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# Potential futures for road transportation $CO_2$ emissions in the Asia Pacific

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**Abstract:** *Will future transportation carbon dioxide ($CO_2$) emissions per capita in Asia Pacific economies follow historical trends of the now developed world? Evidence to date is inconclusive. A comparison at similar income levels (purchasing power parity) between recent emissions in Asia Pacific countries and historical emissions in developed countries suggests diverging patterns. (A) High-income Asia economies (Japan, Hong Kong and Singapore – 'low emitters') exhibit lower emissions than a selected sample of seven developed countries (United States, Australia, France, the Netherlands, Italy, Sweden and United Kingdom). (B) Another set of Asian countries (South Korea and Taiwan – 'medium emitters') follow the emissions trends of European countries, which are lower than those of Australia and the United States. (C) A third Asian group (Malaysia and Thailand – 'high emitters') exhibit emission trends comparable to that of Australia. We describe these trends, examine their causes and extrapolate likely futures for emissions in low-income Asia Pacific economies (China, Indonesia, Philippines and Vietnam). Although such predictions are speculative, the available evidence suggests that road $CO_2$ emissions for Indonesia, the Philippines and Vietnam will follow those of the third group (high emitters), while those for China may follow either Group B or Group C.*

**Keywords:** *Asia Pacific*, *carbon dioxide emissions*, *road transportation*

## Introduction

With its large population and rapidly rising economic wealth, the Asia Pacific region has become an important environmental focal point for both consumption of resources and generation of carbon dioxide ($CO_2$) emissions at local, regional and global scales. This region[1] includes several large and growing economies of differing per capita incomes. The region's population is expected to grow by 25% over the next 25 years to reach almost 2.5 billion (United Nations, 2002). Predicted economic growth (2006–2010) for the Association of Southeast Asian Nations (ASEAN), 5.6–6.5% annually, is higher than that for the developed world (3.1–3.5%), the United States (2.5–3.5%) and Japan (1.2–2.8%). China's forecasted annual growth (6.6–8.6%) is more than double the world average during the same period (The Economist Intelligence Unit, 2006).

This rapid development has been accompanied by severe environmental impact (Asian Development Bank, 1997). Of global concern are greenhouse gas (GHG) emissions, of which $CO_2$ is a major contributor. Anthropogenic emissions are the largest cause of the observed increases in global $CO_2$ concentrations, which are believed to be responsible for extant and future climate change (Watson & the Core Writing Team, 2001; The Stern Review, 2006). The annual $CO_2$ concentration growth rate was larger during the last 10 years (1995–2005) than it has been since the beginning of continuous direct atmospheric measurements (1960–2005) (Alley *et al.*, 2007). Overall, carbon emissions are likely to increase by 62% by 2030 under a business-as-usual-scenario, with more than


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two-thirds expected from developing countries (Commission on Sustainable Development, 2006).

Current and expected future $CO_2$ emissions will have multiple global impacts, including rising average temperatures and climate change. Global climate change, in turn, is expected to impact on water resources, agricultural and food production, global sea levels, prevalence of storms and other weather events, polar ice sheets, coastal development, settlements and urban infrastructure, human health, species abundance and diversity, and ecosystem structure and functions (Watson & the Core Writing Team, 2001).

Fossil fuel consumption by on-road vehicles is a significant contributor to total GHG emissions (Button and Rothengatter, 1993; Delucchi, 1999; Heywood, 2006; Socolow and Pacala, 2006; The Stern Review, 2006). Moreover, emissions from the transport sector are the fastest growing source of GHG emissions (Wright and Fulton, 2005).

The contribution of transportation $CO_2$ emissions differs by country. In Organization for Economic Development and Cooperation (OECD) countries, oil is the major fuel for transportation, and transportation accounts for 54% of primary oil demand and 27% of $CO_2$ emissions (International Energy Agency, 2002). Since 1990, the transport sector has recorded the fastest GHG growth in the European Union, Japan and the United States (Commission on Sustainable Development, 2006). In developing countries, the industrial sector uses a larger share of oil than that of the developed world and transportation oil demand accounts for lower shares of primary oil demand (33%) and $CO_2$ emissions (14%) (International Energy Agency, 2002).

Projected trends for transportation in developed and developing countries also differ. By 2020, in the OECD, the share of transportation energy demand is expected to rise to 62% and transportation's share of $CO_2$ emissions will therefore rise to 31% of total emissions (International Energy Agency, 2002). By 2020, in the developing Asian region alone, the share of transportation energy demand is expected to reach 38%, rising from 29% in 1999, with an average annual growth rate of 4.9% (Kiuru, 2002).

Much of the oil demand in transportation is for motor vehicle use. From the end of World War II until only recently, rapid growth in automobile ownership and use had been largely restricted to the developed world (Newman and Kenworthy, 1999). In the coming century, however, the developing world is expected to become the centre of automobile consumption (Faiz, 1993). By 2030, there is projected to be more vehicles in the developing than in the developed world (Wright and Fulton, 2005).

Asia is of particular interest as the region has recently been absorbing a growing share of the world's motorised vehicles (Table 1). From 1983 to 2003, developing countries in the Asia Pacific increased the number of vehicle registrations from 8 million (2% of the global total) to 70 million (9% of the global total). This share is expected to increase rapidly in coming decades (Wilson *et al.*, 2004; *The Economist*, 2006).

While most of the future growth in motorisation will occur in developing countries in the Asia Pacific region, the patterns of this growth may neither follow that of the developed world nor be uniform within the group of economies. Previous work highlighted, for example, that road and air transportation $CO_2$ emissions occur at lower levels of income in developing than in developed countries, and that the sources of these emissions emerge in a more simultaneous fashion in developing countries than experienced by the United States (Marcotullio *et al.*, 2005). In some cases, annual changes in emission levels are growing as fast as or faster than that experienced by other developed countries (Marcotullio, 2006). Given the current and predicted importance of transport's contribution to GHG emissions, studies of road $CO_2$ emission trends can provide valuable insights into anthropogenic impacts on the global environment.

This paper explores the trends, driving forces and plausible futures for road $CO_2$ emissions in the Asia Pacific region. In this region, trends in road $CO_2$ transportation emissions per capita can be divided into three pathways: low emissions (below historical trends in Western Europe), medium emissions (similar to trends in Western Europe) and high emissions (similar to or higher than historical trends in Australia). We discuss driving forces behind these trends, how they differ among the three groups, and how

**Table 1.** Change in Asia Pacific global share of motor vehicle registration, 1983–2003

| Asia Pacific region/country | 1983 | | 1993 | | 2003 | |
|---|---|---|---|---|---|---|
| | Thousands of units | Per cent of total | Thousands of units | Per cent of total | Thousands of units | Per cent of total |
| Developed | 51 120 | 11.2 | 73 478 | 11.9 | 84 830 | 10.4 |
| Japan | 42 932 | 9.4 | 63 263 | 10.3 | 72 525 | 8.9 |
| Australia | 8 188 | 1.8 | 10 215 | 1.7 | 12 305 | 1.5 |
| Developing | 8 527 | 1.9 | 29 278 | 4.7 | 69 614 | 8.6 |
| Korea | 785 | 0.2 | 6 274 | 1.0 | 14 587 | 1.8 |
| China (PRC) | 2 227 | 0.5 | 8 176 | 1.3 | 24 011 | 3.0 |
| Taiwan (Chinese Taipei) | 1 061 | 0.2 | 4 241 | 0.7 | 6 134 | 0.8 |
| Thailand | 1 369 | 0.3 | 4 136 | 0.7 | 7 695 | 0.9 |
| Indonesia | 1 517 | 0.3 | 3 231 | 0.5 | 6 276 | 0.8 |
| Malaysia | 113 | 0.0 | 166 | 0.0 | 6 732 | 0.8 |
| Philippines | 932 | 0.2 | 1 555 | 0.3 | 2 571 | 0.3 |
| Other | 523 | 0.1 | 1 499 | 0.2 | 1 608 | 0.2 |
| Asia Pacific | 59 646 | 13.1 | 102 756 | 16.7 | 154 444 | 19.0 |
| World | 455 920 | 100.0 | 617 087 | 100.0 | 813 000 | 100.0 |

*Sources:* Ward's (various years) *Motor vehicle facts & figures*. Detroit, Michigan: Ward's Communication; American Automobile Manufacturers Association, Inc (various years) *World motor vehicle data*. Washington, DC: AAMA, p.54; United Nations (2006) *UN statistical database*. Retrieved 15 February 2007, from Website: http://unstats.un.org/unsd/cdb/
*Notes:* Thailand data for 1983 are 1984. Indonesia data for 1983 are for 1982. The 'Other' category includes Brunei Darussalam, Myanmar, Hong Kong (China Special Administrative Region), Singapore and Vietnam.

they are unfolding for the four lower income large nations in the region: China, Indonesia, the Philippines and Vietnam. Extrapolation of current trends – which may or may not provide reliable insights – suggests that these countries will follow medium- or high-emission pathways. However, the future is not yet written; actual emissions will depend on several factors, including policy choices of each government.

The remainder of this paper is divided into four sections. We first provide the theoretical background. Next, we compare empirical trends in road $CO_2$ emissions in the Asia Pacific region and elsewhere. We then examine driving forces for these trends among East and Southeast Asian economies and how they are unfolding for the lower income economies. In the final section, we summarise and discuss the implications of the findings.

