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# Chapter 4

# Key Factors Driving the Future Demand for Surface Transport Infrastructure and Services

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## Executive Summary

This chapter assesses the likely impact of key social, economic, environmental, technological and political factors on future (30-year) demand for road and rail transport infrastructure requirements.

### *Road transport infrastructure requirements (2000 to 2030)*

The key drivers of road transport infrastructure requirements are: *a)* the current existing stock of road infrastructure, as measured by asset value; and *b)* GDP growth, which reflects population growth and per capita income growth. Other factors are considered to have marginal impact around a base-case forecast determined by these economic factors for road transport.

Road transport infrastructure requirements (new construction) of between USD 220-290 billion/year are forecast between 2010 and 30; with perhaps as much as 20% of this amount subject to deliberate policy intervention (*e.g.* fiscal restraint, sustainable development, modal shift to rail) efforts to achieve greater infrastructure efficiency, reduce road congestion and/or improve deteriorating road quality. The largest component of road infrastructure requirement arises from the need to replace/upgrade existing road assets that deteriorate over time. A smaller component actually goes to augment the road capital asset value. Over the entire 2000-30 period, a declining ratio of road capital asset value-to-GDP is forecast – which implies an increase in the productivity of road transport infrastructure.

### *Rail-track infrastructure requirements (2000 to 2030)*

While the same economic factors also determine rail-track infrastructure requirements, government policy to affect modal shift (from road to rail) has an important influence. Rail-track infrastructure requirements (new construction) of between USD 49-58 billion/year are forecast between 2010-30, with a range of ±20% of this amount subject to deliberate policy intervention to fully implement/ accelerate rail upgrading to achieve modal shift targets (or not, as the case may be).

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### *Policy implications*

Relevant policy implications arising from these forecasts, which might be usefully addressed in future work in subsequent phases of the OECD Futures Project, include:

- *Infrastructure benefits* are expected to exceed infrastructure costs. Benefits from road transport infrastructure will be more heavily weighted to economic/productivity benefits, while benefits from rail-track infrastructure will more likely be derived from social/environmental outcomes.
- *Economic/business model.* The current model, reliant on annual appropriations control of general tax revenues, will come under intense stress in coping with the heightened fiscal demands of infrastructure requirements. Greater reliance on specific taxes (*e.g.* hypothecated fuel taxes or road fees) and direct road user charges (*e.g.* heavy vehicle charges, tolls) will need to be encouraged.
- *Governance/funding of infrastructure.* In addition to resolving the funding issue for surface transport infrastructure there is the governance issue, which must address asset management, accrual accounting, administration and oversight, and performance reporting issues.
- *Relationships with other infrastructures* will have to be managed from a systems perspective:

  *a) Energy infrastructure*: there is considerable energy demand impact resulting from this forecast of road/rail transport growth, which in turn brings important sustainability/environmental impacts (*e.g.* GHG emissions, fuel efficiency technologies). The author's forecast of road vehicle ownership/use is considerably higher than other forecasts (*e.g.* IEA, WBCSD), which appear to be more optimistic with regard to the possibility of "decoupling" freight (and passenger) transport growth from economic growth – in particular with the impact of growing freight (and passenger) transport intensity from China, Big 5 and developing country growth.

  *b) Telecom (ICT) infrastructure*: technological advances will provide opportunities to improve vehicle safety and network management, with attendant productivity benefits to both road and rail infrastructure. However, these will be marginal relative to the expected growth in vehicle volumes arising from GDP and population growth. The long-term trend is for continued complementarity between *virtual mobility* (information/communications) and *physical mobility* (transport).

  *c) Water infrastructure*: severe climatic disturbances (*e.g.* shifting weather/climate patterns, rising ocean levels) could require additional road and rail infrastructure spending to mitigate risks/damage to both infrastructure sectors.

*d) Congested urban areas*: integrated infrastructure networks will require careful management in congested urban areas to reduce system-wide life cycle costs and to plan future capacity requirements and right-of-way acquisition to accommodate growth. Subterranean infrastructure asset management and planning will have important cost and security implications.

*e) Other transport infrastructures*: road/rail connectivity to airports/ports is critical to growing international movements – and there is a danger in many cities that local planning and amenity issues could override national/international interests in improving these connections. Better methods to balance local/regional with national/international interests and concerns are critical.

## The "Road Ahead"

There is no doubt that a combined (and concerted) policy involving land use/ spatial distribution/urban density; road-pricing; ICT-inspired improvements in road capacity utilisation; and infrastructure improvements in rail/public modes would have a noticeable and (relatively) significant *marginal* impact on the need for road infrastructure requirements. There is no certainty however that the political constellation(s) will support such a *holistic* policy package – not least as many decisions must be jointly enacted by different levels of governments and require considerable time to build policy consensus.

There are no easy solutions to transport infrastructure funding here. The challenge of funding (and governance) involves a complex mix of public finance, political, economic, environment, and land use issues – with overlapping time frames, decision cycles and deadlines. There is a need to marry public and private sources of funding – to enhance both, and to seek an appropriate role for and balance between the two.

Land transport infrastructure (road and rail) has a very long economic life: 30+ years. Capital planning and budgeting require a lengthy (10- to 20-year) cycle that clearly conflicts with 7-year business cycles, 3- to 5-year political cycles and 2- to 3-year budgetary cycles. Any time there is a short-term crisis, long-term plans for land transport infrastructure funding will be sacrificed for short-term expediency to meet other, more pressing political pressures and policy agenda goals.

The public *willingness to pay* for increased land transport mobility will determine whether these land transport infrastructure requirements are met. Road users (direct and "indirect") are a lot like taxpayers in general, so the finance issue should be what is most publicly palatable to fund required transport infrastructure. There will have to be greater willingness to apply user-pay and commercialisation principles for land transport (especially roads) by public finance/transport authorities and their political masters.

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## 1. Key drivers of future surface transport demand

One meta-study of global/regional transport forecasts found that the main factors considered in modelling transport growth are economic growth; population growth; energy prices; and government/environmental policies.[1] Few studies extend this basic forecast set of variables to include income levels; household size; demographic composition; population density; technology (*e.g.* related to energy efficiency); and regulation.[2]

This study develops quantitative forecasts of road and rail infrastructure "new construction" (*i.e.* net additions to capital stock and maintenance construction to preserve the existing value of capital stock) for the period 2005-30. This is based on an economic framework and methodology similar to that implemented by Fay-Yepes (for the World Bank).[3] The data for the key drivers of GDP growth and population growth come from the World Bank and the United Nations respectively, as highlighted in the OECD background paper prepared for this study.[4]

### *Infrastructure capital stock and new construction model*

The Fay-Yepes methodology for forecasting infrastructure capital stock and new construction is based on the economic relationship (*i.e.* elasticity) between infrastructure (road and rail) capital stock and GDP per capita (GDPpc). Growth in GDPpc results in a forecast for road (or rail) capital stock, which can then be transformed into a forecast for new construction (a complete discussion of the model and data sources is in Annex 4.A2).

Generally, the model was developed in detail for road infrastructure, and then adapted for rail infrastructure. The discussion below will focus only on the road model.

A key parameter is the elasticity of paved road capital stock with respect to GDPpc (or GDP). Table 4.1 shows some of the relevant elasticity relationship found in the literature. Under various assumptions, the different capital stock-to-income elasticities can be compared, giving rise to a range of estimates for the elasticity of paved road capital stock with respect to GDPpc of 0.12-0.90, with a mean estimate of 0.20.[5]

Much has been written about how high-income countries have seen a long-term downward trend of transportation investment (and capital stock to GDP) rates:

- EU: the transportation investment rate fell during the 1980s to 0.9% of GDP.[6]
- OECD: public investment rates fell during 1967-90 to about 4% of GDP:[7]
  - transportation investment may be about 1.4% of GDP.
- US: the value of road capital stock fell during 1950-90 to about 13% of GDP.[8]

Table 4.1. **Relevant elasticity relationships**

| Study | Variable | Elasticity |
|---|---|---|
| **1. Capital stock elasticity** | | |
| Fay-Yepes | Paved road capital stock | GDPpc<br>0.23 high income<br>0.14 low/medium income |
| Canning | Paved road capital stock | GDPpc<br>0.90 panel data |
| Munnell | Public capital stock | GDP per employee<br>0.30 cross-section |
| Munnell | Public capital stock | GDP<br>0.14 time-series |
| Munnell | Road capital stock | GDP<br>0.04 time-series |
| **2. Road kilometre elasticity** | | |
| Canning | Paved road km | GDPpc<br>1.20 cross-section |
| Ingram-Liu | Paved road km | GDPpc<br>1.00 cross-section |
| **3. Road use** | | |
| Hanly *et al*. | Vehicle stock | Income<br>0.73 cross-section |
| Johansson-Schipper | Vehicle stock | Income<br>1.00 |
| Ingram-Liu | Vehicle stock per road (km) | GDPpc<br>0.30 cross-section |
| Hanly *et al*. | Vehicle distance driven (vkm) | Income<br>0.81 cross-section |
| Johansson-Schipper | Vehicle distance driven (vkm) | Income<br>1.20 |
| EU | Vehicle distance driven (passenger-km, tonne-km) | GDP<br>1.00 time-series |

The third of these results implies a time-series elasticity of paved road capital stock with respect to GDP of 0.84[9] – which is consistent with an elasticity with respect to GDP per capita of about 0.27.[10]

It is more difficult to evaluate "investment rate" trends, as (on average) more than half of infrastructure spending is on maintenance of the existing capital stock value and the remainder is on new additions to the capital stock. Whether or not "new construction" actually augments the capital stock depends on whether the replacement investment rate is "optimal" (*i.e.* sufficient to maintain the capital stock value). If this is not the case, then some proportion of the "new construction" is required to replace (*i.e.* rebuild) existing road infrastructure that is being "worn out" (*i.e.* fully depreciated in accounting terms; requiring rebuilding in engineering terms). There has been

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a noted "underinvestment" in transport infrastructure during the 1980-90s in many industrialised countries (due to public spending restraint), so that actual levels of maintenance spending may well be sub-optimal. In the absence of modelling the entire capital depreciation process, and given the relationship of actual maintenance investment to "optimal" investment, it is difficult to reliably relate "new construction" rates (or dollar values) with net additions to the road capital stock.

For example (based on assumptions), the OECD trend would imply a time-series elasticity of paved road capital stock with respect to GDP of 1.95, if 100% of new construction is an augment to road capital stock.[11] In order for the elasticity of paved road capital stock with respect to GDP to be in the order of 0.84 (as above for the US trend), we would have to assume that only 30% of "new construction" is a net addition to the road capital stock. This latter result would indicate that while 50% of road spending might be on new construction, only a third of this (15% of overall road spending) might be a net addition to the capital stock. Another way of stating this is that for every USD 1.00 net addition to road capital stock, it may be necessary to spend USD 6.67 (*i.e.* 1/6) on roads, or about USD 3.33 on "new construction".[12]

The Fay-Yepes approach did estimate components for both net-additions to the capital stock and for maintenance, with only a slightly higher amount of maintenance (60%) relative to net additions (40%). Our analysis suggests that the maintenance component may need to be much greater (by a factor of 2) in the future.

In the Fay-Yepes approach, a two-tiered set of capital stock responses is used:

- For high-income countries (HIC), based on panel data (pooled cross-section and time-series), the elasticity of paved road asset value (*i.e.* infrastructure stock) with respect to GDP per capita is 0.23.
- For low-/medium-income countries (L/MIC) the elasticity is 0.14.[13]

Using these relationships, a world paved road new construction estimate of about USD 260 billion/year was made by Fay-Yepes (see Table 4.2) for the period to 2010 – which involved annual infrastructure growth of about 1.6% for high-income countries, 2.3% for medium-income countries, and 1.4% for low-income countries.[14] The new construction figure was comprised of USD 116 billion of net addition to the capital stock, and road replacement capital investment of about USD 143 billion/year.

As will be seen in Section 2, our comparable (perhaps more involved) methodology is fully consistent in terms of order-of-magnitude with these forecasts.[15] Besides a careful review of and modifications to the underlying methodology, this model has the advantage of extending the analysis beyond 2010 to 2030.

Table 4.2. **(Fay-Yepes) Road infrastructure estimates to 2010**

| | Total infrastructure stock 2000 | Total infrastructure stock 2010 | Growth-infrastructure 2000-10 | Annual investment-infrastructure | Annual % growth |
|---|---|---|---|---|---|
| **Regions of the world** | | | | | |
| 1. High-income/industrialised | 3 951 | 4 587 | 636 | 63.6 | 1.61 |
| 2. Medium-income | 1 177 | 1 450 | 273 | 27.3 | 2.32 |
| 3. Low-income/developing | 1 001 | 1 143 | 142 | 14.2 | 1.42 |
| 4. Developing (low/medium income) | 2 178 | 2 593 | 415 | 41.5 | 1.91 |
| East Asia and Pacific | 681 | 811 | 130 | 13.0 | |
| Europe and Central Asia | 371 | 442 | 71 | 7.1 | |
| Latin America and Caribbean | 552 | 657 | 105 | 10.5 | |
| Middle East and North Africa | 186 | 221 | 35 | 3.5 | |
| South Asia | 231 | 275 | 44 | 4.4 | |
| Sub-Sahara Africa | 158 | 188 | 30 | 3.0 | |
| ***World*** | ***6 129*** | ***7 180*** | ***1 051*** | ***259.4*** | ***1.71*** |

The result that developing countries will need to invest in roads at an accelerated rate is consistent with empirical evidence that finds general underinvestment in road infrastructure among less-developed regions. Over the period 1950-92 (using panel data), there were strong relationships running bi-directionally between infrastructure (including paved roads) and GDP per capita – implying long-run causality in both directions. The effect was not homogeneous across all countries: the productivity-enhancing benefits of additional infrastructure spending is determined by whether the infrastructure stock is in "wealth-maximising" equilibrium (*i.e.* is optimal). Where infrastructure stocks are below optimal, additional spending on infrastructure is productivity-enhancing, whereas additional spending on infrastructure is destructive of wealth when infrastructure stocks are above optimal (*i.e.* overbuilt).[16] While the net (global) impact of additional infrastructure spending was about zero (*i.e.* infrastructure stock about optimal), there are clear signs of underinvestment in infrastructure in most developing countries, especially for paved roads.[17]

## *Key drivers for road capital stock and new construction*

By far the biggest driver for future road transport use and infrastructure comes from growth in GDP and population – and rising GDP per capita. This is modelled directly in terms of the impact of GDP growth on road capital stock, but it is also observed and used for measures of road use and vehicle ownership.

