17]. The transportation sector will continue to pursue every possible policy or measure by which to enhance energy-saving and reach emission-reduction goals. However, as an export-oriented economy, Taiwan's next targets in saving energy and developing low-carbon technology will require further green innovations from the industrial sector, as well as movements from the residential and commercial sectors.

4.3 Calculations of high-speed rail's carbon emissions reduction effect

Given Taiwan's brisk industrialization—which led also to its brisk environmental deterioration in the 1960s and 1970s—the people of Taiwan have since the late 1970s become very sensitive to the environmental impacts of new public infrastructure or huge business/factory investment projects. The IOT (2010b) in charge of the Taiwan HSR plan prepared estimates of the degree to which the HSR has helped reduce carbon emissions, by assessing conditions before and after the implementation of this high-tech rail project nationwide.

According to the environmental impact assessment for the HSR—prepared by the Provisional Engineering Office of the HSR (POHSR) in November 1994—building an HSR can save energy that would otherwise be consumed by passenger cars, buses, and airplanes; alleviate highway congestion; and improve air quality by reducing pollutants (e.g., total suspended particulate [TSP], NO_x, SO_x, CO_2, etc.). While conducting simulations, it was found that the most significant effect of HSR vis-à-vis improving air quality was with respect to CO_2 reductions. The quantities of TSP, NOx, SO_x, and CO_2 reduction in Taiwan are shown in Table 5.

Taiwan's HSR began operations in February 2007. Based on the 2010 transportation volumes of the Taiwan High-Speed Rail Company, Chen (2011) performed simulations and estimated that the carbon reduction of the transport sector was 355,700 tons (i.e., 603,300 tons [carbon reduction due to mode shifts], minus 247,600 tons [carbon increase due to HSR operations]). Thus, the carbon reduction potential that stems from building more HSRs is highly promising for Asia and the rest of the world.

The above calculation was based on the following parameter assumptions: that the modal shift from private cars to HSR was 50%; from buses, 13%;

[17] Refer to Table 4 on page 15 of the 2014 report of the Bureau of Energy, Ministry of Economic Affairs: http://web3.moeaboe.gov.tw/ECW/populace/content/wHandMenuFile.ashx?menu_id=363

Table 5. Comparison of various air pollutant emissions: with and without HSR operations.

Air pollutants (Unit: tons/day)	Decrease: Passenger cars (1)	Decrease: Buses (2)	Decrease: Total reduction (1) + (2) = (3)	Increase: Power plans (4)	Differences (3) + (4) = (5)
TSP (total suspended particulate)	–0.522	–0.307	–0.829	+0.186	–0.643
SO_x (sulfur dioxide)	–0.424	–0.050	–0.474	+0.044	–0.430
NO_x (nitrogen oxides)	–0.565	–0.696	–1.261	+1.046	–0.215
CO_2 (carbon dioxide)	–3.318	–0.909	–4.227	+0.170	–4.057

Data Source: POHSR, "Environmental Impact Assessment (EIA) of High-Speed Rail (HSR)", 1994.

from traditional trains, 27%; and from aviation (for which the carbon emission per person-kilometer is 5.6 times that of a HSR), 10%. Other parameter assumptions included those pertaining to the average passenger load rate of a private car (2.3 persons) and a bus (13.34 persons); a modal energy (or fuel exhaustive) efficiency rate of 11.6 km/l for private cars and 3.1 km/l for bus per person; energy intensity rates of 0.071 degrees/person-km for traditional rail, 0.054 degrees/person-km for HSR, and 0.078 l/person-km for air travel; and CO_2 emission coefficient values of 2.26 km/l for vehicle gasoline, 2.61 kg/l for diesel, 2.39 kg/l for aircraft gasoline, and 0.612 kg CO_2/degree for electricity.

5 Concluding remarks: policy implications and the East Asian perspective

It is not easy to make international comparisons of policy history vis-à-vis energy-saving and GHG emission reductions in the transport sector; transport economists, after all, are highly concerned about bases of comparison (e.g., terminology definitions, quantitative calculations, and country-specific green standards). Each country is rich in different resources and differs markedly in terms of transport infrastructure—all of which influence the meanings of such comparisons. However, this study does make some conclusions based on the current evidence. As such, this study serves as a basis for further and more in-depth research in the future.