## Theoretical background

Recent studies of the relationship between increasing wealth and the environment emphasise the importance of changing contexts of development (Lekakis, 2000; Lindmark, 2002, 2004; Stern, 2004). Changing historical context includes both time- and space-related effects. Time-related effects are induced by historical changes in the speed and efficiency of human activities. They tend to shift the speed and emergence of environmental burdens such that conditions appear at lower levels of economic wealth and change faster over time. Space-related effects are induced by increased availability and spatial concentration of diverse social, economic, political, technological and other phenomena. At the urban scale, cities are increasingly diverse places with greater concentrations of diverse phenomena. Hence, it is common in cities of rapidly developing Asia Pacific countries to find modern houses and transportation (cars, airports) next to traditional housing without basic infrastructure, whose occupants rely on animate (human and animal) power and nearby ecosystems services (within-urban water supplies, urban agricultural products, etc., all of which are often of low quality) for their well-being. At the household scale, families and individuals often mix traditional and modern practices, including consumption behaviours. The result has been a 'telescoping' of phenomena, such that processes that historically took longer periods of time and whose patterns and structures varied over great expanses of space are now appearing over shorter intervals of time in a simultaneous fashion and located in concentrated spatial nodes (i.e. cities). The combination of these time–space effects has been called *time–space telescoping* and involves a collapsing, compression and telescoping of previously experienced development patterns (Marcotullio, 2005; Marcotullio *et al.*, 2005). The temporal results include the occurrence of environmental burdens *sooner* (at lower levels of income), which rise *faster* (over time) and emerge *more simultaneously* (in an overlapping fashion) than the historical experiences of the now developed world.

Notwithstanding these complications, however, there are significant differences in the levels of environmental burdens between some rapidly developing and developed countries when compared at similar levels of income. For example, in rapidly developing Asia, some countries demonstrate lower road $CO_2$ emissions per capita than those in the developed world at similar levels of income. This suggests that some rapidly developing countries may be more efficient and less polluting than the developed world was historically.

The processes determining time- and space-related effects are varied. The drivers are both indirect and direct. Indirect drivers are forces that act at a distance and whose influence can rarely be measured directly. These include the slow forces of change, which affect entire societies in general, such as demographic shifts, institutional and technological change, cultural preferences, etc. Direct drivers are those forces that immediately impinge on environmental conditions and typically can be measured and correlated to environmental impact. Of a number of direct drivers, those related to changes in transport include shifts in consumption patterns, road infrastructure and changes in fuel prices.

This study is interested in identifying the patterns and forces that create so-called *time–space telescoping*, a combination of drivers whose effects can be traced to current development patterns. We consider three main questions: (i) Do patterns of road $CO_2$ emissions differ among countries in the region? (ii) If so, what are the driving forces between the developed and now developing world associated with these differences? (iii) Based on emerging trends in the lower income economies and the patterns of forces observed in our sample, what road $CO_2$ emission future trends might we expect in the largest countries in the Asia Pacific region?

Ultimately, these comparisons highlight broader questions of what ‘development’ is and how it can meaningfully be measured and compared across nations and over time. To many, ‘development’ means increased economic productivity, or increased capacity of production. Others point out that this definition focuses exclusively on a specific type of development and leaves out important changes in social, political and other structures. Still, others concentrate on equity and the reduction of poverty as indicators of development. Among the plethora of metrics used to track development, common ones include measures of material consumption, government provision of social services and the United Nations’ Human Development Indicator. Broadly, these various definitions suggest that ‘Development must therefore be conceived of as a multidimensional process involving major changes in social structure, popular attitudes and national institutions, as well as the acceleration of economic growth, the reduction of inequality and the eradication of poverty’ (Todaro, 1997: 16).

In this paper, we track changes in affluence among countries and over time, as measured by international-dollar gross domestic product (GDP) per capita, at purchasing power parity (PPP). We do not attempt to measure development. One of our goals is to demonstrate the changing complexity of development. We thus explore how factors responsible for generating road $CO_2$ emission differ both between developed and developing countries and among developing countries themselves. Others have used this method successfully to demonstrate differences in social and quality of life indicators across time (see for example, Crafts, 2000).

## Current trends

A recent study of liquid fuel transportation $CO_2$ emissions from three technologies (automobiles, freight trucks and airplanes) suggests that emissions from rapidly developing countries appear sooner (at lower levels of income) and emerge in a more simultaneous manner than those of the United States. In the most rapidly developing countries, $CO_2$ emissions rise at least as fast as those of the United States (Marcotullio *et al.*, 2005). A follow-up study further explored the 'faster' aspect by comparing selected Asia Pacific road $CO_2$ emissions with those of six other developed countries (Australia, France, Italy, the Netherlands, Sweden and the United Kingdom). Evidence suggests that in general, road $CO_2$ emissions rise at least as fast as or faster in rapidly developing Asia Pacific economies than they did historically in European economies, at similar ranges of PPP (Marcotullio, 2006).[2]

The conclusions of both of these studies, however, note that while rapidly developing Asia Pacific (among other) economies demonstrate these tendencies, they still have lower transport emissions levels at similar GDP per capita PPP when compared with that of the United States. Figure 1, for example, demonstrates that per capita road $CO_2$ emissions of countries in the Asia Pacific are lower than those of the United States at levels of GDP per capita above G-K$6500. This may not be a surprise given the high motor vehicle usage in the United States even when compared with other developed countries. Figure 2 presents the comparative increases in road $CO_2$ emissions per GDP increase for selected developed

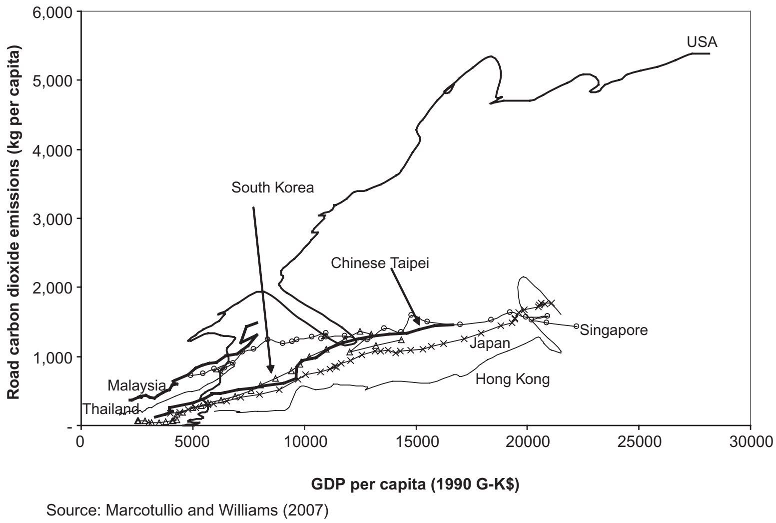


**Figure 1.** Road carbon dioxide emissions per capita by gross domestic product (GDP) per capita – United States and selected Asian economies

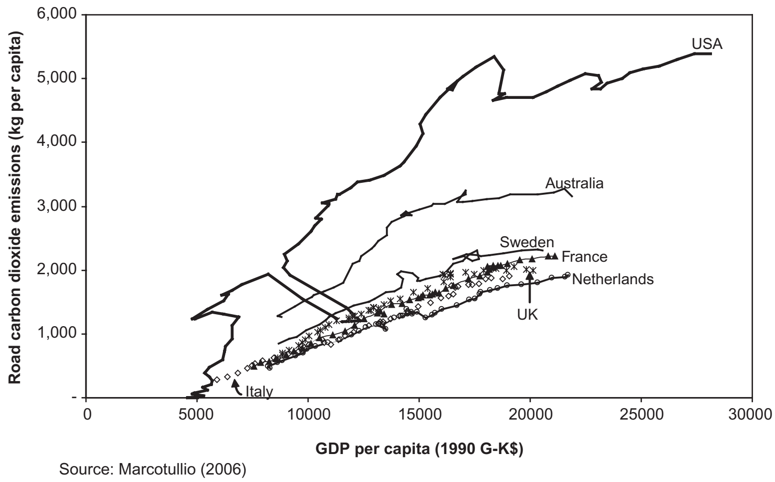


**Figure 2.** Road carbon dioxide emissions per capita by gross domestic product (GDP) per capita – United States and selected Asian economies

**Table 2.** Comparison of changes in road CO2 emission per capita to changes in GDP per capita, over comparable income ranges (GDP in 1990 G-K$, values of kg/GDP)

| | Range for Asian values | United States | Australia | France | The Netherlands | Italy | Sweden | United Kingdom |
|---|---|---|---|---|---|---|---|---|
| Hong Kong | 0.06–0.09 | 0.30 | 0.19 | 0.11 | 0.11 | 0.13 | 0.14 | 0.13 |
| Japan | 0.09 | 0.35 | 0.19 | 0.11 | 0.11 | 0.13 | 0.14 | 0.13 |
| Malaysia | 0.20–0.28 | 0.60 | – | – | – | 0.13 | – | – |
| Singapore | 0.03–0.06 | 0.33 | 0.17 | 0.11 | 0.11 | 0.13 | 0.14 | 0.13 |
| South Korea | 0.11–0.13 | 0.36 | 0.28 | 0.13 | 0.13 | 0.12 | 0.18 | 0.17 |
| Taiwan | 0.10–0.11 | 0.36 | 0.27 | 0.12 | 0.12 | 0.12 | 0.16 | 0.16 |
| Thailand | 0.2 | 0.58 | – | – | – | – | – | – |

*Source:* Marcotullio (2006).
–, indicates comparisons are not applicable; GDP, gross domestic product.

economies and the United States. The lowest and highest level European emitters in the sample are the Netherlands and Sweden, respectively. Australia's emissions are higher-than those of Europe, but below those of the United States.