The elasticity of vehicle stock with respect to income (*e.g.* GDP) is 0.75-1.25, with a mean estimate of 1.0; meanwhile the elasticity of annual per vehicle driving distance with respect to income is 0.05 to 1.60, with a mean estimate of 0.2. Taken together, the figures imply an elasticity of distance travelled with respect to income is 0.65-1.25, with a median estimate of 1.2.[18]

World GDP growth of 2.7-3.1% per annum is forecast by the World Bank over 2000-15. Here, the later period growth trend is continued for the entire period to 2030. World population growth of 0.8-1.2% per annum is forecast by the United Nations over 2000-30. The resulting World GDPpc growth rate is 1.8-2.1% per annum. A summary of the key economic growth assumptions are found in Annex 4.A3.

### *Key drivers for vehicle ownership and road use*

Prior to estimating a model for paved road capital stock and new construction, a forecast for vehicle ownership and road use was made (see Annexes 4.A4 and 4.A5 for forecast details). The key variable is road vehicle ownership, which is clearly linked to GDPpc growth on a log-log basis. A key "threshold" of accelerating vehicle ownership occurs around USD 5 000 per capita GDP. This non-linearity is modeled through a simple step function, with a transition occurring between USD 5 000-10 000 GDPpc.

Table 4.3 shows rapid growth in road vehicle ownership per 100 population (vhp) for Big 5[19] countries (principally China) – with a slow upward trend for the world as a whole.

Table 4.3. **Vehicle ownership forecast**

| Region | 2000<br>vehicles per 100 pop. | 2010<br>vehicles per 100 pop. | 2020<br>vehicles per 100 pop. | 2030<br>vehicles per 100 pop. |
|---|---|---|---|---|
| **Industrialised** | | | | |
| OECD | 52.0 | 55.8 | 63.3 | 72.4 |
| Non-OECD | 19.0 | 24.1 | 32.6 | 43.6 |
| **Developing** | | | | |
| Big 5 | 2.9 | 4.2 | 8.8 | 14.6 |
| Others | 5.0 | 5.4 | 6.7 | 8.3 |
| **World** | **13.1** | **14.4** | **18.0** | **22.5** |

Rapid motorisation and growth in vehicle ownership in China (and other Big 5) is of great concern for energy and transport planners. Independent forecasts see China vehicle ownership grow from 0.6-1.3 per 100 population (vhp) in 2000 to 3.9-11.9 in 2020. There is comparable growth in India from 0.4 to 1.2, and in Indonesia from 1.5 to 6.7.[20]

Table 4.4 shows rapid growth in annual distance driven, which is the product of total vehicles and an estimate of annual distance per vehicle (adv) – which trends downward over time for most industrialised countries, with

Table 4.4. **Road use forecast**

| Region | 2000 distance driven (Bvkm) | 2010 distance driven (Bvkm) | 2020 distance driven (Bvkm) | 2030 distance driven (Bvkm) |
|---|---|---|---|---|
| **Industrialised** | | | | |
| OECD | 10 323 | 11 558 | 13 734 | 16 484 |
| Non-OECD | 917 | 1 205 | 1 697 | 2 285 |
| **Developing** | | | | |
| Big 5 | 2 322 | 3 808 | 8 226 | 13 677 |
| Others | 2 517 | 2 966 | 3 974 | 5 186 |
| **World** | **16 079** | **19 537** | **27 631** | **37 632** |

"convergence" around 15 000 km/vehicle/year in the long term as vehicle ownership rates increase.[21] Rising GDPpc and vehicle ownership rates in industrialised countries are expected to increase total annual distance driven by 67% over the 30-year time period, but will result in a 290% increase among Big 5 and developing countries. This puts some stark figures to the challenge for energy sources and global sustainability.

### *Key drivers for rail capital stock and new construction*

While there are economic drivers for future rail use and infrastructure – principally for rail freight growth – the nurturing and encouragement of rail passenger use is primarily determined by government policy and specific investment programmes (*e.g.* TEN-T priority projects). This has very consciously been a "sustainability" policy agenda to shift some road use to rail and at least dampen somewhat the future growth in local passenger road use (*e.g.* commuters) and intercity air use (*e.g.* business, pleasure), although there is a growing awareness that forms of inter-metropolitan interaction are blurring the distinction between daily commuter and intercity travel.

## 2. Future requirements for surface transport infrastructure

Based on the models developed in the preceding section, future "new construction" infrastructure requirements for both roads and railways have been developed. It should be noted that the road-model is the more robust and carefully analysed model, while the rail-model should be treated as highly indicative.

### *Road infrastructure requirements*

Table 4.5 summarises the key estimates for road new construction for the years 2000, 2010, 2020 and 2030. More complete results can be found in Annex 4.A6.


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Table 4.5. **Road new construction requirements**

| Region | 2000 USD-B and (% GDP) | 2010 USD-B and (% GDP) | 2020 USD-B and (% GDP) | 2030 USD-B and (% GDP) |
|---|---|---|---|---|
| **Industrialised** | | | | |
| OECD | 98.7 (0.31%) | 159.4 (0.44%) | 167.1 (0.37%) | 178.1 (0.32%) |
| Non-OECD | 1.7 (0.05%) | 8.6 (0.22%) | 9.5 (0.19%) | 13.1 (0.21%) |
| **Developing** | | | | |
| Big 5 | 9.3 (0.07%) | 36.6 (0.19%) | 46.6 (0.17%) | 64.7 (0.16%) |
| Others | 5.0 (0.08%) | 15.7 (0.20%) | 22.0 (0.21%) | 36.4 (0.26%) |
| **World** | **114.8** (0.21%) | **220.3** (0.33%) | **245.2** (0.28%) | **292.3** (0.25%) |

These road new construction estimates of between USD 200-300 billion/year over 2005-30 are considerably higher than the 2000 base year levels, and comparable in order of magnitude to the previous forecast of Fay-Yepes (USD 260 billion/year for 2005-10). As already noted, the latter was based on a roughly equal ratio of net additions to the capital stock and replacement capital requirements. This forecast models a much higher requirement for replacement (*i.e.* maintenance) construction spending.

Replacement construction to maintain the existing capital stock value is particularly important in countries/regions that have large base year stocks of road capital (especially former communist states of Europe and Central Asia[22]). With respect to the former, the significant additional new construction requirements (over base year spending) are relatively evenly split across regions between OECD-industrialised, Big 5 and developing countries, with relatively little coming from non-OECD-industrialised countries. The future consequence of rebuilding depreciated existing assets is not reflected in the base year new construction figure – indicating that most governments are still engaged in practices ingrained during the 1980-90s when capital expenditures and maintenance budgets were generally squeezed very hard to deal with public debt/deficit challenges.

To put these forecasts of road new construction into perspective, it is worth remembering that the postwar construction of industrialised country road networks largely occurred over a 40-year period from 1945-85, so that the 30-year time period considered here may witness comparable road network construction in some of the rapidly growing and more prosperous Big 5 and developing countries of the world (*e.g.* China).

There is some risk that the future new construction requirements in Table 4.5 may be too high. Certainly there has been no conscious effort to force "sustainability" and climate change (*e.g.* greenhouse gas, GHG) targets onto the road sector, although there has been some attempt to place upper-bound limits on road capital asset-to-GDP ratios. As GDPpc grows across the "threshold" value of USD 5 000 per capita in many countries (*e.g.* China) there will be enormous social/consumer pressures for vehicle ownership and road infrastructure responses, which will be extremely difficult to dampen.

A substantial amount of the initial "upward drift" in the new construction (as a percentage of GDP) results from the model assumption that countries will seek to "converge" toward industrialised ratios of road capital stock-to-GDP – even as these decline among industrialised countries. It may well be that the fiscal challenge to finance this rate of new construction spending will lose out to other public/private spending and investment options. However, it should be noted that the increased Big 5, developing and non-OECD-industrialised new construction rates (percentage of GDP) remain significantly below OECD-industrialised rates – and that the road capital stock-to-GDP ratios also remain well below OECD-industrialised ratios. In fact, it must be remembered that the actual road capital stock-to-GDP ratios *fall* for all regions – which reminds us that there are inevitable future costs just to maintain existing large stocks of road capital.

If there is one aspect of the road model that may overstate new construction forecasts of requirements, it may be how the replacement capital requirement is estimated. The model has effectively assumed that 1/30th of the 10-year lagged road capital stock must be replaced per year. Better minor maintenance practices and management could make that an overstatement.

The road capital stock value consistent with these results grows from USD 5 370 billion in 2000 to USD 7 130 billion in 2030, a cumulative growth of only 33% over 30 years. The ratio of road capital stock-to-GDP falls from 9.7% to 6.1% over this period, so the overall elasticity and observed downward trend of this ratio is certainly captured (for industrialised countries). The corollary of these results is that the productivity of road infrastructure continues to rise.

## Ex post *elasticities for road capital stock*

This model began with the *ex ante* Fay-Yepes-type elasticities (with respect to GDPpc) of 0.25 (high-income countries) and 0.15 (low-income countries). However, two significant modifications have been made: *a)* to adjust for rising road new construction costs (per route-km); and *b)* with convergence over time towards high-income ratios of road capital stock to GDP.

The application of these adjustments resulted in *ex post* elasticities (with respect to GDP) for the entire 2000-30 period of: 0.20 (high-income countries);

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0.64 (Big 5 countries); and 0.76 (developing countries).[23] Not surprisingly, the adjustment factors had little impact for high-income countries, but significantly higher PRCS impact for Big 5 and developing countries.

There is no logical inconsistency between the *ex ante* and *ex post* elasticities. The *ex ante* Fay-Yepes elasticities represent what was actually experienced over the past three decades, during which there is every reason to believe that there was substantial underinvestment in road capital stock among developing countries. This is the thesis (supported by empirical evidence) from Canning-Pedroni. The convergence adjustment for developing countries is here *normative*, and represents what needs to occur in order to provide one of the necessary preconditions for rapid economic growth for the Big 5 countries, and for some of the faster-growing developing countries.

### *Risk factors for road new construction*

The results above are based on economic drivers and assumptions, and do not reflect "wish lists" based on engineering needs. However, as already noted, there are many factors that might prevent (if desirable) or render unnecessary (*i.e.* make undesirable) the forecast levels of new construction on roads.

These include:

- Conscious government policy to constrain/reduce public expenditures – particularly focused on road new construction (but separate from "sustainability" concerns which are addressed next):
  - Up to (perhaps) 20% of the road new construction (*i.e.* USD 40-60 billion/ year) could be diverted with some attendant (but possible bearable) consequences in terms of deteriorating overall road infrastructure quality (*i.e.* as experienced during the 1980-90s) and higher road congestion (especially in urban areas).[24]
- Conscious government policy to shift transport infrastructure spending and use away from road-vehicles toward rail (including high-speed rail):
  - Up to (perhaps) 10% of the road new construction (*i.e.* USD 20-30 billion/year) could be so diverted with some attendant (but possible bearable) consequences in terms of deteriorating overall road infrastructure quality.[25]
- Land use and environmental limitations on road infrastructure expansion, although most of the road new construction is driven from replacement requirements to maintain an existing stock of road capital.
- Improvements in road maintenance and management (especially efficiency enhancements through ICT/telematics, and extension of infrastructure life):
  - Up to (perhaps) 5% of the road new construction (*i.e.* USD 10-15 billion/ year) could be saved in the long run.

- Reduced safety and security requirements (which appear unlikely). Generally, with the exception of in-vehicle communications/navigation/tracking technologies, these concerns are unlikely to add substantially to road new construction requirement (especially as road safety is a major influence in road design).

Conversely, there are factors that might increase the requirement for new construction on roads. These include:

- Increased costs associated with road construction in urban and congested traffic areas (*e.g.* right-of-way acquisition, environmental mitigation, integration with other infrastructures). Generally, it is believed these are factored into the model.
- Greater than anticipated geographic (spatial) dispersion of economic activity, especially in Big 5 and developing countries. It is difficult to imagine greater spatial dispersion occurring within existing industrialised countries, but such a phenomenon might occur within the larger of the Big 5 and developing countries (*e.g.* China, Russia, Brazil).
- Higher than anticipated growth in vehicle ownership and traffic use. Generally, a flexible upper-limit has been placed on vehicle ownership (vhp) and average distance driven per vehicle (adv). These might not hold, which would put further upward pressure on road construction.

### *Rail infrastructure requirements*

Table 4.6 summarises the key estimates for rail new construction for the years 2000, 2010, 2020 and 2030. More complete results can be found in Annex 4.A7. It must be noted that the rail model was based on the road model and involves weaker base year data and significant manual adjustment to reflect known rail spending plans for China and OECD/EU-Europe.

These rail new construction estimates of between US$50-60/year over 2005-30 are only somewhat higher than the 2000 base year levels, but are substantially greater than the previous forecasts of Fay-Yepes. The latter forecast annual investment requirements of about USD 17 billion/year over 2005-10, and did not appear to reflect the significant rail upgrading plans envisioned and commenced under the EU TEN-T programme.