This study surveys four of the five key factors that play key roles in managing energy-saving and carbon reduction initiatives in the transportation industry—namely, (1) integrated land-use and transport planning, (2) taxation and pricing, (3) fuel economy standards (for road transport), and (4) transport demand management and comparisons of various policies.

In examining the aforementioned international, East Asian, and Taiwanese experiences, we assert that successful transportation energy-saving and carbon emission reduction strategies should consider the following policies and action plans.

1. The fundamental duty of the government (at either the central or local level) is to pay attention to how energy-saving and low-carbon urban settlements are constructed, while bearing in mind integrated land-use and transportation plans. The natural geography and planned conditions of the city, region, and country (i.e., high versus low-density land use and economic activities) will demand the provision of different modal choices for public transport, and mitigate the ownership of private cars. Regardless of whether a transport type or land use (or marine logistic network, in the case of ASEAN) master plan exists, the duty of central and local governments is to integrate inter-city and intra-metropolitan land use and transportation networks in order to maximize energy-saving and minimize GHG emissions.
2. Area licensing, taxation, and strategic pricing have been found to be effective measures in saving energy and reducing GHG emissions among private car users. Income level (or stages of economic development), demand elasticity, and the fiscal (budgetary) conditions of the planning nation, region, or city will all affect investment capabilities vis-à-vis transportation infrastructure and citizen welfare. Comparisons of energy-saving pricing policy and demand elasticity between Taiwan and Korea indicate its importance in aggregate transport fuel demand. Our second important finding pertained to the price elasticity between gasoline and diesel. Price elasticity tends to be lower in higher-income countries and higher in lower-income countries, and this information can be leveraged in setting the pricing of any transportation mode. Transport energy-saving pricing policies and measures will generate better effects if multiple measures are adopted; indeed, both Singapore and Korea have demonstrated such effects.
3. This study also concludes that policy and the R&D division of labor among developed and developing countries alike need to be examined, with an eye to developing sustainable transportation worldwide. The aggregate energy intensity of travel or freight transport is determined by ascertaining vehicle fuel intensity and optimizing vehicle capacity. Comparisons of eight OECD countries best demonstrate why high-intensity public transport is generally good for saving energy. Second, transportation demand and modal structural changes in freight are influenced by business practices—for example, "just-in-time" delivery in the manufacturing sector

(e.g., Europe and Japan), or the use of a well-planned thruport freight infrastructure and the leveraging of management ability (e.g., North America). Given that environmental conditions in these areas are roughly equal, saving energy in the transportation sector seems to be easier to bring about than controlling GHG emissions.

4. With respect to the R&D division of labor vis-à-vis fuel economy standards, this study's findings suggest that East Asian countries choose "Improving drive train efficiency and low-carbon electricity" and "Alternative fuels" as the prior PPP areas, given the enormous volume of ocean and air transportation among ASEAN countries.
5. Taiwan's transportation energy-saving policies and measures, as well as its evaluation and implementation process, are unique. The people-centered green transportation system—which superseded the adoption of an area licensing scheme, vehicle registration fees, and congestion charges, given that they do not meet social justice criteria—serves as a good example of national policy preference.
6. The realization of the goal inherent in *AEC 2015* requires intra-regional trade and investment cooperation with respect to new green technologies and its related R&D, especially with regard to the use of certain ships, vehicles, and fuels. Indeed, public–private partnership will be important here.
7. In low-density transportation networks, the utilization rate of HSRs may be relatively low, especially in comparison to its costly construction costs. Such countries (e.g., the United States and Australia) may pursue technologies by which to improve existing air service and green vehicle transportation networks.

New green transportation development schemes require cross-border negotiation, as well as infrastructure investment support from the World Bank and the Asian Development Bank, if a sustainable transportation system is to be realized among ASEAN countries. Such schemes include those involving more R&D on green freight trucks (for small and medium-sized countries) or on thruport freight train systems (for countries with large land areas and scattered industrial development) in moving goods; alternative fuels R&D; public–private partnerships in East Asia; and more clean energy transportation for moving goods and passengers.

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