Table 2 presents the comparative increases in road $CO_2$ emissions per GDP increases for selected Asia Pacific economies and seven developed economies over similar levels of income ranges. (Rates of increase represent average slopes for the lines in Figure 1 over similar economic development, GDP per capita, ranges.) When the trends in Asia Pacific economies are compared with trends in a larger sample of developed countries rather than only the United States, a few exceptions emerge (e.g. Malaysia) wherein rapidly developing economies exhibit road $CO_2$ emissions increases as high as or higher than those in Europe.

From these data we created a simplified set of charts that draws out the differences between road $CO_2$ emission trajectories in the Asia Pacific. For visual clarity, the plots provide data at 10-year intervals. Interesting differences among nations emerge from these figures. To highlight differences in trends, we shaded the area between the lowest European country trend (the Netherlands) and that of Australia. When compared with various developed world countries, three sets of trends among Asia Pacific economies emerge, as seen in Figure 3a,b,c. We argue that despite the small number of countries that makes up each group (two to three countries per group), the three trajectories represent possible futures for other countries in the region.

Current emissions of some Asia Pacific nations (Hong Kong, Japan, Singapore) are below those of the United States, Australian and Europe (Group A, Fig. 3a). In a few cases, at a specific income level, emission levels were slightly higher for a Group A country (e.g. Singapore) than that for the lowest-emission European country. However, such exceptions are brief. In all cases, *current* emissions are lower for Group A countries than for European countries. The different slopes – less steep for the Group A countries than for the European countries – suggest that in the near future the emissions of Group A will remain below those of the European countries.

A second group of Asia Pacific countries (Korea and Taiwan) appear to be following the same trends as European economies (Group B, Fig. 3b). Emission trends for Group B are only slightly higher than those for Group A – just enough to place this group inside the grey area.

Finally, some Asia Pacific countries have road $CO_2$ emissions above those of the European economies (Group C, Fig. 3c). For example, emission trends for Malaysia and Thailand suggest that future emissions (at comparable income levels) will continue to surpass the emissions from Sweden and possibly match those of Australia.

The observed emission patterns among countries mirror similar transportation-related patterns that others have observed within urban areas (Barter, 2000). The first pattern Barter (2000) calls the 'modern transit city', which might be like those of Japan (Tokyo and Osaka) or Hong Kong or Singapore.[3] These cities have high investment in transit systems and have

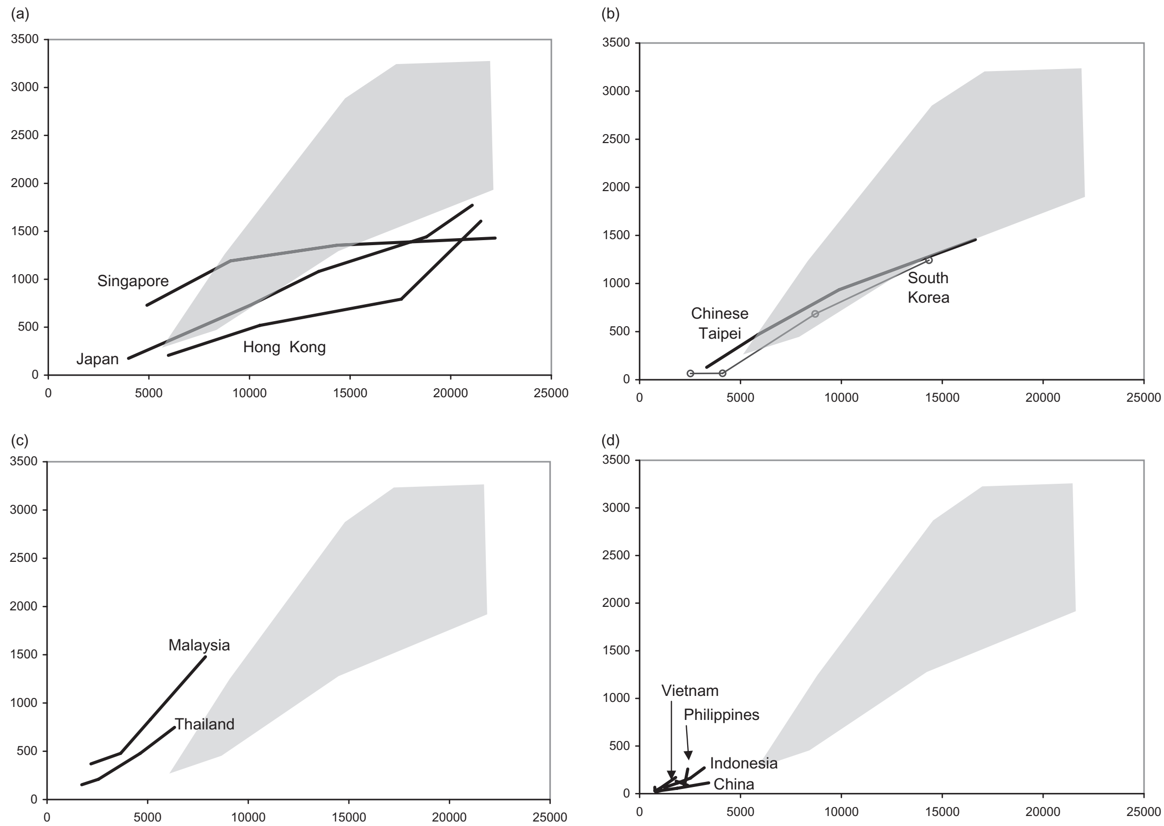


**Figure 3.** Comparisons of road carbon dioxide emissions per gross domestic product (GDP) per capita increases in different Asia Pacific economies

experienced a period of restrained motorisation early in their histories. A second pattern he represents as the 'automobile city', which has transit systems but also experienced a higher dependence upon the automobile or the motorbike. These cities refer to American or Australian cities. According to this model, it is reasonable to imagine Korean and Taiwanese cities falling within the spectrum between those of the 'modern transit city' and the 'automobile city'. Cities in Taiwan and Korea are similar in urban formation as cities found in Europe.[4] This placement of cities from these economies suggests that they have avoided major traffic congestion, but did not restrain cars to the extent of transit cities. Finally, the third pattern is called the 'automobile disaster' city. There are different forms of this city. In one variant, the model calls attention to cities such as Houston or Phoenix, where all but a tiny fraction of motorised travel is by private car, but the cities are low density and spread out. Another variant of this form is defined by narrow, dense street networks without extensive transit systems. In this type of city, modest vehicle usage per person translates into very high traffic per urbanised hectare. While car domination can be reversed, the traffic situation is often 'saturated' (examples include Kuala Lumpur and Bangkok) (Kenworthy, 2003; Barter, 2004).

Statistical tests of differences between slopes suggest there are significant differences between all three groups ($P < 0.01$). That is, when the economies are grouped together (groups A, B and C), the three slopes are significantly different from each other. Tests of slopes of individual economies provide further interesting analyses. First, the slopes vary from the highest emissions growth countries (Malaysia and Thailand), then those of the middle-trend economies (South Korea and Taiwan), and the lowest slopes are for Japan, Hong Kong and Singapore. Second, two outliers emerge, Singapore and Malaysia. Singapore is an outlier: it has the lowest slope and highest intercept value. After a rise in road fuel consumption, the level of road $CO_2$ emissions rose slowly despite rapid increases in income (almost flat curve). Malaysia, on the other hand, has the highest slope and the most rapid road $CO_2$ emission growth. Moreover, the slope for Malaysia is also different from that for Thailand ($P = 0.044$), and significantly different from those for all other economies. Japan and Hong Kong are not statistically different from each other, and both slopes are different from the trends in all other economies. Finally, the slopes for South Korea and Taiwan are not statistically different from each other. However, South Korea's slope is not statistically different from that of Thailand. This could be due to the rapid growth of motorisation in the country during and after the 1980s.

We now consider four countries whose GDP per capita was too low in 2000 to make comparisons with historical patterns of economies in the developed world. Our goal is to first identify patterns and second to hypothesise which paths these countries might follow. Figure 3d shows the low levels and difficulty of identifying how these economies might develop when compared with the now developed world. Upon closer inspection, however, the data suggest that three of the countries are following a path similar to Group C, and China is not. Figure 4 provides a closer examination of these trends. (Fig. 4 is similar to Fig. 3, but with a shifted axis scale and containing yearly rather than decadal data.) The figure suggests that trends in three countries (Indonesia, Philippines and Vietnam) are similar to Group C (in Fig. 4, lines for these three countries roughly follow the line for Thailand). Currently, China's slope for road $CO_2$ emissions over income lies between the economies of groups B and C. The direction that China will take is open to interpretation.[5] To provide more background, we next compare the driving forces of change among the various groups. At issue is how such factors differ among countries at present and whether those for the lower income economies bear resemblance to any of the other groups.

## Factors influencing future road $CO_2$ emissions

In this section, we explore several of the forces influencing road $CO_2$ emissions, and how these factors may change over the next 20–30 years. The following five subsections cover five sets of factors influencing road $CO_2$ emissions (and also vehicle ownership and use). Owing to space constraints, we discuss only these five factors and do not elucidate on all possible influences.

### *Demographic shifts and social geography*

Population increases affect total, but not necessarily per capita, road $CO_2$ emissions (although increasing population density may reduce emissions per capita). This paper focuses on per capita emissions.