The significant additional new construction requirements (over base year spending) are primarily driven by Big 5 countries (especially China, which has committed to a major rail-building programme, including high-speed rail).

There is some risk that the future rail new construction requirements in Table 4.6 may be too low. Certainly, there has been no conscious effort to force additional "sustainability" and GHG targets by shifting traffic from road to rail – except to the extent this is built into the EU TENT-T programme.


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Table 4.6. **Rail new construction requirements**

| Region | 2000 USD-B and (%GDP) | 2010 USD-B and (%GDP) | 2020 USD-B and (%GDP) | 2030 USD-B and (%GDP) |
|---|---|---|---|---|
| **Industrialised** | | | | |
| OECD | 26.9 (0.09%) | 31.1 (0.09%) | 34.3 (0.08%) | 33.4 (0.06%) |
| Non-OECD | 0.8 (0.02%) | 2.3 (0.06%) | 2.5 (0.05%) | 3.4 (0.06%) |
| **Developing** | | | | |
| Big 5 | 4.4 (0.03%) | 12.2 (0.06%) | 13.3 (0.05%) | 15.0 (0.04%) |
| Others | 1.9 (0.03%) | 3.5 (0.04%) | 3.4 (0.03%) | 6.3 (0.04%) |
| **World** | **34.0** (0.06%) | **49.0** (0.07%) | **53.5** (0.06%) | **58.1** (0.05%) |

The rail capital stock consistent with these results grows from USD 631 billion in 2000 to USD 1 342 billion in 2030, a cumulative growth of 110% over 30 years. The ratio of rail capital stock-to-GDP increases slightly from 1.1% to 1.2% over that period, which is only impressive in light of the downward trend of this ratio for road capital stock (for industrialised countries).

### *Risk factors for rail new construction*

The results above are based on very subjective assumptions, which might reflect "wish lists" to the extent that these are embedded in EU TEN-T programme and Chinese plans for railway expansion. Unlike road construction – for which there is a clear consumer-revealed preference through autonomous traffic growth and vehicle ownership – rail construction is largely driven around the world by government policy.[26]

There are many factors that might prevent (if desirable) or render unnecessary (*i.e.* make undesirable) the forecast levels of new construction on rails. These include:

- Conscious government policy to constrain/reduce public expenditures – (and clearly antagonistic to "sustainablility" concerns which are addressed next):
  - Up to (perhaps) 20% of the rail new construction (*i.e.* USD 10-12 billion/year) could be diverted with some attendant (but possible bearable) consequences in terms of deteriorating overall rail infrastructure quality and continued modal shift toward road vehicles (as perhaps did happen inadvertently over 1970s-90s in many countries).[27]
- Land use and environmental limitations of rail infrastructure expansion, especially the difficulty of right-of-way access around urban areas.

- Improvement in rail maintenance and management (especially efficiency enhancements and extension of infrastructure life):
  - Up to (perhaps) 5% of the rail new construction (*i.e.* USD 3 billion/year) could be saved in the long run.
- Lower-than-anticipated growth in HSR use and rail freight traffic.

Conversely, there are factors that might increase the requirement for new construction on rail infrastructure. These include:

- Conscious government policy to shift transport infrastructure spending and use away from road vehicles toward rail (including high-speed rail):
  - Up to (perhaps) 10% of the road new construction (*i.e.* USD 20-30 billion/year) could be diverted from road to rail infrastructure, with some attendant (but possible bearable) consequences in terms of deteriorating overall road infrastructure quality (*i.e.* as experienced during the 1980s-90s) and higher road congestion (especially in urban areas).
  - Up to (perhaps) a further 15% of rail construction (USD 5-10 billion/year) could be added if non-EU countries embraced high-speed rail (*e.g.* United States, Canada) during this period.
- Increased safety and security requirements. Additional tunnel, access, security and monitoring systems could add up to 5% of additional rail new construction requirement.
- Increased costs associated with rail construction in urban and congested-traffic areas. It is believed these are factored into the model.
- Higher-than-anticipated growth in HSR use and rail freight traffic. One optimistic forecast for passenger modal shift for Western Europe (over 2000-50) predicted a decline in daily travel distance by car (from 35 km to 20 km) and an increase in daily travel distance by air/HSR (from 5 km to 70 km).[28]

### *Benefits of transport infrastructure*

There are several implicit assumptions related to anticipated benefits that are embedded in the approach and model of transport infrastructure requirements over the period to 2030[29]:

1. The bulk of existing transport infrastructure (in place in 2000) is cost-beneficial to maintain, and to marginally improve in terms of quality (*i.e.* rising replacement cost per route-km).
2. Most of the transport infrastructure investments over the past 20 years have been cost-beneficial, and it is very that likely some amount of cost-beneficial new construction has been constrained by public finance availability (*i.e.* trends in infrastructure spending to GDP, and capital stocks to GDP have been close to "optimal", if somewhat sub-optimal).

3. While political factors may have resulted in some uneconomic projects proceeding, and some reorientation of priorities, the aggregate transport infrastructure profiles reflect economic principles (*i.e.* are cost-beneficial).
4. Generally, there has been chronic under-funding of transport (and other) infrastructure in most Big 5/developing countries, reflecting public finance availability (despite IFI and donor country lending/grants).[30]

These assumptions allow us to invoke the following lemma: that transport infrastructure requirements estimated on the basis of historical relationships between road capital stock and GDP will also be cost-beneficial – so that the benefits of road infrastructure spending will exceed their costs.

Therefore, the model forecasts of road transport infrastructure requirements (in terms of cost) – namely USD 220-290 billion per year over 2000-30 – also represent a conservative estimate of the expected benefits of such transport infrastructure investments.[31]

A similar (but different) assumption may be made about rail transport infrastructure requirements (USD 49-58 billion per year), as much of this is driven by government policy to effect a deliberate modal shift (at the *margin*) from road to rail, to: *a)* achieve environmental/sustainability objectives and benefits; and *b)* to manage rising congestion and postpone future road infrastructure needs. Therefore, the benefits from rail transport infrastructure requirements will involve a lesser degree of economic benefit (in terms of productivity/GDP growth), and a greater degree of environmental/social benefit (likely *not* reflected in productivity/GDP growth, as currently measured).

### *Productivity/utilisation of transport infrastructure*

A combined (freight and passenger) forecast over 2000-30 of 2.9% annual growth in vehicle transport use (vkm) has been produced – largely driven by rising vehicle ownership (as GDPpc rises), growth in underlying GDP, and assumptions about annual per-vehicle use.[32]

Over the 2000-30 period, the model (vkm growth relative to GDP growth) indicates that road-use intensity (to output flow) will rise about 0.4% per annum.[33] A similar measure (vkm growth relative to road asset value) indicates that road-use intensity (to capital stock) will rise about 1.3% per annum.[34]

Other studies have looked at intensities of freight (tkm/GDP) and passenger (pkm/GDP) transport and found:

- For the United States (over 1960-98) a falling ratio of road ton-miles per $GDP.[35]
- For other industrialised countries (over 1970-98) mixed results with: a falling ratio of road tkm per $GDP for Japan and the United Kingdom; a relatively stable ratio for Germany; and an increasing ratio for France and Sweden.[36]

- For the United States and Japan (over 1970-2000) a falling ratio of passenger transport, while for the EU rising passenger ratios, and relatively stable ratios for freight.[37]

In the absence of reliable cross-country data on freight (linking tkm to vkm by country) and passengers (linking pkm to vkm by country), there is no attempt to forecast freight (tkm) or passenger (pkm) transport volumes. It could be speculated that vkm growth (over 2000-30) will be higher than underlying pkm growth, since passenger occupancy per vehicle generally falls as vehicle ownership rates rise with rising GDPpc, and since freight growth might outstrip population growth. It could also be speculated that vkm growth (over 2000-30) will be lower than underlying tkm growth, as the latter (but not the former) is influenced by rising vehicle ownership rates, as the size/weight of trucks increase with GDPpc growth (and better-quality roads), and as freight distances grow with industrialisation, specialisation and intensive trade/supply chain complexity.

## 3. Impact of key drivers on future surface transport demand

As discussed in the previous section, there are clear upside and downside risks (or pressures) that would influence the road and rail capital stock and new construction forecasts to 2030. This section addresses the following factors:

- Modal split and shift from road to rail.
- Freight *vs.* passenger transport growth.
- Information and communications technologies (ICT).
- Road capacity utilisation.
- Road pricing.
- Spatial distribution/population density.
- Security and climate change risk.
- Country-specific and regional variation.
- Demographic factors.
- Public capital constraint as a limit on surface transport.

### *Modal split – shift from road to rail*

A natural "policy experiment" was undertaken during the 1980-90s to put the macroeconomy and public finance on a more stable and growth-oriented basis. This policy experiment involved significant curtailing of public capital spending in many areas – particularly in transportation. The subsequent slowdown in productivity growth, rising work-time pressures and growing road congestion suggest that the "do-nothing" approach to effect modal shift from road to rail – by hoping that enough road congestion will force commuters/ passengers to rail – does not work in the absence of improvements to rail (and public transit) infrastructure.

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While *public* investment in road infrastructure was curtailed in most countries (the United States being a possible exception), *private* investment in road vehicle ownership and spending to sustain road use grew. This was despite growing awareness of environmental and sustainability concerns and problems from growing automobile dependence and use.

In order to fundamentally alter the future land transport growth (as forecast here), a very substantial amount of land transport infrastructure investment will need to be diverted from road to rail infrastructure – in urban areas (for commuters) and in intercity freight and high-speed rail capacity. What makes this difficult to envision and implement is that it is very likely over and above the significant existing commitments in China and the EU-OECD for railway (and HSR) upgrading – and would still require a very substantial increase in road construction spending. There is no "sustainability" fiscal dividend involved. Public finance and transport authorities will be spending more on road infrastructure than currently – but there is a margin of land transport infrastructure investment that can be shifted from road to rail infrastructure.

The biggest challenge will be in urban areas – where additional rail-track capacity is often very difficult and expensive and involves local amenity issues (*e.g.* NIMBY). The latter also exist for road infrastructure. Rapid urbanisation growth in the Big 5 and developing countries will require large investments in road and rail infrastructure. Roads are far more flexible (in terms of route choice) for most suburban commuters, and the urban rail network must be extensive (with relatively high urban housing/population density to support it).

The (general) political unpalatability of road pricing has meant that decentralised local-based funding and decision-making models have not been capable of rapidly expanding urban rail networks. There is a need for higher-level government planning and funding support, whether or not private partnership is invited.

Rising fuel prices have been shown to affect both road and rail use (this depends somewhat on the degree of rail electrification) – although passenger and freight traffic are remarkably fuel-price inelastic in the short term.

Over the 2000-30 period, there are no breakthrough technologies that will fundamentally affect land transport demand. High-speed rail (and Maglev) technology is around and tried. Improved vehicle technology (*e.g.* fuel efficiency, fuel technology) and vehicle design can offer substantial environmental benefits. Improved road/rail infrastructure management will be achieved through ICT (*e.g.* advanced vehicle guidance systems, network management systems), which will boost transport infrastructure productivity and have a marginal dampening effect on future infrastructure requirements.

Security and safety concerns may run counter to environmental concerns. Additional security/safety costs will probably need to be built into rail systems to counteract security/traveler concerns. It is unclear whether (relative to air) there is a clear security/safety benefit for high-speed rail.

Regional integration and international connectivity demand that rail systems be capable of meeting long-distance freight requirements (where rail still has a natural advantage), and that road systems are adequate for shorter-distance freight and passenger movements. History has shown that road transport linkages have been more important than rail, although our understanding (and decomposition) of traffic flows allows for a more sophisticated approach on a corridor basis.

Investments in other transport infrastructures (air, ports, inland water) are also required, although there is some trade-off potential between air and land transport for medium-distance high-speed rail (with sufficient population density and gravity-interaction between nodes), and between inland water and rail for medium-distance freight movements. There is also considerable complementarity between land transport infrastructure and access to ports/airports, which act as respective international (long-distance) transport hubs. Road and rail connectivity to airports/ports is critical to growing international movements – and there is a danger in many cities that local planning and amenity issues could override national/international interests in improving these connections. Better methods to balance local/regional with national/international interests and concerns are critical – and for this the EU TEN-T process has been exemplary.

### *Freight* vs. *passenger transport growth*

Historical analysis shows that there is a strong statistical correlation between the growth of GDP and transport, both passenger and freight – even though there may be significant variation in the relationship between freight tkm/GDP across various individual countries.[38]

Several factors are influencing (industrialised country) traffic growth:[39]

1. An indeterminate change in freight transport elasticity (relative to GDP) over the past ten years due to three intersecting factors:
   - Reduced trade barriers (*i.e.* globalisation) and increased international transport – which are increasing freight intensity.
   - Reduced material (especially weight) requirements in goods – which are decreasing freight intensity.
   - Decreased proportion of GDP comprised of goods *vs.* services – which is decreasing freight intensity.
2. A decline in passenger transport elasticity (relative to GDP) over the past ten years, due to population ageing.[40]

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### *Freight transport*

There is clear evidence from trade/traffic data that average km-distance traveled is growing – so that tonne-km and freight vehicle-km are growing faster than tonne-km – and that this is particularly concentrated in key corridors of national/continental networks.[41]

Freight traffic must deal with modal split (especially road-rail) which is typically distance-related and time-sensitive. Road is more cost-efficient for short haul (perhaps up to 500 km), while rail is more cost-efficient for long haul (over 500 km). Time-sensitive goods are more likely to be moved by road, which is more flexible in terms of routeing, door-to-door delivery, and journey scheduling.