We consider two aspects of national population structures: the share of the young population and urbanisation characteristics. Population structure is one determinant of the per cent share of those demanding automobiles. For example, a

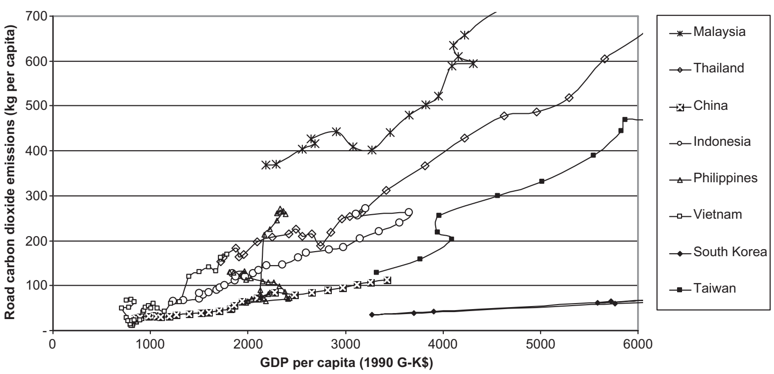


**Figure 4.** Comparison of road carbon dioxide emissions by gross domestic product (GDP) – Group C, Group B and low-income Asia Pacific countries

population may be large but currently composed of those too young or too old to drive automobiles. Arguably, the per cent share of the driving-age individuals provides an indication of the potential car market. The per cent of total population under age 24 is smaller in East Asia than in Southeast Asia (Table 3), and is also smaller in more industrialised than in less industrialised nations. The per cent of population under age 24 is approximately 33% in Japan and Singapore, and approximately 40% in Thailand and China. All else being equal, higher proportions of young people can yield more rapid future growth in vehicle emissions.

Population structures change as they undergo the 'demographic transition' from those having a high per cent share of young people to those with more evenly distributed shares of individuals at different age structures, including the elderly. What is surprising for many of the Asia Pacific countries is the large, and rapidly growing, population of those over 65 years old. The United Nations (2002) predicts that by 2050 many of the countries in the region will have shares of elderly populations larger than those of the United States. The impact of greater shares of elderly populations is not well understood. On the one hand, there may be downward pressure on vehicle consumption and use, if as people age they travel less. On the other hand, with longer, healthier lives, the elderly may drive more, as they have time and resources to travel in their retirement.

Spatial distribution of population includes factors such as urban versus rural population size; population densities within cities; city size and number; and distances between cities. Such factors can influence road $CO_2$ emissions. Generally, in developing countries in the region, automobile usage may be higher in cities than in rural areas. This relationship is determined by a number of factors, including higher incomes of urban residents, access to vehicle markets and access to good roads on which to drive vehicles. As countries increase in wealth, this relationship changes and those in suburban and rural areas tend to emit more road $CO_2$ than urban residents.

In the Asia Pacific, between 1975 and 2000, the urban population increased from 349 million to 764 million (United Nations, 1999). This growth is predicted to continue, as by 2030 the urban population in the region will top 1.3 billion (Table 4). Again, there are large differences between East and Southeast Asia.

Urbanisation levels among countries in the region vary greatly. Hong Kong and Singapore are 'city-state' economies and therefore both reached a high level of urbanisation early. Japan urbanised rapidly after World War II, so that by 1980 it had reached European and North American levels of urbanisation. South Korea followed these economies but with a slightly delayed history. South Korea experienced an even faster urbanisation transition than that of Japan, moving from less than 30% to over 80% urban in 40 years. The Southeast Asian economies were at low levels of urbanisation in 1960 (Indonesia 15%, Malaysia 27%, Thailand 13% and the Philippines 30.3%), and by 2000 none had been 60% urbanised. While the Philippines' and Indonesia's post-war urbanisation histories mirror that of Malaysia, China and Vietnam are closer to that of Thailand.

The number of cities in the Asia Pacific region with greater than 1 million people increased from 31 in 1960 to more than 120 in 2000. In terms of mega-cities, or those with a population of 10 million people or more, there were only two in the region (Tokyo and Shanghai) in 1975, but the number had risen to eight by 2000 (Tokyo, Jakarta, Metro Manila, Shanghai, Beijing, Osaka, Tianjin and Bangkok), according to the United Nations.

Not only does the emergence of mega-cities have social, economic and inter-urban environmental consequences, but these cities also have spatial characteristics that can be associated with increased road $CO_2$ emissions. Planners, for example, believing that density is related to energy usage have sought to find the transport-efficient city form (Newman and Kenworthy, 1989, 1999; Banister, 1992; Cervero, 1998). In the United States, households in the dense central city drive less than residents of less dense suburban and rural areas. In this respect, Asian cities have an advantage over their European and North American counterparts, as they are typically denser. For example, in a global sample of cities, Asia Pacific urban densities were typically over 5000 people per $km^2$ with several cities having densities of over 10 000 people per $km^2$ (Table 5). In Europe, most cities have densities lower than 20 000 people per

**Table 3.** Comparison of young population among select Asia Pacific countries (percentage of total)

| Region/country and age (in years) | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 |
|---|---|---|---|---|---|---|
| East Asia | | | | | | |
| 0–4 | 13.7 | 13.7 | 15.1 | 9.8 | 9.7 | 7.2 |
| 5–14 | 20.4 | 24.3 | 23.1 | 24.5 | 17.0 | 16.5 |
| 15–24 | 18.5 | 16.6 | 19.0 | 9.1 | 21.1 | 15.4 |
| 0–24 | 52.6 | 54.6 | 57.2 | 43.4 | 47.8 | 39.1 |
| Southeast Asia | | | | | | |
| 0–4 | 15.0 | 17.3 | 16.7 | 15.7 | 12.9 | 10.5 |
| 5–14 | 23.9 | 24.2 | 26.5 | 26.4 | 24.0 | 21.5 |
| 15–24 | 19.3 | 18.1 | 18.1 | 19.6 | 20.5 | 19.8 |
| 0–24 | 58.2 | 59.6 | 61.3 | 61.7 | 57.4 | 51.8 |
| Japan | | | | | | |
| 0–4 | 13.4 | 8.5 | 8.5 | 7.4 | 5.3 | 4.8 |
| 5–14 | 22.1 | 21.7 | 15.5 | 16.2 | 13.1 | 9.9 |
| 15–24 | 19.6 | 18.9 | 19.0 | 13.8 | 15.2 | 12.7 |
| 0–24 | 55.1 | 49.1 | 43.0 | 37.4 | 33.6 | 27.4 |
| South Korea | | | | | | |
| 0–4 | 15.7 | 18.6 | 13.7 | 11.3 | 7.7 | 6.6 |
| 5–14 | 26.0 | 23.3 | 28.3 | 22.7 | 18.2 | 14.3 |
| 15–24 | 18.6 | 18.8 | 17.8 | 23.0 | 20.4 | 16.4 |
| 0–24 | 60.3 | 60.7 | 59.8 | 57.0 | 46.3 | 37.3 |
| Hong Kong | | | | | | |
| 0–4 | 16.0 | 16.0 | 10.8 | 8.2 | 6.6 | 4.9 |
| 5–14 | 14.3 | 24.9 | 26.2 | 17.3 | 14.9 | 11.7 |
| 15–24 | 22.7 | 11.6 | 19.7 | 22.6 | 15.7 | 14.1 |
| 0–24 | 53.0 | 52.5 | 56.7 | 48.1 | 37.2 | 30.7 |
| Singapore | | | | | | |
| 0–4 | 16.1 | 18.5 | 11.3 | 8.0 | 7.6 | 6.8 |
| 5–14 | 24.4 | 24.7 | 27.4 | 19.0 | 13.9 | 14.9 |
| 15–24 | 17.8 | 17.4 | 21.7 | 24.2 | 18.7 | 12.5 |
| 0–24 | 58.3 | 60.6 | 60.4 | 51.2 | 40.2 | 34.2 |
| Indonesia | | | | | | |
| 0–4 | 14.3 | 16.7 | 16.5 | 14.8 | 12.0 | 10.0 |
| 5–14 | 24.8 | 23.3 | 25.6 | 25.7 | 23.8 | 20.2 |
| 15–24 | 20.0 | 19.3 | 17.7 | 19.7 | 20.7 | 20.2 |
| 0–24 | 59.1 | 59.3 | 59.8 | 60.2 | 56.5 | 50.4 |
| Malaysia | | | | | | |
| 0–4 | 16.7 | 18.6 | 16.4 | 13.6 | 12.8 | 11.9 |
| 5–14 | 24.2 | 26.7 | 28.2 | 25.8 | 23.7 | 21.8 |
| 15–24 | 17.9 | 17.5 | 19.3 | 21.3 | 19.1 | 18.8 |
| 0–24 | 58.8 | 62.8 | 63.9 | 60.7 | 55.6 | 52.5 |
| Philippines | | | | | | |
| 0–4 | 17.5 | 18.4 | 17.3 | 16.3 | 15.0 | 13.0 |
| 5–14 | 26.1 | 27.4 | 28.0 | 26.9 | 25.9 | 24.5 |
| 15–24 | 17.9 | 18.6 | 19.7 | 20.6 | 20.4 | 20.4 |
| 0–24 | 61.5 | 64.4 | 65.0 | 63.8 | 61.3 | 57.9 |
| Thailand | | | | | | |
| 0–4 | 16.4 | 18.2 | 16.9 | 13.3 | 10.1 | 8.2 |
| 5–14 | 25.7 | 26.2 | 28.0 | 26.1 | 21.8 | 17.4 |
| 15–24 | 20.1 | 18.4 | 18.8 | 21.6 | 21.5 | 17.9 |
| 0–24 | 62.2 | 62.8 | 63.7 | 61.0 | 53.4 | 43.5 |
| China | | | | | | |
| 0–4 | 13.7 | 14.2 | 15.9 | 10.0 | 10.3 | 7.5 |
| 5–14 | 19.9 | 24.7 | 23.8 | 25.5 | 17.4 | 17.3 |
| 15–24 | 18.3 | 16.1 | 19.0 | 19.5 | 21.8 | 15.6 |
| 0–24 | 51.9 | 55.0 | 58.7 | 55.0 | 49.5 | 40.4 |
| Vietnam | | | | | | |
| 0–4 | 12.4 | 17.6 | 17.1 | 15.4 | 14.4 | 9.9 |
| 5–14 | 19.4 | 21.8 | 27.0 | 26.3 | 24.5 | 23.5 |
| 15–24 | 18.9 | 14.7 | 16.2 | 20.7 | 20.4 | 20.2 |
| 0–24 | 50.7 | 54.1 | 60.3 | 62.4 | 59.3 | 53.6 |

*Source:* United Nations (2005) *World population prospects, the 2004 revision*, Volume 1: Comprehensive tables. New York: United Nations.
*Notes:* For statistical purposes, data for China do not include Hong Kong and Macau, Special Administrative Regions of China. As of 1 July 1997, Hong Kong became a Special Administrative Region of China. Predictions for 2010–2050 are 'medium variant' total fertility level.

**Table 4.** Comparison of urbanisation levels, urban population sizes and numbers of large cities in selected Asia Pacific countries

| Region/country | 1960 | 1980 | 2000 | 2030 |
|---|---|---|---|---|
| East Asia | | | | |
| Urbanisation level | 22.5 | 27.4 | 38.5 | 54.6 |
| Urban population size | 178 341 | 322 665 | 571 673 | 932 937 |
| Number of large cities | 26 | 64 | 109 | – |
| Southeast Asia | | | | |
| Urbanisation level | 17.6 | 24.3 | 37.2 | 55.9 |
| Urban population size | 39 588 | 87 630 | 192 687 | 397 380 |
| Number of large cities | 5 | 10 | 15 | – |
| Japan | | | | |
| Urbanisation level | 62.5 | 76.2 | 78.8 | 84.8 |
| Urban population size | 58 811 | 88 990 | 99 788 | 100 157 |
| Number of large cities | 5 | 6 | 8 | – |
| South Korea | | | | |
| Urbanisation level | 27.7 | 56.9 | 81.9 | 90.5 |
| Urban population size | 6 929 | 21 678 | 38 354 | 47 893 |
| Number of large cities | 2 | 4 | 8 | – |
| Hong Kong | | | | |
| Urbanisation level | 85.0 | 91.5 | 100.0 | 100.0 |
| Urban population size | 2 615 | 4 609 | 6 927 | 7 621 |
| Number of large cities | 1 | 1 | 1 | 1 |
| Singapore | | | | |
| Urbanisation level | 100.0 | 100.0 | 100.0 | 100.0 |
| Urban population size | 1 634 | 2 414 | 3 567 | 4 205 |
| Number of large cities | 1 | 1 | 1 | 1 |
| Indonesia | | | | |
| Urbanisation level | 14.6 | 22.2 | 40.9 | 63.5 |
| Urban population size | 14 031 | 33 514 | 86 833 | 179 915 |
| Number of large cities | 1 | 4 | 6 | – |
| Malaysia | | | | |
| Urbanisation level | 26.6 | 42.0 | 57.4 | 72.7 |
| Urban population size | 2 165 | 5 787 | 12 772 | 23 656 |
| Number of large cities | – | – | 1 | – |
| Philippines | | | | |
| Urbanisation level | 30.3 | 37.5 | 58.6 | 73.8 |
| Urban population size | 8 350 | 18 110 | 44 530 | 84 115 |
| Number of large cities | 1 | 1 | 2 | – |
| Thailand | | | | |
| Urbanisation level | 12.5 | 17.0 | 21.6 | 39.1 |
| Urban population size | 3 302 | 7 961 | 13 252 | 28 954 |
| Number of large cities | 1 | 1 | 1 | – |
| China | | | | |
| Urbanisation level | 16.0 | 19.6 | 32.1 | 50.3 |
| Urban population size | 105 249 | 196 222 | 409 965 | 752 051 |
| Number of large cities | 18 | 52 | 90 | – |
| Vietnam | | | | |
| Urbanisation level | 14.7 | 19.2 | 19.7 | 33.7 |
| Urban population size | 5 107 | 10 338 | 15 749 | 37 991 |
| Number of large cities | 1 | 3 | 3 | – |

*Sources:* United Nations (2000) *World population prospects: The 1999 revision*. New York: United Nations. File 2: Urban population by major area, region and country, 1950–2030 (in thousands), POP/DB/WUP/Rev.1999/1/F2; File 4: Percentage of the population living in urban areas by major area, region and country, 1950–2030, POP/DB/WUP/Rev.1999/1/F4; File 10: Population of urban agglomerations with 750 000 inhabitants or more in 1995 by country, 1950–2015, POP/DB/WUP/Rev.1999/2/F10.

*Notes:* Urbanisation levels are in per cent, urban population size in thousands and large cities are those with greater than 1 million population.

–, data not available.

**Table 5.** Population densities from sample cities in different regions of the world (person per km$^2$)

| Region and city | Size of metropolitan area (km$^2$) | Population density (2001–2005) |
|---|---|---|
| Asia Pacific | | |
| Hong Kong | 220 | 29 400 |
| Macau | 23 | 20 000 |
| Taipei | 440 | 14 750 |
| Hanoi | 130 | 13 500 |
| Manila | 1 334 | 12 550 |
| Yangoon | 350 | 11 150 |
| Seoul–Incheon | 1 943 | 10 050 |
| Vientienne | 60 | 9 650 |
| Singapore | 479 | 8 350 |
| Phnom Penh | 181 | 7 150 |
| Jakarta | 3 108 | 5 850 |
| Bangkok | 1 554 | 5 150 |
| Europe | | |
| Seville | 135 | 5 550 |
| Palermo | 145 | 5 150 |
| London | 1 623 | 5 100 |
| Munich | 466 | 3 600 |
| Paris | 3 043 | 3 400 |
| Vienna | 453 | 3 400 |
| Stockholm | 518 | 2 700 |
| Amsterdam | 414 | 2 650 |
| Lisbon | 881 | 2 550 |
| North America | | |
| Toronto-Hamilton | 2 152 | 2 450 |
| Los Angeles | 5 812 | 2 400 |
| Montreal | 1 740 | 1 850 |
| New York | 11 264 | 1 750 |
| Miami | 2 891 | 1 700 |

*Source:* Demographia, http://www.demographia.com/db-intlua-data.htm

square mile. Cities in North America typically have even lower densities – below 2500 people per km$^2$.[6]

## *Affluence and consumption*

Economic growth occurs faster now than in the past (Crafts, 2000). Over the past few decades, among developing countries, those in the Asia Pacific have experienced the most rapid changes. Moreover, these growth rates are unprecedented. In the past, growth rates of more than 4% were rare. The rates of rapid growth experienced by countries now, of 6% or more, are historically new.

These rapid growth rates have translated into significant increases in capital accumulation among households in developing countries in Asia. According to the Boston Consulting Group, in December 2003, Asia had 2 million 'high-net-worth individuals' – people with more than US$1 million (*The Economist*, 2004). While the proportion of millionaires in each country remains low, the absolute numbers, given the levels of economic income per capita, are impressive.

More impressive is the rapid rise in middle-class populations. Dargay and Gately (1999) have shown that worldwide, when economies obtain GDP per capita levels of between US$2000 and US$5000, vehicle and automobile ownership increases rapidly. This range is associated with the rise of a middle class. A recent prediction suggests that by 2030, 16% of the world population will belong to what can be called a global middle class, which is an increase from 7.6 % in 2000. In 2000, approximately 400 million people in developing countries could engage in activities and consumption behaviours associated with middle-class status. By 2030, this number is expected to reach 1 billion people (Bussolo and van der Mensbrugghe, 2006). In China alone, by 2015, the number of people with incomes of over US$3000 could reach 600 million (Wilson *et al.*, 2004).

We consider next how wealth accumulation relates to (i) vehicle ownership and (ii) land consumption. The rapid growth in the economies of the Asia Pacific is matched by the rapid growth of vehicles in use (Table 1). National growth of vehicles in use was higher in the 1980s than in the 1990s for most Asia Pacific economies except for some ASEAN countries. In each case, rates of growth in vehicle use move similarly with rates of economic growth. Increased wealth in the region translates directly into increased demand for automobiles. Furthermore, predictions of vehicle sales in the region suggest continued growth into the near future (Table 6). Increases in car sales for the core automobile economies (Japan, South Korea and China) are very positive, but, surprisingly, the compound average growth rates for vehicle sales in the ASEAN region are expected to be 10–20% annually (Veloso and Kumar, 2002).

A unique aspect of some countries in the region is the high number of two- and three-wheeled vehicles in use, accounting for between 50% and 90% of the total vehicle fleet.

**Table 6.** Current and projected vehicle sales in selected Asian economies (thousands of units)

| Economy | 1999 | 2010 | Per cent increase |
|---|---|---|---|
| Developed | | | |
| Japan | 5861 | 7000 | 19 |
| Australia | 797 | 1051 | 32 |
| Developing | | | |
| Korea | 1275 | 2550 | 100 |
| Thailand | 218 | 1253 | 475 |
| Taiwan (Chinese Taipei) | 423 | 638 | 51 |
| Malaysia | 289 | 747 | 158 |
| Indonesia | 94 | 696 | 640 |
| Philippines | 74 | 533 | 620 |

*Source:* Veloso and Kumar (2002).