While there is considerable interest in the issue of "decoupling" transport (and related energy-use) growth from economic growth, there are many factors operating to mediate between GDP growth and freight transport growth:

- The relative importance of services (versus goods), whose production and sales are less freight transport-intensive (although services may be more passenger transport-intensive).
- The relative reduction in material content/weight per dollar value of goods.
- The relative importance of international (and inter-regional) trade (versus local commerce), which involves longer distances and greater freight-transport intensity.
- The relative importance of production specialisation (and complexity of supply chain management), which may involve greater spatial distribution of supply chains, longer distances and greater freight-transport intensity.

The first and second factors may (in a long-term steady state) result in a lower freight-transport intensity (and global freight transport growth lower than global GDP growth). However, with continuing elimination of trade barriers (*e.g.* WTO agricultural trade barriers), the emergence of Big 5 countries as major economic powers (on both production and consumption sides of the economy), and rapid technological change among all "emerging" developing countries, the third and (especially) fourth factors are likely to dominate the evolution of global freight-transport intensity over the 2000-30 period.

The model here does not explicitly forecast freight transport use. It does forecast vehicle use (freight and passenger), based on vehicle ownership and annual distance driven, to grow at the same 2.9% annual rate as GDP – implying an elasticity of vehicle use of 1.0 over 2000-30.

A summary of relevant freight elasticities indicates that a range from 0.7 to 1.5 has been observed historically in industrialised countries, with a recent OECD average of 0.8. However, most of these estimated are for combined freight (mostly road and rail). Against this is the possibility that the Big 5/developing countries could experience higher freight elasticities, perhaps in the 1.5-1.8 range experienced by industrialised countries in the earlier 1950-70s period.

Table 4.7. **Relevant freight elasticity relationships**

| Study | Variable | Elasticity |
|---|---|---|
| **1. Road and rail freight** | | |
| Meersman-Van de Voorde (2003) selected EU countries (1990-2000) | GDP | Range from 0.7 (France) to 1.5 (Denmark), with most estimates in narrower range of 0.9-1.4 |
| Landwehr-Marie-Lilleu (2002) OECD (total freight, 1986-97) | GDP | OECD 0.8 – with range of 0.8 (North America, Japan) to 1.3 (Western Europe) |
| Tsamboulas (nd) EU accession countries (2000-20) | GDP | Forecast of 1.6 |
| WBCSD (2004) Global (2000-30) | GDP | Forecast of 0.83 |
| Landwehr-Marie-Lilleu (2002) Global (2000-30) | GDP | Forecast of 0.63 |
| **2. Road freight** | | |
| AU-BTCE (1990) Australian Corridors | GDP (real income) | Range from 1.0 to 2.0, with higher value generally for dense long-haul routes |
| Song *et al.* (1993) selected industrialised countries (1950-70s) | GDPpc | Range from 1.4 to 2.5, with most estimates in narrower range of 1.5-1.8 |

## *Passenger transport*

Because local transport accounts for more than 80% of traffic in most countries, urban sprawl has a major impact on trends in personal/commuter passenger traffic; an increasing proportion is based on multi-purpose travel chains. Another major segment of passenger transport is "leisure/tourism" which takes place over medium to long distances and which is heavily influenced by GDPpc lifestyle factors such as increased leisure time; more frequent but often shorter trips; and diversification of leisure (*e.g.* visiting friends and relatives, cultural, educational).

Passenger traffic (*e.g.* traveler mobility) is influenced strongly by:[42]

- *Car ownership* – where rates have increased much more quickly than income levels and population age structure suggested (*e.g.* multiple car ownership).
- *Population ageing* – where this is slowing the increase in short-haul (local) transport.
- *Family structures* – where increasing single-parent families are reducing vehicle occupancy levels and group travel sizes.

Factors operating to mediate between GDP growth and passenger transport growth are:

- Rising vehicle ownership rates, especially with national GDPpc rising through the USD 5 000 "inflection point" (where vehicle ownership accelerates).
- Urban spatial distribution (density *vs.* sprawl), which support (or limit) the efficiency/viability of rapid public transit as an alternative to private vehicle use.

- Social factors (*e.g.* ageing population, family structure, migration patterns), which support (or limit) the private vehicle trip use (relative to time-choice, and local *vs.* non-local accessibility to family/activities/etc.).

The first factor is dominant in some Big 5/developing countries and will result in higher passenger-transport intensity (*i.e.* faster than national GDP growth), and be supported by the third factor (*e.g.* younger population, greater international/regional migration). For many industrialised countries (where vehicle ownership rates are flatter), the third factor (especially ageing of the population) may reduce passenger-transport intensity – although this will be highly related to the second (urban spatial distribution) factor – and the availability of public transport alternatives.

A summary of relevant passenger elasticities indicates that a range from 0.6 to 1.4 has been observed historically in industrialised countries, with a recent OECD average of 1.0. Against this is the possibility that Big 5/developing countries could experience higher passenger elasticities, perhaps in the 1.5-2.0 range experienced by industrialised countries in the earlier 1950-70s period.

Table 4.8. **Relevant passenger elasticity relationships**

| Study | Variable | Elasticity |
|---|---|---|
| **1. Road and Rail Passenger** | | |
| Landwehr-Marie-Lilleu (2002) OECD (1986-97) | GDP | OECD 1.0 – with range of 0.6 (North America) to 1.4 (Western Europe) |
| Tsamboulas (nd) EU accession countries (2000-20) | GDP | Forecast of 1.0 |
| WBCSD (2004) Global (2000-30) | GDP | Forecast of 0.53 |
| Landwehr-Marie-Lilleu (2002) Global (2000-30) | GDP | Forecast of 0.43 |
| **2. Road passenger** | | |
| Song *et al.* (1993) selected industrialised countries (1950-70s) | GDPpc | Range from 1.1 to 2.3, with most estimates in narrower range of 1.5-2.0 |
| Johansson-Schipper (1997) | GDP | Range from 0.7 to 1.3, with best-guess of 1.2 |

### *Information and Communications Technologies (ICT)*

A study of the impact of ICT on transport found that advanced vehicle technologies have the future potential for automated driving, which (along with improved road network management technologies) holds promise for increasing transport safety and capacity.[43] There is no doubt that, over the 2000-30 period, continued vehicle and energy-efficiency technology improvements will shape transport energy use and driver behaviour. However, it is not expected that technology will fundamentally affect the growth of passenger transport (relative to the impacts of rising income, GDPpc and vehicle ownership).

There are likely to be ICT-inspired improvements in road capacity utilisation – but these will operate at the margin of incremental demand, and will not substantially impact the overall road infrastructure requirements (rising from GDP, population, vehicle ownership growth; increased urbanisation; urban development – except as mediated by urban density/spatial distribution/road pricing policies around land use).

Generally, the broad literature on the interaction of ICT and transport suggests that these are complementary (rather than substitutes); the potential for ICT to change travel patterns, times of day, choice of destinations, etc. may distribute anticipated demand increases over time and (potentially) reduce peak-hour urban-road congestion.

### *Road capacity utilisation*

Typically (over time) we often see new road infrastructure installed in anticipation of future traffic growth. Significant periods of new road construction (*e.g.* North America over 1950s-70s) result in periods of low capacity utilisation, followed by steady increases in traffic relative to additional road capacity, resulting in rising capacity utilisation. This has been observed at national/regional levels as well as in urban/suburban areas. New construction infrastructure spending is usually motivated by one (or more) of the following factors:

- National security/sovereignty and/or regional integration (*e.g.* accessibility to remote border regions).
- Land development (*e.g.* new towns, suburbs, industrial areas, resource access, major facilities).
- Road congestion due to traffic growth (passenger, freight) beyond the existing road capacity.
- Safety improvements (*e.g.* passing lanes, shoulders, realignment, barriers, signage, level-crossing elimination).
- Environmental improvements (*e.g.* flood control, damage mitigation, noise reduction).

The important point to make is that traffic-related road congestion is one of five drivers for new construction, although it is typically a more important factor in determining benefits (from time-savings) than are safety/environmental benefits. Typically, the first two (non-congestion) factors have played the largest roles in major national transport infrastructure development.[44]

ICT-inspired improvements in road capacity utilisation are anticipated (*e.g.* network management, accident response, driver information, automated driving advances). However, such improvements will have only modest impacts on road infrastructure requirements because:

- In industrialised countries, most road infrastructure requirements are generated from replacement (maintenance of depreciation) needs.
- In many Big 5/developing countries, most road infrastructure requirements are generated from urban/land development and regional integration needs.

### *Road pricing*

The policy of road pricing has two aspects: *a)* as a sustainable source of infrastructure pricing and funding (as part of an overall transport infrastructure management/governance approach); and *b)* as a means to influence mode-choice and properly incorporate externalities into consumer travel decisions. There is no doubt that own-price and cross-price elasticities for freight and passenger transport are positive; and that increased (relative) costs of road use will result in a marginal shift from road to rail (for freight/passenger) and other public modes (for passengers).

The behavioural impact strength of such elasticities remains an empirical question, relative to: the overall income elasticity of road freight/passenger transport; the availability/capacity/service levels of the alternatives; and other factors (such as urban density/spatial distribution, vehicle ownership rates).

There is no doubt that a combined (and concerted) policy involving land-use/spatial distribution/urban density; road-pricing; ICT-inspired improvements in road capacity utilisation; and infrastructure improvements in rail/public modes would have a noticeable and (relatively) significant marginal impact on the need for road infrastructure requirements. There is, however, no certainty that the political constellation(s) will support such a holistic policy package – not least as many decisions must be jointly enacted by different levels of governments and require considerable time to build policy consensus.

### *Spatial distribution/population density*

Perhaps the most difficult policy to gain political approval involves (more compact) spatial distribution and (higher) population density – especially within/between major urban areas. Besides the difficulties of achieving public consensus and political co-ordination, there is the path dependency of urban forms. If infrastructure is best viewed as a system, there is no more complex system than the urban form – comprised of overlapped multi-generational, life-cycle decisions related to migration, urban location, housing choice, employment opportunities, transport choices and decisions, lifestyle choices, etc. The current spatial urban forms of cities as diverse as London, Paris, New York, Houston, Sydney, Tokyo, Hong Kong, etc. have developed over centuries, and while they can be shaped/

influenced (both at the margin and intensively) over several decades, such change is often costly, disruptive, chaotic, politically divisive, etc. and often limited to specific sub-areas of the overall urban form.[45]

There is no doubt that more spatially compact and densely populated nations and urban areas support very high volumes of freight and passenger transport within limited, congested urban road networks and extensive public transport systems. Generally, such urban congestion and density mean that transport infrastructure is highly integrated with other urban infrastructure systems (*e.g.* telecommunication, water/sewer, energy); maintenance and added capacity are very expensive. Thus, while measures of road capacity utilisation are much higher, the dollar cost of road infrastructure (per km) is much higher as well.

A particularly important issue from the perspective of integration infrastructure system planning relates to right-of-way acquisition and protection (from encroachment). Within urban areas (especially) there is a need for long-term planning to ensure that urban spatial growth will be adequately and efficiently managed by infrastructure investments, along dedicated infrastructure rights-of-way, and in an integrated manner.

Encouragement of greater density within existing urban areas would (likely) have a moderate impact on reducing road infrastructure requirements, although such an achievement would require a holistic policy package, including significant urban transport infrastructure investment.

### *Security and climate change risk*

Overall, measures to manage security risks, increase transport security and address climate change would have a marginal to moderate impact on increasing road infrastructure requirements. Some of this would likely be embedded in various ICT improvements in road capacity utilisation, and new construction requirements to address safety/environmental issues.

Perhaps the biggest risks over 2000-30 are the impacts on road and rail networks (national/regional/urban) that could arise from: *a)* natural disasters (*e.g.* earthquakes); and *b)* rising water levels (and flood risk) from global warming. While the former is a risk factor built into transport infrastructure management in many countries/regions of the world, the latter is a more recent issue to arise, and has not been systematically assessed in terms of risk management (exposure/impact). Many large urban centres are at sea level, making rising ocean levels a long-term threat. Climatic disturbances (*e.g.* affecting rainfall levels/ patterns) may also result in unanticipated flooding of certain links in national/ regional transport networks, and unanticipated changes in freeze-thaw cycles affecting infrastructure integrity and maintenance costs.

### *Country-specific and regional variation*

The base-year regional/development groupings used in the model for this study reflect cross-country aggregation of national-level data. There are considerable regional/national variations in road/rail networks, vehicle ownership, infrastructure capital value and GDP growth that are built in.[46]

The model relies principally on road/rail transport infrastructure capital stock elasticities with respect to GDPpc (with adjustments for: *a)* increasing road quality over time in route-km costs; and *b)* convergence in transport infrastructure spending [as a percentage of GDP] towards industrialised levels), and associated road-use elasticities with respect to GDP (and GDPpc for vehicle ownership). While the model growth parameters are insensitive to other factors (*e.g.* spatial distribution, population densities, demography), such factors are reflected in the base-year disaggregated national data, on which the growth is based. Therefore, the model does incorporate base-year variations in such models, even if it does not allow for growth rate variations (other than GDP growth and GDPpc levels). The underlying growth rate assumptions (*e.g.* World Bank for GDP growth, UN for population growth) would themselves have recognised, and taken into account the impact of some of these factors.

Excluded are any sub-national variations that would affect the distribution of population, economic activity and transport activity within countries. This is the inevitable price of a global focus and aggregation ability, as well as availability of suitable data.

### *Demographic factors*

There is no doubt that demographic factors (principally the population ageing in most industrialised countries) will impact future transportation infrastructure requirements. While the model does not explicitly deal with such factors, they are embedded in the base-year data and in the underlying growth rate assumptions (from World Bank and UN sources).

It is assumed that the bulk of demographic changes are captured in the model through GDP and population growth (which are considerably lower in industrialised countries with low population growth and population ageing), and through the "convergence" adjustment relating transport infrastructure stock (as a percentage of GDP) towards industrialised levels.

Population ageing has been observed in many industrialised countries since the 1980s, so the trends observed (and incorporated in this model) – *a)* slowing growth in vehicle ownership rates; *b)* little/no growth in annual vkm per vehicle; and *c)* declining rate of road capital stock (as a percentage of GDP) – are felt to adequately capture the future impact of demographic change on road/rail transport use and infrastructure requirements.

### *Public capital constraint – limit for surface transport*

A major factor impacting whether transport infrastructure requirements are met is the public willingness to pay for increased land transport mobility – either through general taxation (as mediated by public finance authorities), specific taxation (where this exists) or user-charges (including in support of private participation, *i.e.* PPP). Road users (direct and "indirect") are a lot like taxpayers in general – so the finance issue should be, what is most publicly palatable to fund required transport infrastructure? Unfortunately (for land transport authorities), the concept that there should be a "price" for public capital access and that such revenue should remain within the land transport sector appears to be rejected (or overridden) by other public finance "principals" and spending priorities.[47]

The ageing of the world population (at least in industrialised regions) will put pressure on health care systems and lead to many competing policy pressures for limited public funds – especially with the apparent "cap" on taxpayer willingness to pay. The increasing conversion of taxes into user fees has (partially) provided a relief valve, but there has been limited public willingness to pay for (previously) "free" road access – and public finance authorities have not generally been willing to cede what they consider as "taxation power" to land transport authorities.

Land transport infrastructure (road and rail) has a very long economic life (30+ years) – and capital planning and budgeting requires a lengthy (10- to 20-year) cycle that clearly conflicts with 7-year business cycles, 3- to 5-year political cycles and 2- to 3-year budgetary cycles. Any time there is a short-term crisis, long-term plans for land transport infrastructure funding will be sacrificed for short-term expediency. As the experience of the 1970-90s showed in many countries, it is politically possible to starve public capital for a long time before the public starts to notice.

The ability to balance stakeholder and political accountabilities makes the governance of land transport infrastructure systems (and their funding) difficult – requiring sustained political commitment over a considerable period (*e.g.* Swiss referenda on land transport). There are real dangers in over-investment in road transport infrastructure, in poor land use policies, in low-density urban sprawl, etc. It is difficult to manage these effectively except at the relatively local level – but with policy guidance, planning and co-ordination involving senior levels of government (*e.g.* regional, national, supranational).

Long-term investments require political and economic stability. The world inflationary and macroeconomic environment is currently very stable, although there are concerns over the US "twin deficits" (current account and public finance) for which there is no clear equilibrating mechanism.

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## 4. Viability of current model for surface transport infrastructure

The EU TEN-T process has already been cited above as an exemplary model of transport infrastructure planning and inter-governmental consultation. However, the EU nation-state funding commitments and project timetables have not always been met, for all the reasons discussed in the previous sections.

The road and rail infrastructure (new construction) requirements forecast in Section 2 require substantial additional funds. The world annual road and rail new construction requirements could be in the order of USD 270-350 billion/year over 2010-30. This represents an enormous increase over the estimated current (2000) world spending of about USD 150 billion/year – even allowing for some efficiencies, deferred plans and possible overestimation.

### *Public sources of funds*

Economic growth is driving most of these land transport infrastructure requirements, so that – provided there is proportional growth in public revenues – there should be sufficient public funds to finance most of the requirements. However, as stated above, there is general taxpayer resistance and political unwillingness to have tax revenues grow at the same pace as economic growth, and there are competing and very pressing public policy issues competing for scarce taxpayer funds (*e.g.* education, health care, poverty reduction).

The public revenue capacity to finance needed land transport infrastructure will be most difficult to obtain in the developing and Big 5 countries – where there may also be issues of tax avoidance/evasion, black markets and political corruption, which all undermine tax revenue generation.

However, the naïve belief that if the public sector cannot finance transport infrastructure the private sector will has been proved wrong, as many of the same problems that confound public finance also impact on private finance (*e.g.* inflation risk, political instability risk, contract risk). In fact, it is precisely those countries with the most "potential" for public revenue generation that are also the most attractive and have the greatest potential for private financing of transport infrastructure.

Clearly, therefore, there is a need to marry public and private sources of funding – to enhance both, and to seek an appropriate role and balance between the two.

### *Private sources of funds*

Private investment in transport (and other) infrastructure over 1990-2001 was especially strong in Latin America – along with policies of deregulation, privatisation and other economic reforms – although the dollar volume of "greenfield" projects was greatest in the East Asia-Pacific region.[48]

These forecasts of road and rail transport infrastructure requirements suggest that the greatest opportunity for private financing of "greenfield" projects will be in China, and other Big 5 and developing countries.[49] At the same time, there will be considerable growth in the market for concessions and other "brownfield" packaging of existing (with some possible new) infrastructure in industrialised countries.

There are no easy solutions here. The challenge of transport infrastructure funding (and governance) involves a complex mix of public finance, political, economic, environment, and land use issues – with overlapping time frames, decision cycles, and deadlines.

### Governance of infrastructure funding

One study that investigated the governance of transportation infrastructure financing mechanisms looked at international evidence pertaining to:[50]

- *Financing of infrastructure*, including: stability of funding; multi-year plans; range and composition of funding; degree of "user-pay"; borrowing power (*e.g.* issuance of bonds); analytical basis for capital/programme expenditures; range and scope of activities supported, etc.
- *Governance of funding mechanism*, including: selection and role of board of directors; oversight by government departments; oversight by parliament/legislature; transparency of reporting/evaluation; amount of information available from official Web site; guidelines for ethics/conflict of interest, etc.

The study found four types of transportation infrastructure financing mechanisms:

1. *Traditional grant programmes:* the mainstay of the public sector, usually of medium-term duration (up to five years) and subject to annual political appropriations control and review.
2. *Special-purpose funds:* involving dedicated user-pay revenue sources that provide multi-year funding stability and usually imply an indefinite, ongoing commitment – although these involve traditional (bureaucratic/political) governance.
3. *Commercial funding agencies:* involving some form of privatisation/commercialisation of the infrastructure and/or the establishment of a quasi-public agency to provide infrastructure funding on a (generally) commercial, self-financing basis (*e.g.* through repayable loans, revolving fund, user-pay), or long-term public revenue commitment.
4. *Innovative financing mechanisms:* which, by definition, do not fit the above three moulds, and cannot be characterised in terms of features.

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Some of the desirable features of well-functioning infrastructure funding mechanisms are:

- Clear objectives, stable multi-year operation, strategic/capital plans and project selection processes.
- Major user-fee revenue contributions.
- Strong local stakeholder involvement, government oversight, public transparency and evaluation/audit oversight.
- Reasonable balance between policy objectives of: *a)* efficiency, fiscal sustainability and environmental sustainability; *b)* high degrees of public/ political support; and *c)* strong accountability for performance results.

Some of the innovative features of transportation infrastructure financing mechanisms are:

- Accrual public accounting for infrastructure cost, depreciation expense and financing costs (including appropriate return to the shareholder).
- Use of commercial borrowing as a funding source to encourage fiscal sustainability and demand fiduciary accountability for fund uses, better link accountability to performance, and better distribute benefits and costs.
- Use of user-pay pricing for heavy goods vehicles as a major aspect of revenue generation for infrastructure and "efficiency gain-sharing", and to effect modal shift (from road to rail) and/or full-cost user pricing to achieve efficiency and environmental sustainability objectives.
- Network-wide asset planning and project identification, and comprehensive asset management and performance measures.
- Involvement of local stakeholders in mechanism management, strategic planning and project selection, with high degrees of public transparency.
- Explicit criteria to promote inter-jurisdictional standardisation/interoperability of equipment-technologies-processes in infrastructure management.

## 5. Conclusions

Key drivers of land transport infrastructure (capital stock and new construction) are the relationships between, on the one hand, GDP and population growth (and GDP per capita growth), and on the other, measures of road use, vehicle ownership and paved-road capital stock – which are embodied in the elasticity between infrastructure (road and rail) capital stock and GDP per capita. Growth in GDP per capita results in higher vehicle ownership, more freight transport, more road traffic, and demand for road infrastructure. There is a relationship between paved-road capital stock (current and lagged) and new construction requirements. The latter include both new construction required for net additions to the value of the paved-road capital stock, and new construction to replace depreciation of existing (lagged) paved-road capital stock.

These key drivers primarily relate to road transport – and while they are also relevant for rail transport – rail use and infrastructure investment is much more controlled by public spending priorities and sustainability policy to affect modal shift from road to rail. Some of these priorities and policies are seen in existing government infrastructure plans (*e.g.* EU TEN-T projects, China's railway upgrading plan, Swiss transport policy).

Road transport infrastructure requirements (new construction) of between USD 220-290 billion/year over 2005-30 are estimated. These are comparable in order of magnitude to previous World Bank forecasts of Fay-Yepes. They are also a substantial increase above the estimate base-year (2000) level of investment of about USD 110 billion/year – so that their planning, financing and implementation will require considerable effort and challenge. A majority of these investment requirements do not result in net additions to the value of the paved-road capital stock, and are required to replace (*i.e.* maintain) the depreciating paved-road capital stock. These road infrastructure investment levels require a higher (than present) rate of spending (as a percentage of GDP) – although the ratio of the paved-road capital stock-to-GDP is consistently falling over time.

Rail transport infrastructure requirements (new construction) of between USD 49-58 billion/year over 2005-30 are estimated. These are greater than previous World Bank forecasts of Fay-Yepes. They are also a substantial increase above the estimate base-year (2000) level of investment of about USD 35 billion/year – so that their planning, financing and implementation will also require considerable effort and challenge. There is a more even split of these investment requirements between net additions to the value of the rail-track capital stock and replacements of depreciating rail-track capital stock. These rail infrastructure investment levels require a relatively constant (to present) rate of spending (as a % of GDP) – and the ratio of the rail-track capital stock-to-GDP is relatively stable over time.

There is considerable scope for deliberate government policy to influence modal use – and shift more road use to rail – through the diversion of up to 10% of road new construction (*i.e.* USD 20-30 billion/year) to rail (in addition to the levels of investment already forecast). These would have some attendant (but possible bearable) consequences in terms of deteriorating overall road infrastructure quality and rising road congestion.

Whether vehicle ownership and road traffic use will remain as "constrained" as forecast here – and whether rail traffic will grow as fast as "hoped" – remain to be seen. Despite what public finance authorities may hope for, there is no "sustainability" fiscal dividend involved, so that public finance and transport authorities will be spending more on road infrastructure in the future. The shift is in terms of moderating the future increase in road infrastructure spending, not in its elimination.

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The biggest challenge will be the public willingness-to-pay for increased land transport mobility – either through general taxation (as mediated by public finance authorities), specific taxation (where this exists) or user-charges (including in support of private participation, *i.e.* PPP). Serious discussion is required by public finance/transport authorities and the public over an appropriate "price" for access to public capital, and how such revenue remains within the land transport sector (and is allocated between road and rail).

Somewhat perversely, the countries with the most "potential" for public revenue generation will also be the most attractive and have the greatest potential for private financing of transport infrastructure. The greatest opportunity for private financing of "greenfield" projects will be in China and other Big 5 and developing countries, while there is considerable scope for growth in the market for concessions and other "brownfield" packaging of existing (with some possible new) infrastructure in industrialised countries.

There are no easy solutions to transport infrastructure funding here. The challenge of that funding (and governance) involves a complex mix of public finance, political, economic, environment, and land-use issues – with overlapping time frames, decision cycles and deadlines. Clearly therefore, there is a need to marry public and private sources of funding – to enhance both, and to seek an appropriate role and balance between the two.

The ability to balance stakeholder and political accountabilities makes the governance of land transport infrastructure systems (and their funding) difficult – requiring sustained political commitment over a considerable period. There are real dangers in over-investment in road transport infrastructure, in poor land-use policies, in low-density urban sprawl, etc. It is difficult to manage these effectively except at the relatively local level – but with policy guidance, planning and co-ordination involving senior levels of government.

While it is tempting to focus on the absolute US dollar volume of land transportation infrastructure requirements to 2030, it is equally (if not more) important to assess the entire governance and accountability regime of land transportation infrastructure funding – and in particular, issues of funding stability, "user-pay", political and government oversight, transparency of reporting/evaluation, and accountability for performance.

## *Notes*

1. OECD (2005), p. 10. That study noted that "methodological approaches are difficult to characterise and elucidate since only a few of the projections describe these in sufficient detail".
2. OECD (2005), p. 10. Studies with a broader range of forecast variables included UK-Royal Academy of Engineering (RAE) (2005) (*i.e.* ICT impact on transport efficiency); US-DoT (2000) (*i.e.* immigration impact); and DE-ifmo (2005)

(*i.e.* security impact; climate change/extreme weather impact). The rationale for a limited set of forecast variables include: parsimony (*i.e.* Occam's Razor); co-integration (*i.e.* joint determinism of variables); and impact uncertainty (*e.g.* absence of historical evidence).