The use of these vehicles has increased rapidly in cities such as Kuala Lumpur, Bangkok, Ho Chi Minh and Surabaya. In Kuala Lumpur, Bangkok and Surabaya, there was a dramatic surge in motorcycle ownership rate during the 1980–1993 period (Barter, 1999). These technologies are cheaper than automobiles; given the weather conditions in the region, they are often just as useful. (In congested roadway conditions, motorcycles can be more convenient than cars.) Given the size of the fleets and their emissions, the Asian Development Bank (2003a) states that two- and three-wheelers contribute significantly to total vehicle emissions, especially for urban air pollution.

Motorisation in China is worth exploring in more detail. Before the 1990s, the low numbers of vehicles in use reflected low private ownership, as most passenger and commercial vehicles were owned by the government. As recently as 1993, 96% of all vehicle sales in China were to government departments or state-owned enterprises. Increasingly, however, private citizens have enough money to purchase cars. Private sales during the 1990s grew at approximately 20% a year. Given the low starting levels, by 1997, vehicular ownership was only two vehicles per 1000 households (*The Economist*, 1997). Thereafter, evidence suggests that private consumption of automobiles changed. By the year 2000, approximately 50% of the newly purchased vehicles were bought by private citizens (Liu, 2002). Growth since then has been explosive. Between 2001 and 2005, the Chinese National Bureau of Statistics estimates that as many as 6 million Chinese purchased cars (Asia Pulse, 2005). Moreover, by 2001, China's motorcycle population surpassed 31.6 million. In 2001, China also manufactured over 12 million motorcycles, more than half the world total (Asian Development Bank, 2003a). China has now become the world's second largest car market and may account for 40% of global car consumption by 2015 (Gan, 2003; *China Business Daily News*, 2006). By 2040, China is expected to have over 420 million cars in use (approximately 50% of today's global total), and at that proportion of cars per population (29 per 100 people) it will still be lower than the level in the United States in 2000 (48 per 100 people) (Wilson *et al.*, 2004; *The Economist*, 2006).

In terms of land consumption, major metropolitan centres in the Asia Pacific have grown outwards. One form, called the *desakota*, was identified by McGee (1991) in Southeast Asia and subsequently in other parts of the Asia Pacific. In the past, despite these large physical areas linked to the urban economy, city cores remained dense. However, massive expansion of urban built-up areas has been occurring throughout the region. These include residential de-densification, addition of large-scale office buildings in the city centre, lower density residential development in the city fringe and the relocation of manufacturing businesses from the city centre to the suburbs. In a 20-year period, from 1978 to 2002, the size of Chengdu, China, for example, increased by threefold, from 81 $km^2$ to nearly 220 $km^2$ (Schneider *et al.*, 2003). Increases in land development have been propelling a growing demand for improvement in transportation systems, including private car ownership and use. In turn, motorisation acts as a tool that facilitates such land-use changes and could expedite the decentralisation process (Schipper and Ng, 2004).

Some authors have noted that the housing consumption patterns of the middle-income segment in developing-country cities are leading to patterns of urban land uses similar to the suburbanisation and suburban sprawl associated with developed countries, particularly the United States (Leichenko and Solecki, 2005). Of note in this study were those developments in East and Southeast Asia outside of major metropolitan centres. American-style suburban-type sprawl would have the tendency to increase vehicle usage and promote private car ownership.

*Technology development and adoption*

Schipper (1995) notes that fuel economy increases as the total car stock in a country grows and new cars replace old ones. According to Schipper, there has been no question that from the 1970s to the early 1990s, new cars became more energy efficient. Ayres *et al.* (2003) also suggest that transportation technologies have become more energy-efficient over time. Two broad approaches for increasing vehicle energy efficiency and lowering $CO_2$ emissions per kilometre are improved fuels and alternative engine technologies. Engine modifications have provided improvements in road $CO_2$ emissions per kilometre. It is still an open question whether biofuels offer significant net $CO_2$ reductions per vehicle-km (relative to fossil fuel), after accounting for life-cycle energy inputs for crop and fuel production. Recent findings suggest that biofuels can offer a net $CO_2$ benefit (Farrell *et al.* (2006) estimated that at present, US corn ethanol offers a minor reduction, less than 20%, in $CO_2$ emissions compared with gasoline, but more research is needed) (Farrell *et al.*, 2006; Tilman *et al.*, 2006).[7]

While clean fuel and engine technologies hold promise, current trends in adopting these $CO_2$-reducing measures suggest that they will not immediately overcome the pressures for increases in automobile use to reduce or even stabilise road $CO_2$ trends. To put the state of adoption of alternatives to internal combustion engines in perspective, a recent study suggests that vehicles using compressed natural gas account for approximately 0.5% of vehicles worldwide, hybrid-electric vehicles account for about 0.5% and vehicles running on biofuels account for less than 1% of transport fuel consumption (Mytelka and Boyle, 2006). Given the inertia of the global automobile market, adoption of these new technologies may not occur for another 30–55 years (Heywood, 2006).

*Institutions and policies*

Another important factor in determining the future of road $CO_2$ emissions are the institutional capacity to regulate and plan transport, particularly in terms of policies related to fuel and automobile use. In general, institutions have played an important role in development in the Asia Pacific region (World Bank, 1993; Rowan, 1998). In this subsection, we examine the role of both institutional development and policies in encouraging fuel efficiency. There is no 'one size fits all' policy prescription to reduce GHG emissions from the transport sector, but the capacity of institutions to plan and manage transport systems both locally and nationally is important.

In the Asia Pacific region, urban transport systems vary from integrated systems seen in Japan, Hong Kong and Singapore to institutionally weak, largely road-based, systems where transit planning occurs in a more piecemeal fashion (Barter, 1999; Laquian, 2005). In the first case, land-use policies are integrated into transport schemes. In cities such as Singapore and Hong Kong, we find transit routes planned with housing development, so that residents have easy access to mass transit. In the Greater Tokyo Metro region, plans are in place to continue integrating road, rail, bus and trolley infrastructure.

For developing country cities in the Asia Pacific, transport planning in the Indonesian capital Jakarta is representative. Using five-year plans, the metropolitan and national governments have promoted the development of new communities in the peri-urban area and the construction of extensive road networks to serve these communities. Two aspects of these plans have combined to enhance automobile consumption and usage. First, the construction of major roads, such as the 58-km toll road connecting the northwestern and northeastern ends of the Harbour Toll Road, has increased accessibility to, and encouraged the commercial, industrial and residential development of the urban periphery. Second, the new urban nodes in the periphery are largely connected via highway linkages, without secondary road networks. The result has been the encouragement of vehicle consumption and the lack of development of potentially valuable land closer to the city. Both of these factors led to urban sprawl and the potential higher uses of motor vehicles (Laquian, 2005).[8]

There are exceptions to the encouragement of automobile mobility in developing parts of the region. Shanghai, for example, despite traffic congestion problems, has one of the lowest vehicle ownership levels among major Chinese cities. The city is promoting investment in both road and rail, integrating land-use planning and transportation, implementing vehicle restraint policies and developing 'intelligent transport systems' technologies (Zhou *et al.*, 2001). Shanghai also boasts the first maglev train in Asia.

Several cities in economies of Group A and some in Group B have discouraged motor vehicle consumption through taxes (or tax relief) and congestion pricing. Car taxation can increase the price differential between larger and smaller cars. Where taxed by value and weight (Italy, Denmark, United Kingdom, the Netherlands), cars are on average smaller than where lightly taxed (Schipper, 1995).

Since the 1970s, Singapore has relied on purchase and ownership taxes, including an additional registration fee, an excise city and an annual road tax, to lower vehicle demand. In 1990, the 'Vehicle Quota System', which included the sale of a limited number of 10-year permits, known as Certificates of Entitlement, were auctioned twice every month and controlled by the government. The costs of taxes and Certificate of Entitlement could raise the price of a car four times above its open market value (Barter, 2005). Japan and Korea also have significant vehicle taxes.

Singapore pioneered congestion pricing beginning in the mid-1970s (Barter, 2005). This strategy is now being tested in a developed-world city, London.[9]

Other forms of ownership and usage restraint can be seen in Seoul, Hong Kong, Osaka and Tokyo (Hook and Replogle, 1996). Some observers have argued that this slowdown in motor vehicle ownership provided a window of opportunity for building a viable long-term competitive transit system, providing alternatives to private vehicles (Barter, 1999; Barter *et al.*, 2003).

However, not all cases of transport demand management in the region have been successful in reducing automobile ownership or use. In some cases, there are tax programmes, such as those in Malaysia, that are designed to protect the domestic automobile industry. These import taxes may not have significantly impacted on vehicle ownership rates (Barter, 2004).

Fuel prices are recognised as an important determinant of automobile fuel consumption. For example, when fuel prices increased rapidly in the 1970s, driving decreased in OECD countries. However, as a result of the decline in real fuel prices during the 1990s, the cost per vehicle-km for fuel was lower in 1992 than in 1973 in six of the nine countries studied (Schipper, 1995). It is no wonder then why fuel consumption increased in countries like the United States. Recent global fuel price increases, however, may change this equation. One would expect the short-, medium-, and long-term impacts of price increases to differ (i.e. the elasticity of demand depends on the time scale of interest).

Countries with high fuel taxes tend to have fleets with higher fuel efficiency (Gorham, 2002). Few economies used fuel taxes to encourage or discourage car buying or usage behaviour. Rather most countries have used fuel taxes to raise government revenue. Pigouvian taxes on fuels are experimented with in European economies and in some Latin American cities. In the Group A economies, Japan and Singapore have fuel taxes. Both South Korea and Taiwan in Group B have fuel taxes. Vietnam also currently has a fuel tax, and China and Malaysia are contemplating implementation.

Many countries in the region use the automobile industry as a pillar of economic development policy. The automobile industry was an important factor in the growth of the US economy and is associated with the decline of transit. Currently, the world car industry is adding approximately 63 million vehicles a year to the global vehicle population. The rise of importance in Asian car production globally is demonstrated in Table 7. China, South Korea, Japan, Thailand, Malaysia, the Philippines and Indonesia have car manufacturing industries and plants. Since 1984, the Asia Pacific region has increased its share of global automobile production from approximately 29% to 33 %. While both Japan and Australia have been important vehicle manufacturers for decades, the increase noted in the table has largely been through a dramatic rise in production in the developing economies.

**Table 7.** Change in regional share of global motor vehicle production, 1984–2004

| Region/country | 1984 | | 1994 | | 2004 | |
|---|---|---|---|---|---|---|
| | Thousands of units | Per cent of total | Thousands of units | Per cent of total | Thousands of units | Per cent of total |
| Asia Pacific region | 12 263 | 29.0 | 15 334 | 30.7 | 20 931 | 32.7 |
| Developed | 11 840 | 28.0 | 10 854 | 21.7 | 10 917 | 17.1 |
| Japan | 11 465 | 27.1 | 10 554 | 21.1 | 10 512 | 16.4 |
| Australia | 375 | 0.9 | 300 | 0.6 | 405 | 0.6 |
| Developing | 423 | 1.0 | 4480 | 9.0 | 10 014 | 15.7 |
| Korea | 263 | 0.6 | 2312 | 4.6 | 3 469 | 5.4 |
| China (PRC) | 160 | 0.4 | 1206 | 2.4 | 5 071 | 7.9 |
| Taiwan (Chinese Taipei) | – | – | 396 | 0.8 | 431 | 0.7 |
| Indonesia | – | – | 326 | 0.7 | 483 | 0.8 |
| Malaysia | – | – | 137 | 0.3 | 472 | 0.7 |
| Philippines | – | – | 103 | 0.2 | 88 | 0.1 |
| World total | 42 330 | NA | 49 968 | NA | 63 948 | NA |

*Source:* Ward's (various years) *Ward's automotive yearbook*. Detriot, MI, Ward's Communication.
–, data not available; NA, not applicable.

The fact that an economy has a strong motor vehicle industrial production component does not necessarily translate directly into high domestic vehicle ownership and usage. Japan's case is instructive. Before the 1940s, the government encouraged consumption constraints on vehicles, as manufacturers were foreign, until its domestic industry could compete. Constrained consumption, along with intensive investments in high-density urban growth and rail-based transport, was part of economic nationalism. Together, these policies facilitated high costs of land. High densities, transit orientation and high land prices were further strengthened by governmental planning and regulations. After the 1960s, with the rise of firms such as Toyota and Honda, Japan looked abroad to sell its products, as there were strong economic interests in keeping the country highly dense and moving under rail. Much of Japanese production was exported. However, as the Western car market matured in the 1990s, Japan needed to stimulate automotive markets in the country and in Asia. Vehicle ownership increased domestically, but as previously mentioned, public transit could compete. Meanwhile, Japanese aid went into road development in Southeast Asia, among other places (Hook and Replogle, 1996). There are similarities between this narrative and that of South Korea (Barter, 1999).

On the other hand, however, the Group C economies have also focused on vehicle production and consumption. For example, the former prime minister of Malaysia, Dr Mahathir bin Mohammad, during his long tenure promoted automobile production and consumption as one way to promote economic development. The establishment of the Malaysian car, the Proton, has been an important symbol of the country's economic growth. Thailand has also promoted a car industry. The results in these cases have been significant increases in motor vehicle ownership and usage.

Some of the low-income economies, for example Indonesia and China, are the economies that use motor vehicle production as a vehicle to development. The government of Indonesia has strongly encouraged motor vehicle ownership and use through protection of the domestic automobile industry, massive subsidies to road users and general lack of investment in public transport (an exception is the TransJakarta busway) (Hook and Replogle, 1996; Aswicahyono *et al*., 1999). These policies have helped to make Indonesia the third largest car market in Southeast Asia, after Thailand and Malaysia (Guerin, 2005). In China, the government has also played a major role in the development of industries, but rather than protectionism, they have embraced the globalisation of the automobile industry. By 1998, for example, there were more than 600 international investors from the automobile industry established in the country (Gan, 2003). At the same time, consumption has been stimulated by, *inter alia*, the relaxation of price controls for automobile sales. The results have been an explosion in motor vehicle production. By 2004, China was producing over 5 million vehicles per year or almost 8% of global annual production (see Table 7). Schipper and Ng (2004) suggest that car production is propelling the rapid rise of automobile ownership in China (see Table 1).

In summary, the institutions and policies that promote greater transport planning integration and lower car consumption and use are more common in Group A economies. South Korea also demonstrates similar types of policies. Policies that protect domestic industries and promote car use, or do not restrict it, are more common in Group C economies. Some of the lower income economies in the region are engaged in both demand management and promotion of motor vehicle production.

*Physical infrastructure and mass transit*

Provision of transportation infrastructure is associated with economic development (World Bank, 1994) as well as automobile usage (Downs, 1992). We briefly look at the following aspects of infrastructure: rail transit infrastructure, the provision of roads in the region and some cases of motorised mass transit.

The increase in urban population in many Asian countries over the past three decades often manifested itself in the physical environment in chaotic and inefficient ways. Planning for holistic transport systems, including transit, in developing cities, was made impractical because of rapid growth rates and the perceived need to address other priority areas (such as health, energy, water resources, etc.).

At the same time, the high densities of these cities offer greater opportunities for mass transit, including subway, light rail and rapid bus transport. Some Asia Pacific cities have been able to capitalise on this advantage, despite rapid growth, and have provided a number of viable public transit options. Japan and Korea have excellent systems, of which Tokyo and Seoul are premier examples. By the early 1990s, the mass transit systems in these cities were a dominant feature of the urban transport system in many cities in Asia (Midgley, 1994). The 1990s, however, brought rapid motorisation to cities and countries across the region. Although motor vehicle ownership rates vary greatly across East and Southeast Asia, increases were greater than 10% per annum (Asian Development Bank, 2003b) in general. Public transit systems were subsequently harmed, although differentially, and not completely.

Kenworthy *et al.* (1999) sampled 46 cities worldwide and compiled a comprehensive set of urban transport parameters for each city. Their study suggests that the proportion of urban workers using public transit in the Asian countries was the highest among six groups of cities from different parts of the world. In 1990, Tokyo, Hong Kong, Seoul, Singapore and Manila had recorded higher annual public transport passenger-kilometres per capita than any of the Western cities. Hong Kong, Seoul, Singapore and Manila also have particularly high proportions of work trips carried by public transport.

Recent evidence suggests that the public transport sector has been growing in absolute size, but used differentially in the region. In low-income[10] and middle-income[11] Asian cities, the percentage of public transport on rail is as low as 13% and the percentages of motorised (i.e. non-rail) public modes of transport are 28% and 26%, respectively. Compare this with 57% of public transport trips on rail and 32% in motorised public modes in high-income Asia cities[12] (Kenworthy and Townsend, 2007).

Asian cities have a wide variety of public transport modes. The urban mass transit systems in the Asia Pacific are made up of four components: rapid transit (rail-based high-speed, grade-separated); light rail (capable of operating at grade or in grade-separated systems, with higher capacities and higher speeds than buses); and guided rapid transit (buses and vans operating on fixed routes, point-to-point or on non-fixed route bases); and taxis, small motorised two- and three-wheeled vehicles (providing access to trunk line bus and rail systems). Much of the region's urban rail transit systems are found operating in the major cities in North Asia. In Southeast Asia and China, there is a diversity of components available in any one city.

Increasingly, light rail transit systems are becoming an option for large cities. For example, Metro Manila has a light rail transit constructed in 1980 and a rapid transit line built in 1984–1985. The systems were upgraded in 1992–1999 to increase passenger capacity. In 2004, the system lines were extended by 5.5 km. In addition, two separate transit lines were also built to extend the system, one of which is an orbital line covering 17 km. In Bangkok, the Skytrain was constructed in 1992 and finished seven years later. The system currently maintains two lines and runs 23.5 km along Sukhumivt and Silom Roads (Laquian, 2005). Japan also has cities with extensive light rail systems integrated into bus and rapid transit systems (Kenworthy and Townsend, 2007).

One of the most recent and exciting advances has been the bus rapid transit (BRT) system. BRT can be developed either as an 'open' or as a 'closed' system (Hook, 2005). 'Closed' systems have enclosed bus stops where passengers pay upon entry. Once inside the bus stop, passengers can board buses or transfer to other lines. Only BRT buses use the segregated high-speed busways. 'Open' systems have all their buses, whether BRT or otherwise, use the busways. Examples of new 'closed' systems in the region include those in Jakarta, Seoul and Beijing. Examples of open systems include those in Taipei, Hangzhou and Kunming. Other systems are planned for Xi'an, Shenzhen, Jinan, Shenyang, Chongqing and Guangzhou (Pucher *et al.*, 2005; Daramaningtyas, 2006; Duan and Fjellstrom, 2006).

Some of these systems have been increasingly successful. For example, TransJakarta, which opened in January 2004, carries over 100 000 people each day and plans are being made to add 10 new corridors to the original three by 2007 (Daramaningtyas, 2006). In Seoul, after the bus reforms of July 2004, the BRT system quickly improved its ridership to 700 000 passengers a day and forestalled a looming financial crisis (Pucher *et al.*, 2005).