3. Fay-Yepes (2003).
4. Andrieu (2005).
5. This mean estimate excludes the Canning value. The transformations are: GDP per capita elasticity is about 3.1 times the GDP elasticity (for GDP growth of 3% and population growth of 2%); and GDP per employee elasticity should be equal to the GDP per capita elasticity with a constant employment rate. The equation is $\xi_{pc} = \xi * [g (1 + g) ]/(p – g)$ ; where g is the GDP growth rate and p is the population growth rate.
6. Stevens-Michalski (1993), p. 1. This is for all forms of transportation.
7. Munnell (1993), Figure 3. Investment rates varied from 2-6% of GDP across OECD countries. If transport represents about 35% (as in the United States) of this investment, this would put the OECD range of road investment (*i.e.* new construction) at between 0.7 and 2.1% of GDP, with a mean of about 1.4%.
8. Munnell (1993), Table 2. Roughly 35% (1990) of US public (non-defence) public capital is road (highways and streets).
9. Evaluated for GDP growth rate of 3%.
10. Evaluated using the 3.1 ratio of GDP elasticity relative to GDP per capita elasticity.
11. Evaluated for GDP growth rate of 2.5%, base capital stock-to-GDP ratio of 12% (*i.e.* slightly lower than the US ratio), and assumptions that 35% of public investment is road transport, and 50% of that is for new construction.
12. Across a wide range of industrialised countries the ratio of 50% maintenance/50% new construction is often seen (more or less). The distinction between maintenance/ new construction is based on engineering criteria and the nature of the works involved, and not on life cycle asset management and asset value accounting.
13. Fay-Yepes (2003), Table 4. The equation also included an elasticity for population density (0.37 HIC; 0.46 L/MIC) and a coefficient on lagged asset value (0.28 HIC; 0.02 L/MIC).
14. Fay-Yepes (2003), Tables 5, 7. New construction costs were assumed to be about USD 0.41 M per km of two-lane paved road.
15. It should be noted that the author's starting paved road capital stock (2000) is USD 5 372 billion, compared to the Fay-Yepes value of USD 6 129 billion (*i.e.* 12% lower).
16. Canning-Pedroni (1999), p. 6.
17. Canning-Pedroni (1999), p. 31.
18. OECD (2004), Table 4, based on work by Johansson-Schipper (1997).
19. The Big 5 are China, India, Russia, Brazil and Indonesia.
20. Schipper and Marie-Lilliu (2001), Table 2; Zhongyuan *et al.* (2002), Table 3.5. The author's estimates for 2020 are: China-10.6; India-3.7 and Indonesia-3.8 – which are comparable for China, much lower for Indonesia, and much higher for India – although of a comparable magnitude.

21. One major anomaly in the author's "received" data (from IRF) is the China estimate of annual distance driven per vehicle of 50 000 km (reported consistently over three years). This is much higher than the industrialised and most developing countries. The author uses that figure – with a continuous decline to 35 000 km per vehicle by 2030. To the extent that this remains an over-estimation (*e.g.* relative to likely 15 000 km convergence target), the vehicle-use result for China is overstated by a substantial amount (perhaps 50%). This has no bearing, however, on our other forecasts for vehicle ownership or road construction requirements.

22. Some of these countries/regions may in fact decide that they have over-invested in certain aspects of their road system, and may choose to allow some to deteriorate in quality. This model generally assumes that all replacement capital needs are met.

23. These are arc-elasticities calculated over the 10-year period, and are not equivalent to "marginal" (behavioural) elasticities.

24. This does not imply that such new construction is not economically desirable, just that public finance policy and constraints may not allow the "wealth/output-maximising" level of road new construction to occur. Several of the political/finance factors that might be limiting include: degree of political stability, degree of public corruption, lack of public revenue raising capacity, tax avoidance and high inflation.

25. This would not generally be practical along with the public finance factor.

26. The exception is the North American privately owned freight railways.

27. This does not imply that such new construction is not economically desirable, just that public finance policy and constraints may not allow the "wealth/output-maximising" level of road new construction to occur.

28. Bleijenberg (2002), p. 4.

29. The discussion at the Second Steering Group Meeting (12 December 2005) of the OECD Futures Project: Global Infrastructure Needs identified the importance of relating "needs" and "costs" to "benefits" – so as to highlight that such requirements were economically justified (*i.e.* as cost-beneficial), rather than being engineering/political "wish lists".

30. This is a finding of Canning-Pedroni (1999).

31. Conservative, as benefits are expected to exceed costs (by an unknown amount), on the maintained assumption that these relationships reflect some amount of public capital constrained behaviour.

32. This compares to annual GDP growth of 2.9% (2004-30), implying an arc-elasticity of vkm-to-GDP of 1.00. Note that this was not assumed, but resulted from the combination of model assumptions.

33. From 290 M vkm per billion USD-GDP (2000) to 323 M vkm per billion USD-GDP (2030), a cumulative growth of 11%.

34. From 3 560 M vkm per billion USD-road asset value (2000) to 5 280 M vkm per billion USD-road asset value (2030), a cumulative growth of 48%.

35. Lakshmanan-Anderson (2002), p. 10.

36. Lakshmanan-Anderson (2002), p. 17.

37. OECD (2004), p. 58.

38. Hilferink (2003), p. 80, specifically dealing with the EU.

39. Reynaud (2004), p. 10.

40. Population ageing will not be operative over the 2000-30 period in most Big 5 and developing countries.

41. Tardieu (2005), Slide 37 which shows EU growth of 1.5% for tonnes, 2.7% for tonne-km, 3.4% for vehicle-km, and 4-5% for corridor-specific vehicle-km.

42. Reynaud (2004), p. 8.

43. UK-RAE (2005), p. 33.

44. Specific examples include: US national highways (1950s security); Canada railways (1880s land settlement, response to annexation threat); China-Tibet political linkage (ongoing); Brazil-Amazon resource development (1970s-ongoing).

45. See Ackroyd (2001), for detail on London development over the millennia.

46. For example, vehicle ownership, road/rail network lengths, and road/rail capital value per route-km are all estimated at the national level for countries for which data are available from the primary sources (*e.g.* CIA Factbook, IRF Road Statistics). These national data reflect base-year (roughly 2000) experience resulting from variation in spatial distribution, population density, topographical features, demographics, etc.

47. The concept that taxes represent a "price" for public services is well accepted in *theory* in the public economics literature. As more public services have become "commercialised" with explicit user charges, there has been growing acceptance of this in *practice*. However, generalised road access has not been one of the public services for which this principle has been applied in practice – leading to much unproductive debate about whether road users already "pay" their fair share for road access through general taxes which go to general government revenues and are not available specifically for road (and other land transport) infrastructure operation, maintenance, or investment.

48. Andrieu (2005), Figure 3, citing Beecher (2003).

49. *Globe and Mail* (2 November 2005) reports that China seeks private (likely minority) involvement in major rail infrastructure plans.

50. TC (2005).

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# ANNEX 4.A1

## *Acronyms*

| Term/acronym | Definition |
|---|---|
| Ξ | Elasticity |
| %Δ | Percentage Change |
| adv | Annual Distance Driven per Vehicle |
| CIA | Central Intelligence Agency (US) |
| DoT/MoT | Department (Ministry) of Transport |
| ECMT | European Conference of Ministers of Transport |
| EU | European Union |
| GDP | Gross Domestic Product |
| GDPpc | Gross Domestic Product per capita |
| GHG | Green-House Gases |
| HIC | High-Income Countries |
| HSR | High-Speed Rail |
| IRF | International Road Federation |
| km | Kilometres |
| L/MIC | Low- and Medium-Income Countries |
| NC | New Construction |
| NIMBY | Not In My Back Yard |
| OECD | Organisation for Economic Co-operation and Development |
| PPP | Public-Private Partnerships |
| PRCS | Paved-Road Capital Stock |
| RTCS | Rail-Track Capital Stock |
| TEN-T | Trans-European Network for Transport |
| UK | United Kingdom |
| UN | United Nations |
| US | United States |
| vhp | Vehicles per Hundred (100) Population |
| vkm | Vehicle Kilometres (Distance Driven) |
| WB | World Bank |

# ANNEX 4.A2

# *Data Sources and Model*

## A. Socioeconomic drivers

***Population:*** Base-level population (2004) is from US-CIA (2005); while growth rates for 2000-30 are from the United Nations (2004) – medium scenario.

***Output:*** Base-level GDP and GDPpc (2004) are from US-CIA (2005); while growth rates for 2000-30 are from the World Bank (2005), with the latter adjusted so that:

- GDP growth rates for the period 2000-06 were used for 2004-10; and for the period 2006-15 were used for 2010-20 and 2020-30;
- some adjustments were made to specific (disaggregated) regions to respect regional-summary growth rates; and
- GDPpc growth rates for the period 2000-30 were calculated to be consistent with UN-population forecasts.

## B. Road variables

***Vehicles:*** Base-level road vehicle stock (roughly 2000) is from IRF (2003); with "missing values" estimated from vehicles per 100 population (vhp), which were themselves estimated on the basis of GDPpc. Regional results for vhp were then calculated.

The estimates of vhp for individual countries exploited a simplified step-function of the (basically logarithmic) relationship between vhp and GDPpc, so that:

vhp = fcn (GDPpc) such that:

- (for GDPpc < USD 5 000): = 1.00 * (GDPpc/1 000)
- (for USD 5 000 < GDPpc < USD 10 000): = [3 – (10 000/GDPpc) * (GDPpc/1 000)
- (for USD 10 000 < GDPpc): = 2.00 * (GDPpc/1 000)

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The growth rate of vhp for 2000-30 exploited the above relationship and the forecast growth in GDPpc (derived from WB and UN forecasts for GDP and population), with specific adjustment factors for each region to allow for "convergence" to the expected vhp by 2030 for developing countries, while dampening (*i.e.* capping) the higher vhp result for industrialised countries.

***Distance driven (vkm):*** Base-level distance driven (roughly 2000) is from IRF (2003) – based on vehicle stock and annual distance per vehicle (adv); with "missing values" assumed based on known "matched countries" or otherwise "guestimated". Regional results for distance driven (vkm) and for annual distance per vehicle (adv) were then calculated.

The future levels of adv for 2010, 2020 and 2030 were based on assumption of "convergence" towards an adv = 15 000 long-term point, such that among industrialised countries/regions there would be cross-country convergence around the current mean values of adv, and there would be long-term declines in adv for (almost all) Big 5 and developing countries as the rate of vehicle ownership grew and high-adv buses were (relatively) displaced by lower-adv private vehicles.

***Paved highways (pkm):*** Base-level paved highways (roughly 2000) are from US-CIA (2005) and IRF (2003).

***Paved road capital stock (USD billion):*** Base-level paved-road capital stock (PRCS) is estimated based on paved highways (pkm) and an estimate of asset value per pkm. The latter was based on two empirical observations. The first, (Heggie-Vickers, 1998) is that the mean asset value per pkm for 13 developing countries was about USD 0.2M. The second, (Munnell, 1993) was that the road asset value for the United States was about 13% of GDP in 1990 – which with these base-level values implies a mean asset value per pkm of about USD 0.4 M. This suggests that the "quality" of paved-roads also increases as GDPpc rises. In order to allow for some transition between these levels, it is assumed in calculating base-level PRCS that:

Asset value per pkm = fcn (GDPpc) such that:

- (for GDPpc < USD 5 000): = 0.2
- (for USD 5 000 < GDPpc < USD 10 000): = 0.2 + [((GDPpc – 5 000)/1000) * 0.04]
- (for USD 10 000 < GDPpc): = 0.4

The ratio of PRCS to GDP is of considerable importance, as evidence (Munnell, 1993, etc.) indicates that this is falling over time for high-income industrialised countries, but likely needs to rise for developing countries (Canning-Padroni, 1999) as the evidence indicates a positive elasticity of PRCS with respect to GDPpc. Effectively, three relationships are exploited in the estimation of future levels of PRCS.

- Step 1: a rising level of PCRS as GDPpc rises;

- Step 2: a rising quality of asset value per pkm as GDPpc rises (as above); and
- Step 3: long-term convergence of the ratio of PRCS-GDP.

Initially, empirical estimates were made using the first two steps. This generally resulted in the downward drift over time of the ratio of PRCS-GDP in industrialised countries, but it did not produce any noticeably upward change in the ratio of PRCS-GDP for Big 5 and developing countries. The reason for this (*ex post* rationalisation) was that the elasticity effect (Step 1) assumes implicitly that the base level of PRCS is "optimal" to some degree – whereas in most cases it is significantly sub-optimal (see Canning-Pedroni, 1999; and casual empiricism). Therefore, there is a need to some closing of the "infrastructure gap" by raising the ratio of PRCS-GDP over time for Big 5 and developing countries.

### *Step 1: Application of elasticity of PRCS wrt GDP*

It is assumed, based on a review of estimates and the 2-tier approach of Fay-Yepes (2003) that the elasticity of PRCS-GDP ($\xi_{pr}$) is:

- $\xi_{pr}$ = fcn (GDPpc) such that:
- (for GDPpc < USD 5 000): = 0.15
- (for USD 5 000 < GDPpc < USD 10 000): = 0.15 + [((GDPpc – 5 000)/1000) * 0.02]
- (for USD 10 000 < GDPpc): = 0.25

The forecast PRCS is then the straightforward application of the %Δ-PCRS = $\xi_{pr}$ * %Δ-GDPpc; the latter coming from the author's GDP and population growth forecasts – where:

$$PRCS_t^1 = PRCS_{t-10} * [(1 + \%\Delta\text{-}PCRS)^{10}] \text{ (for t = 2010, 2020, 2030)}$$

### *Step 2: Application of rising asset value per pkm as GDPpc rise:*

The Step-1 estimate of $PRCS_t^1$ is transformed into units of pkm based on the initial asset value per pkm, and then this amount is multiplied by the current asset value per pkm (which may have risen as GDPpc rises) – which was estimated using the step-function shown above for PRCS.

$$PRCS_t^2 = PRCS_t^1 * \text{Factor (depending on step-function)}$$

It should be noted that this has a relatively minor effect for countries whose GDPpc rises from USD 5 000 to USD 10 000 only.