The development of transit and public transport systems would suggest lower $CO_2$ emissions from vehicles as people turn towards these modes of transport. However, in the region, this trend is matched, if not overcome, by infrastructure that promotes vehicle usage: roads. Many countries in the region, such as Japan, Korea, Taiwan and Malaysia, already have good road infrastructure. Other countries are funding highway expansion. By the end of 2004, China had 34 000 km (21 000 miles) of motorways, more than double the 2000 figure (17 years ago, it had none). Only the United States has more. China's total road network is the third longest in the world: 1.8 million km, of which 44% was built in the past 15 years. Nor will it stop there. By 2020, China plans to double again the length of its motorways (*The Economist*, 2005).

Building motorways has been used by the Chinese government as a tool for stimulating economic growth. Most roads are financed by loans from the state banks. The chances of repaying debt on time appear to be low, because for many road stretches, toll revenue barely covers the cost of the toll collectors. The Beijing city government decided to end toll charges on the new $1.6 billion expressway around the city, just a few months after it opened, as early usage suggested it would take more than two centuries to repay its loan (*The Economist*, 2005).

The provision of road infrastructure associates directly with increases in automobile usage (Ingram and Liu, n.d.). A recent study of comparative road construction and road $CO_2$ emission found that road $CO_2$ emissions per kilometre of surfaced road increase are far higher for developing countries than for the United States and Japan (Marcotullio and Williams, 2007). For example, for comparable levels of income, the United States experienced approximately 203 tonnes and Japan 209 tonnes of increased $CO_2$ emissions for every kilometre of paved road added, while rapidly developing Asia Pacific economies experienced between 1000 and 9000 tonnes of $CO_2$ emissions for every kilometre of road added (Fig. 5). Table 8 shows the net changes using GDP per capita equivalent time intervals. This suggests that as new roads are developed, geometric increases in road $CO_2$ emissions would not be surprising.

In summary, we find a diversity of public transit options throughout East and Southeast Asia. Road development in the region continues apace and with it increases in motor vehicle usage. However, while public transit usage has increased recently, the share of those using mass transit has declined. Of course, factors and results vary by city and economy. Some of the

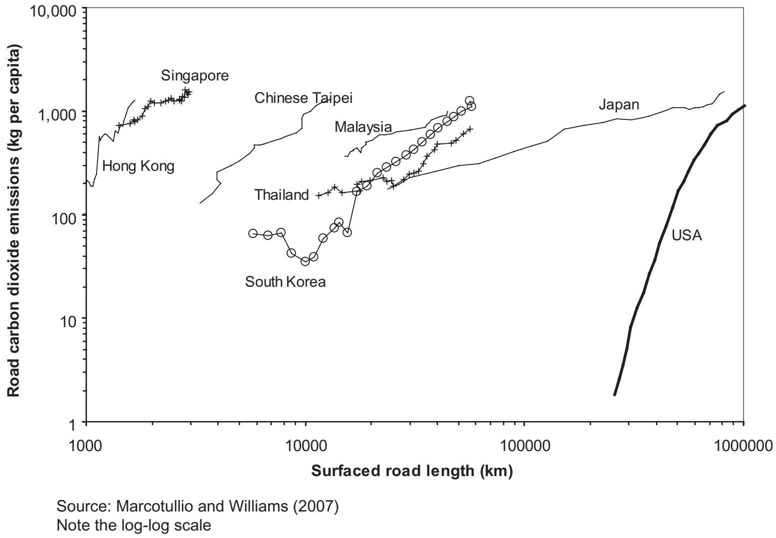


**Figure 5.** Road carbon dioxide emissions per capita by surfaced road length

**Table 8.** Comparison of per cent growth in surfaced road length and carbon dioxide ($CO_2$) emission per surfaced road length over comparable time intervals

| | That country's surfaced road length growth (%) | That country's road $CO_2$ emissions per surfaced road length (tonnes/km) | United States | |
|---|---|---|---|---|
| | | | Surfaced road length growth (per cent) | Increase in road $CO_2$ emissions per surfaced road length (tonnes/km) |
| Hong Kong | 77 | 9286 | 193 | 227 |
| Japan | 3246 | 209 | 2080 | 203 |
| Malaysia | 42 | 1074 | 899 | 128 |
| Singapore | 108 | 2124 | 1883 | 192 |
| South Korea | 237 | 1173 | 1624 | 141 |
| Taiwan | 41 | 3826 | 1624 | 141 |
| Thailand | 42 | 1228 | 749 | 130 |

*Source:* Marcotullio and Williams (2007).

best systems are found in the high-income Asian cities, where heavy rail, subways, light rail and bus system coexist. Tokyo's system, for example, moves enormous numbers of people daily (between 8:00 AM and 10:00 AM approximately 1 million people pass through one transit hub, Tokyo Station). In middle- and low-income Asia, however, public transport offers fewer examples of rail and greater vehicle diversity, including buses and vans. These on-grade systems, however, often get caught in traffic, which reduces effectiveness. New examples of BRT are increasingly found and a large number of experiments are being undertaken in cities such as those in China, which suggest possible reasons for optimism regarding this new form of public transit.

## Discussion

To forecast road $CO_2$ emission trends for the lower income economies, we need to weigh the importance of factors pushing in different directions. Given the analyses presented, we cannot conclusively identify which sets of factors are strongest or how different economies will respond to their particular set. However, we can present two possible futures.

The first possibility involves a combination of the following: lower population growth; urban growth that is friendly to non-motorised and mass transit; low annual per person vehicle-miles travelled; and technology shifting towards cleaner fuels and engines. The second possibility, involving higher road $CO_2$, involves reverse trends: rapid population growth; automobile-focused urban growth; and either lack of attention to emissions or greater reliance on more-polluting and less fuel efficient vehicles.

While developing housing units outside the city may provide an opportunity for rapid transit, it is also a recipe for private passenger car consumption and use. The slow start on transit development in many cities, owing in part to the lack of finances and the emphasis on road development that encourages car ownership, adds to this scenario. Moreover, in many countries, the automobile industry is seen as a potential economic development vehicle, owing to its upstream and downstream industrial employment and service linkages. Government promotion of the car industry can be effective, yielding increases in vehicle purchasing and use, and therefore increases in $CO_2$ emissions. The dominance of this future pattern also depends upon whether and to what extent the world will continue to globalise and how trade in fuels will develop. China's entrance into the World Trade Organisation has boosted its trade and arguably this has manifested in the country's automobile production industry. In this potential future, those economies with already lower levels of emissions and well-developed policies and institutions to keep emissions low will continue to do so. Those economies with higher road $CO_2$ emissions (i.e. Group C) and those lower income economies currently developing modern transportation systems would increase their emissions. All things being equal, this pathway seems the more likely midterm future trend.

Notwithstanding the impact of changing oil supplies, we suggest that while the second seems more possible, both pathways described are plausible, meaning there is an opportunity for economies in the region to realise lower road $CO_2$ emissions per capita with increasing wealth. The future patterns depend on structural changes in economic and socio-demographic factors as well as policy and technology adoption trends, particularly in the lower income countries.

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## Notes

1 For this study, the Asia Pacific includes the economies of China, Hong Kong (China Special Administrative Region), Democratic People's Republic of Korea, Japan, Mongolia, Republic of Korea, Brunei Darussalam, Cambodia, East Timor, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Taiwan (Chinese Taipei) and Vietnam.

2 Several studies conducted by the authors compared changes in transportation $CO_2$ emissions between developed and developing countries. Comparisons and tests for differences were performed across similar levels of economic ranges. Details of the database and methodologies for comparison can be found in the appendix of Marcotullio *et al.* (2005).

3 Tokyo, Osaka, Hong Kong and Singapore were able to curtail motorisation for a significant period at an early stage (before motorisation reached 150 vehicles per 1000 population). In these cases slow motorisation despite rapid rises in income and substantial investment in public transport allowed these cities to avoid transport-related problems (Barter *et al.*, 2003).

4 Seoul, Korea is also cited as a city that is similar to Singapore, Hong Kong and those in Japan as it curtailed motorisation and invested in public transit. At the same time, Taipei is characterised as more like Kuala Lumpur and Bangkok (Barter *et al.*, 2003). However, it is not unreasonable to find Korean and Taiwanese cities are lying on the spectrum between these two types of cities, with obvious exceptions within each economy.

5 It is important to note that the data for China are inclusive from 1970 to 2000. An analysis of the trends in road $CO_2$ emissions suggests that they may be following group C (see below).

6 See Demographia at http://www.demographia.com/db-intlua-data.htm. Data on urban densities are difficult to compare because of variation in boundary definitions. At the same time, these data match trends in other databases as well as the experiences of the authors.

7 Biofuel production and consumption are increasingly important to many economies in the region, including Malaysia, the Philippines and Indonesia.

8 One cause for this pattern, based on interviews with decision makers in Jakarta, is that the government plans for elite Jakarta residents and visitors rather than for the middle and lower class citizens (Marshall 2005).

9 According to a recent report, London's 2003 implementation has already reduced road $CO_2$ emissions by almost 20% (Beevers and Carslaw, 2005). New York City broached the topic of congestion pricing, with Mayor Bloomberg including it in his recent plaNYC 2030 plan. However, at present, this move appears

unlikely, owing to a lack of political will in the New York State legislature.

10 Guangzhou, Shanghai, Manila, Jakarta, Beijing, Ho Chi Minh, Mumbai and Chennai.

11 Taipei, Seoul, Kuala Lumpur and Bangkok.

12 Tokyo, Osaka, Sapporo, Hong Kong and Singapore.

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