### *Step 3: Application of convergence in ratio of PRCS-GDP:*

Among the industrialised countries/regions for which this model is applied, the average ratio of PRCS-GDP is 0.127 (in 2000) – with a range from a low of 0.039 (Germany) to a high of 0.276 (Non-OECD Europe and Central Asia). As already noted, there is a general downward trend for most industrialised countries over time (*e.g.* US, EU-12 as a whole), and there is evidence and widespread consensus that the current level of paved-road infrastructure in most Big 5 and developing countries is too low (*i.e.* sub-optimal). Among combined Big 5 and developing countries/regions, the average ratio of PRCS-GDP is 0.046 (in 2000) – with a range from a low of 0.012 (China) to a high of 0.138 (developing Europe and Central Asia).[1]

It is therefore assumed that a lower-bound ratio of PRCS-GDP is about 0.050 (*i.e.* although the possible long-run "convergence point" may be somewhat higher). Countries whose ratio of PRCS-GDP fall below 0.050 will face pressure (or desire to) close the gap between their current level of PRCS-GDP and this "lower-bound". However, the elimination of this "infrastructure gap" is allowed to extend over the entire 30-year period (or more for most countries/regions). The "makeup factors" are determined as:

- *For the period 2000-10:* for countries/regions with an infrastructure gap, 33% of the PRCS-gap which existed in 2000 (*i.e.* lagged 10 years) is expected to be closed over the 10-year period;
- *For the period 2010-20:* for countries/regions with an infrastructure gap, 66% of the PRCS-gap which existed in 2010 (*i.e.* lagged 10 years) is expected to be closed over the 10-year period; and
- *For the period 2020-30:* for countries/regions with an infrastructure gap, 100% of the PRCS-gap which existed in 2020 (*i.e.* lagged 10 years) is expected to be closed over the 10-year period.

Because it is assumed that the 10-year lagged "infrastructure gap" is closed, none of the Big 5 or industrialised countries/regions with an "infrastructure gap" in 2000 actually reaches the 0.050 ratio of PRCS-GDP by 2030. In fact, even with the "convergence" approach (in Step 3), the average ratio of PRCS-GDP among combined Big 5 and developing countries/regions *actually falls* from 0.046 (in 2000) to 0.038 (in 2030). Clearly, a very-long term convergence process has been allowed for.

$PRCS_t^3 = PRCS_t^2$ + "Makeup Factor" (as described above)

The impact of "make-up" factors is most significant for China, Brazil, and developing East Asia-Pacific.

***New construction (USD billion):*** Base-level annual new construction (NC) figures (assumed to be for paved roads) are from IRF (2003), with "missing values" assumed based on known "matched countries" or otherwise "guestimated".[2]

The future levels of new construction for 2010, 2020 and 2030 were determined from the forecast values of PCRS, based on two components:

- the annualised value from growth in paved road asset value (D-PCRS) over the decade; and
- replacement capital needed to maintain the existing value of PCRS from 10 years ago.

### *Component 1: Growth in PRCS*

Annual new construction is simply 1/10th the paved road asset value growth over the decade.

$NC_t^1 = (PRCS_t - PRCS_{t-10})/10$ (for t = 2010, 2020, 2030)

### *Component 2: Replacement capital due to PRCS depreciation*

In capital costing and accounting for roads, the economic useful life of the road asset is assumed to be about 30 years. This means that each year (in a steady state of no asset growth), about 1/30th of the asset value must be replaced per year. As there is new construction but no desire to construct a complicated depreciation/capital asset model, the 1/30th depreciation factor is applied to the PRCS lagged 10 years.

$NC_t^2 = (PRCS_{t-10})/30$ (for t = 2010, 2020, 2030)

The total annual value of new construction is the sum of these two components:

$NC_t = NC_t^1 + NC_t^2$

$= [(PRCS_t - PRCS_{t-10})/10] + [(PRCS_{t-10})/30]$

$= [(PRCS_t - (2/3 * PRCS_{t-10}))/10]$ (for t = 2010, 2020, 2030)

It should be noted that the replacement capital is much the greater of the two, accounting for 81% of NC in 2010, falling to 72% in 2030 (*i.e.* is 3-4 times as large as the new construction which results in net addition to the PRCS asset value).

## C. Rail variables

***Rail-track (rkm):*** Base-level railway lengths (roughly 2000) are from US-CIA (2005).

***Rail-track Capital Stock (USD billion):*** Base-level rail-track capital stock (RTCS) is estimated based on rail-track length (rkm) and an estimate of asset value per rkm. The latter was based on many discrete railway sources, and varied from a high of USD 3.33M/rkm in Japan, to an assumed low of USD 0.25M/rkm in developing countries – with an observed low of USD 0.31M/rkm for Canada.[3]

The same "model" was applied to rail as in road – with various parameters (principally dealing with asset value per rkm) both to allow for rising quality of infrastructure over time, and (more importantly) to boost the rail new construction levels to be consistent with published spending intentions for China railways,[4] and for OECD (TEN-T High-Speed Rail).[5]

***Rail-track new construction (USD billion):*** Base-level rail-track new construction (RTNC) is estimated based on a proportion of RTCS. These

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proportions were estimated from the same discrete railway sources, and varied from a high of 8.9% in Italy to an assumed low of 2.5% in developing countries – with an observed low of 4.0% in Japan.[6]

The future levels of new construction for 2010, 2020 and 2030 were determined from the forecast values of RTRS, based on the same two components and methodology as for roads.

## Notes

1. The high (relative) ratios of PRCS-GDP for the industrialised and developing regions of Europe and Central Asia are believed (hypothesised) to be a result of communist central planning practises – which were not shared by China and North Korea.

2. The estimation process for base-year new construction is somewhat involved, and has no impact on forecast estimates. It is used solely as a point of comparison. In general terms, the expected level of maintenance spending on paved roads was estimated using a known (or assumed) value per pkm (ranging from USD 2 000-10 000, depending on GDPpc) times the number of pkm. The percentage of road spending devoted to new construction (% new) was then either known or assumed (depending on growth rate and GDPpc, with a range from 20% to 60%).

3. Data were primarily for individual railways in particular countries, using Annual Report values for rkm and net asset value for track-buildings-facilities (excluding rolling stock). Railways included: Queensland Rail (Australia), BNSF (United States), JR-East (Japan), Network Rail (United Kingdom), FS/RFI (Italy), CN/CP (Canada), DB (Germany).

4. *Globe and Mail* (2 November 2005), “Chinese railways plan to sell shares” (AP story), which reports planned spending of USD 61 billion over 2006-10, which in this model has been treated as plans for USD 10 billion/year over a 20-year period (2000-20), with roughly half in each of the two 10-year periods.

5. EU (2003), Table 3, p. 390 shows TEN-T priority projects involving dedicated rail-projects worth EUR 130 billion over 20 years, which has been taken to mean about USD 7.7 billion/year. However, there are rail infrastructure investments outside of TEN-T projects, and data for Italy (FS/RFI) suggest that HSR may be only 50% of spending – so it is effectively assumed that European OECD spending will be about USD 15 billion/year over the entire 2000-30 period.

6. The low investment rate for Japan should be seen more as a reflection of the very high rkm values for Japan TRCS than as a sign of underinvestment.

# ANNEX 4.A3

## *Economic Growth Assumptions*

| Global economic outlook<br>Growth assumptions | A | B | Based on World Bank C | Based on World Bank D | Based on World Bank E | F | G |
|---|---|---|---|---|---|---|---|
| | 2004 GDP value (USD-B) | 2004 GDP per capita (USD) | 2000-10 GDP growth (%) | 2010-20 GDP growth (%) | 2020-30 GDP growth (%) | 2030 GDP per capita (USD) | 2030 GDP value (USD-B) |
| **REGIONS OF THE WORLD** | | | | | | | |
| **1. High–income/industrialised** | ***35 023*** | ***24 964*** | ***2.28*** | ***2.14*** | ***2.16*** | ***38 631*** | ***61 325*** |
| ***a)* G-7** | ***24 008*** | ***33 457*** | ***2.21*** | ***2.09*** | ***2.12*** | ***52 489*** | ***41 551*** |
| United States | 11 750 | 40 100 | 2.69 | 2.55 | 2.55 | 62 988 | 22 799 |
| Japan | 3 745 | 29 400 | 1.75 | 1.61 | 1.61 | 46 751 | 5 720 |
| Germany | 2 362 | 28 700 | 1.48 | 1.34 | 1.34 | 41 378 | 3 369 |
| United Kingdom | 1 782 | 29 600 | 1.75 | 1.61 | 1.61 | 41 379 | 2 722 |
| France | 1 737 | 28 700 | 1.81 | 1.67 | 1.67 | 41 959 | 2 697 |
| Italy | 1 609 | 27 700 | 1.52 | 1.38 | 1.38 | 41 658 | 2 317 |
| Canada | 1 023 | 31 500 | 2.57 | 2.43 | 2.43 | 47 932 | 1 927 |
| ***b)* Other–OECD** | ***7 648*** | ***16 998*** | ***2.40*** | ***2.20*** | ***2.20*** | ***26 736*** | ***13 629*** |
| Europe and Central Asia | 5 009 | 18 484 | 2.30 | 2.10 | 2.10 | 29 514 | 8 703 |
| East Asia and Pacific | 1 633 | 22 451 | 2.65 | 2.20 | 2.28 | 37 044 | 2 975 |
| North America (Mexico) | 1 006 | 9 600 | 2.50 | 2.70 | 2.50 | 14 488 | 1 950 |
| **OECD Industrialised** | ***31 656*** | ***27 114*** | ***2.26*** | ***2.12*** | ***2.14*** | ***42 401*** | ***55 180*** |
| ***c)* Non–OECD** | ***3 367*** | ***14 302*** | ***2.49*** | ***2.29*** | ***2.29*** | ***21 480*** | ***6 145*** |
| East Asia and Pacific | 1 186 | 19 905 | 2.69 | 2.49 | 2.29 | 28 917 | 2 232 |
| Europe and Central Asia | 236 | 12 222 | 1.79 | 1.09 | 1.49 | 20 118 | 339 |
| Latin America and Caribbean | 851 | 12 223 | 2.69 | 2.19 | 2.29 | 18 640 | 1 555 |
| Middle East and North Africa | 574 | 14 406 | 2.69 | 3.49 | 2.89 | 19 138 | 1 262 |
| South Asia | 16 | 12 764 | 2.29 | 2.09 | 2.29 | 19 760 | 28 |
| Sub-Sahara Africa | 507 | 11 015 | 1.79 | 0.99 | 1.69 | 17 822 | 736 |

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| Global economic outlook Growth assumptions | A | B | Based on World Bank C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| | 2004 GDP value (USD-B) | 2004 GDP per capita (USD) | 2000-10 GDP growth (%) | 2010-20 GDP growth (%) | 2020-30 GDP growth (%) | 2030 GDP per capita (USD) | 2030 GDP value (USD-B) |
| **2. Big 5** | ***14 308*** | ***4 837*** | ***4.64*** | ***3.99*** | ***4.07*** | ***10 677*** | ***41 393*** |
| China | 7 262 | 5 600 | 5.44 | 4.83 | 4.83 | 15 879 | 25 631 |
| India | 3 319 | 3 100 | 4.17 | 3.26 | 3.26 | 5 117 | 8 058 |
| Brazil | 1 492 | 8 100 | 3.78 | 2.92 | 2.92 | 11 850 | 3 315 |
| Russia | 1 408 | 9 800 | 3.44 | 2.41 | 2.41 | 22 251 | 2 777 |
| Indonesia | 827 | 3 500 | 2.74 | 2.56 | 2.56 | 5 205 | 1 613 |
| **3. Developing** | ***6 252*** | ***3 001*** | ***3.69*** | ***2.95*** | ***2.99*** | ***4 990*** | ***13 957*** |
| East Asia and Pacific | 1 283 | 4 445 | 4.49 | 3.74 | 3.74 | 10 314 | 3 478 |
| Europe and Central Asia | 971 | 4 005 | 5.07 | 3.17 | 3.17 | 8 299 | 2 439 |
| Latin America and Caribbean | 954 | 4 878 | 2.45 | 1.97 | 1.97 | 6 757 | 1 629 |
| Middle East and North Africa | 1 642 | 3 521 | 3.05 | 2.47 | 2.47 | 4 895 | 3 201 |
| South Asia | 780 | 2 104 | 4.12 | 3.43 | 3.43 | 3 977 | 1 951 |
| Sub-Sahara Africa | 622 | 1 197 | 2.73 | 2.75 | 2.75 | 1 606 | 1 259 |
| **WORLD** | ***55 583*** | ***8 625*** | ***3.07*** | ***2.78*** | ***2.89*** | ***14 093*** | ***116 675*** |

# ANNEX 4.A4

## *Road Vehicles and Ownership Forecast*

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| Global road outlook<br>Vehicles and ownership | 2000 Total road vehicles (M) | 2000 Annual distance (Bkm) | 2000 Road vehicles per 100 population | 2010 Road vehicles per 100 population | 2020 Road vehicles per 100 population | 2030 Road vehicles per 100 population | 2030 Annual distance (Bkm) | 2030 Total road vehicles (M) |
| **REGIONS OF THE WORLD** | | | | | | | | |
| **1. High–income/industrialised** | ***652.1*** | ***11 240*** | ***46.5*** | ***50.4*** | ***58.0*** | ***67.3*** | ***18 769*** | ***1 067.6*** |
| ***a)* G-7** | ***466.0*** | ***7 673*** | ***64.9*** | ***69.0*** | ***76.4*** | ***84.6*** | ***11 455*** | ***670.0*** |
| United States | 230.4 | 4 391 | 77.9 | 82.5 | 90.8 | 100.2 | 6 875 | 362.5 |
| Japan | 74.0 | 786 | 58.1 | 61.4 | 67.7 | 74.7 | 1 089 | 91.4 |
| Germany | 46.8 | 648 | 56.8 | 60.2 | 66.3 | 73.1 | 899 | 59.6 |
| United Kingdom | 26.0 | 518 | 42.9 | 45.3 | 49.9 | 55.0 | 705 | 36.2 |
| France | 35.4 | 527 | 58.3 | 61.7 | 68.0 | 75.0 | 753 | 48.2 |
| Italy | 35.2 | 525 | 60.7 | 64.3 | 70.8 | 78.2 | 691 | 43.5 |
| Canada | 18.3 | 278 | 55.7 | 58.7 | 64.5 | 71.2 | 443 | 28.6 |
| ***b)* Other–OECD** | ***141.4*** | ***2 649*** | ***31.4*** | ***35.1*** | ***43.0*** | ***53.5*** | ***5 029*** | ***272.8*** |
| Europe and Central Asia | 94.3 | 1 705 | 34.8 | 38.7 | 47.5 | 59.1 | 3 154 | 174.2 |
| East Asia and Pacific | 28.7 | 587 | 39.5 | 45.7 | 57.5 | 74.0 | 1 136 | 59.5 |
| North America (Mexico) | 18.5 | 358 | 17.4 | 19.4 | 23.7 | 29.0 | 739 | 39.1 |
| **OECD Industrialised** | ***607.5*** | ***10 323*** | ***52.0*** | ***55.8*** | ***63.3*** | ***72.4*** | ***16 484*** | ***942.8*** |
| ***c)* Non–OECD** | ***44.7*** | ***917*** | ***19.0*** | ***24.1*** | ***32.6*** | ***43.6*** | ***2 285*** | ***124.8*** |
| East Asia and Pacific | 13.5 | 235 | 22.6 | 30.1 | 42.5 | 57.8 | 730 | 44.6 |
| Europe and Central Asia | 7.1 | 82 | 36.9 | 40.7 | 45.2 | 51.7 | 116 | 8.7 |
| Latin America and Caribbean | 10.9 | 270 | 15.7 | 20.1 | 27.3 | 37.2 | 608 | 31.0 |
| Middle East and North Africa | 6.3 | 144 | 15.9 | 20.8 | 29.2 | 38.3 | 490 | 25.2 |
| South Asia | 0.1 | 2 | 11.5 | 15.6 | 24.6 | 39.5 | 8 | 0.6 |
| Sub-Sahara Africa | 6.7 | 184 | 14.5 | 18.9 | 25.2 | 35.6 | 332 | 14.7 |

| Global road outlook Vehicles and ownership | A 2000 Total road vehicles (M) | B 2000 Annual distance (Bkm) | C 2000 Road vehicles per 100 population | D 2010 Road vehicles per 100 population | E 2020 Road vehicles per 100 population | F 2030 Road vehicles per 100 population | G 2030 Annual distance (Bkm) | H 2030 Total road vehicles (M) |
|---|---|---|---|---|---|---|---|---|
| **2. Big 5** | ***85.1*** | ***2 322*** | ***2.9*** | ***4.2*** | ***8.8*** | ***14.6*** | ***13 677*** | ***566.8*** |
| China | 16.5 | 880 | 1.3 | 2.9 | 10.6 | 21.3 | 8 595 | 343.7 |
| India | 9.3 | 322 | 0.9 | 1.7 | 3.7 | 5.3 | 2 470 | 84.0 |
| Brazil | 29.0 | 518 | 15.6 | 17.6 | 20.9 | 23.7 | 1 213 | 66.2 |
| Russia | 25.4 | 489 | 17.7 | 21.6 | 30.8 | 44.4 | 1 012 | 55.5 |
| Indonesia | 5.0 | 112 | 2.1 | 2.6 | 3.8 | 5.6 | 388 | 17.4 |
| **3. Developing** | ***103.2*** | ***2 517*** | ***5.0*** | ***5.4*** | ***6.7*** | ***8.3*** | ***5 186*** | ***231.9*** |
| East Asia and Pacific | 22.4 | 499 | 7.8 | 9.2 | 14.2 | 20.6 | 1 343 | 69.6 |
| Europe and Central Asia | 22.7 | 622 | 9.4 | 10.0 | 11.1 | 14.9 | 1 090 | 43.8 |
| Latin America and Caribbean | 11.3 | 271 | 5.8 | 6.5 | 8.1 | 10.3 | 573 | 24.8 |
| Middle East and North Africa | 30.5 | 683 | 6.5 | 6.9 | 7.7 | 8.5 | 1 238 | 55.4 |
| South Asia | 2.7 | 65 | 0.7 | 1.0 | 2.2 | 2.4 | 278 | 11.8 |
| Sub-Sahara Africa | 13.5 | 377 | 2.8 | 2.8 | 3.1 | 3.4 | 664 | 26.6 |
| **WORLD** | ***840.4*** | ***16 079*** | ***13.1*** | ***14.4*** | ***18.0*** | ***22.5*** | ***37 632*** | ***1 866.3*** |

# ANNEX 4.A5

## *Road Use Forecast*

| Global economic outlook<br>Road use | A<br>2000<br>Road use-economy density (Mvkm per USD-B) | B<br>2000<br>Annual distance per vehicles (km) | C<br>2000<br>Annual distance (Bvkm) | D<br>2010<br>Annual distance (Bvkm) | E<br>2020<br>Annual distance (Bvkm) | F<br>2030<br>Annual distance (Bvkm) | G<br>2030<br>Annual distance per vehicles (km) | H<br>2030<br>Road use-economy density (Mvkm per USD-B) |
|---|---|---|---|---|---|---|---|---|
| **REGIONS OF THE WORLD** | | | | | | | | |
| **1. High–income/industrialised** | ***321*** | ***17 236*** | ***11 240*** | ***12 763*** | ***15 431*** | ***18 769*** | ***17 580*** | ***306*** |
| ***a)* G-7** | ***320*** | ***16 465*** | ***7 673*** | ***8 457*** | ***9 756*** | ***11 455*** | ***17 096*** | ***276*** |
| United States | 374 | 19 056 | 4 391 | 4 873 | 5 720 | 6 875 | 18 963 | 302 |
| Japan | 210 | 10 625 | 786 | 865 | 965 | 1 089 | 11 911 | 190 |
| Germany | 274 | 13 854 | 648 | 712 | 801 | 899 | 15 097 | 267 |
| United Kingdom | 291 | 19 960 | 518 | 554 | 624 | 705 | 19 481 | 259 |
| France | 303 | 14 909 | 527 | 579 | 657 | 753 | 15 612 | 279 |
| Italy | 326 | 14 902 | 525 | 566 | 623 | 691 | 15 888 | 298 |
| Canada | 271 | 15 198 | 278 | 307 | 365 | 443 | 15 484 | 230 |
| ***b)* Other–OECD** | ***346*** | ***18 736*** | ***2 649*** | ***3 101*** | ***3 978*** | ***5 029*** | ***18 437*** | ***369*** |
| Europe and Central Asia | 340 | 18 082 | 1 705 | 1 978 | 2 518 | 3 154 | 18 104 | 362 |
| East Asia and Pacific | 360 | 20 488 | 587 | 695 | 891 | 1 136 | 19 103 | 382 |
| North America (Mexico) | 356 | 19 351 | 358 | 428 | 569 | 739 | 18 904 | 379 |
| **OECD Industrialised** | ***326*** | ***16 994*** | ***10 323*** | ***11 558*** | ***13 734*** | ***16 484*** | ***17 484*** | ***299*** |
| ***c)* Non–OECD** | ***272*** | ***20 529*** | ***917*** | ***1 205*** | ***1 697*** | ***2 285*** | ***18 304*** | ***372*** |
| East Asia and Pacific | 198 | 17 410 | 235 | 334 | 510 | 730 | 16 379 | 327 |
| Europe and Central Asia | 346 | 11 462 | 82 | 94 | 104 | 116 | 13 269 | 341 |
| Latin America and Caribbean | 318 | 24 719 | 270 | 345 | 476 | 608 | 19 585 | 391 |
| Middle East and North Africa | 251 | 22 765 | 144 | 204 | 333 | 490 | 19 417 | 389 |
| South Asia | 148 | 16 520 | 2 | 3 | 5 | 8 | 15 125 | 302 |
| Sub-Sahara Africa | 363 | 27 614 | 184 | 224 | 269 | 332 | 22 634 | 452 |

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| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| Global economic outlook Road use | 2000 Road use-economy density (Mvkm per USD-B) | 2000 Annual distance per vehicles (km) | 2000 Annual distance (Bvkm) | 2010 Annual distance (Bvkm) | 2020 Annual distance (Bvkm) | 2030 Annual distance (Bvkm) | 2030 Annual distance per vehicles (km) | 2030 Road use-economy density (Mvkm per USD-B) |
| **2. Big 5** | ***162*** | ***27 275*** | ***2 322*** | ***3 808*** | ***8 226*** | ***13 677*** | ***24 131*** | ***330*** |
| China | 121 | 53 393 | 880 | 1 722 | 4 709 | 8 595 | 25 004 | 335 |
| India | 97 | 34 691 | 322 | 687 | 1 560 | 2 470 | 29 397 | 307 |
| Brazil | 348 | 17 894 | 518 | 673 | 942 | 1 213 | 18 321 | 366 |
| Russia | 347 | 19 262 | 489 | 576 | 766 | 1 012 | 18 248 | 364 |
| Indonesia | 135 | 22 444 | 112 | 150 | 249 | 388 | 22 285 | 240 |
| **3. Developing** | ***403*** | ***24 210*** | ***2 517*** | ***2 966*** | ***3 974*** | ***5 186*** | ***22 363*** | ***372*** |
| East Asia and Pacific | 389 | 22 227 | 499 | 621 | 936 | 1 343 | 19 313 | 386 |
| Europe and Central Asia | 641 | 27 368 | 622 | 704 | 843 | 1 090 | 24 885 | 447 |
| Latin America and Caribbean | 284 | 24 089 | 271 | 327 | 439 | 573 | 23 152 | 352 |
| Middle East and North Africa | 416 | 22 411 | 683 | 796 | 1 002 | 1 238 | 22 324 | 387 |
| South Asia | 83 | 23 684 | 65 | 94 | 231 | 278 | 23 606 | 143 |
| Sub-Sahara Africa | 606 | 26 334 | 377 | 424 | 523 | 664 | 24 985 | 527 |
| **WORLD** | ***289*** | ***19 114*** | ***16 079*** | ***19 537*** | ***27 631*** | ***37 632*** | ***20 164*** | ***323*** |

# ANNEX 4.A6

## *Road Construction Forecast*

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| Global Road Construction Outlook comparison of results | 2000 Asset value (USD-B) | 2000 PRCS % of GDP | 2000 New construction (USD-B) | 2000-10 Annual "new construction" (USD-B) | 2010-20 Annual "new construction" (USD-B) | 2020-30 Annual "new construction" (USD-B) | 2030 PRCS % of GDP | 2030 Asset value (USD-B) |
| **REGIONS OF THE WORLD** | | | | | | | | |
| **1. High-income/industrialised** | ***4 436.5*** | ***12.7*** | ***100.4*** | ***168.0*** | ***176.6*** | ***191.2*** | ***8.4*** | ***5 150.2*** |
| ***a)* G-7** | ***3 030.9*** | ***12.6*** | ***81.5*** | ***113.6*** | ***119.2*** | ***126.4*** | ***8.3*** | ***3 462.0*** |
| United States | 1 672.0 | 14.2 | 52.6 | 62.4 | 65.6 | 69.3 | 8.3 | 1 902.8 |
| Japan | 361.3 | 9.6 | 6.1 | 13.5 | 14.2 | 15.1 | 7.2 | 412.8 |
| Germany | 92.3 | 3.9 | 2.3 | 4.3 | 4.6 | 5.8 | 4.0 | 134.6 |
| United Kingdom | 157.2 | 8.8 | 4.3 | 5.8 | 6.0 | 6.1 | 6.4 | 173.3 |
| France | 357.2 | 20.6 | 8.9 | 13.2 | 13.7 | 14.3 | 14.8 | 398.5 |
| Italy | 191.9 | 11.9 | 2.9 | 7.1 | 7.4 | 7.8 | 9.3 | 215.7 |
| Canada | 198.9 | 19.4 | 4.5 | 7.4 | 7.7 | 8.1 | 11.6 | 224.3 |
| ***b)* Other–OECD** | ***1 194.3*** | ***15.6*** | ***17.2*** | ***45.8*** | ***47.9*** | ***51.7*** | ***10.2*** | ***1 393.4*** |
| Europe and Central Asia | 976.8 | 19.5 | 13.7 | 37.0 | 38.6 | 40.7 | 12.9 | 1 118.6 |
| East Asia and Pacific | 176.0 | 10.8 | 2.3 | 6.8 | 7.0 | 7.5 | 6.8 | 203.8 |
| North America (Mexico) | 41.5 | 4.1 | 1.2 | 2.0 | 2.2 | 3.5 | 3.6 | 71.0 |
| **OECD Industrialised** | ***4 225.2*** | ***13.3*** | ***98.7*** | ***159.4*** | ***167.1*** | ***178.1*** | ***8.8*** | ***4 855.4*** |
| ***c)* Non–OECD** | ***211.3*** | ***6.3*** | ***1.7*** | ***8.6*** | ***9.5*** | ***13.1*** | ***4.8*** | ***294.8*** |
| East Asia and Pacific | 38.9 | 3.3 | 0.5 | 2.1 | 2.5 | 3.8 | 3.4 | 75.7 |
| Europe and Central Asia | 65.0 | 27.6 | 0.4 | 2.5 | 2.6 | 2.8 | 22.2 | 75.3 |
| Latin America and Caribbean | 50.6 | 6.0 | 0.3 | 1.9 | 2.0 | 2.8 | 4.1 | 64.4 |
| Middle East and North Africa | 30.8 | 5.4 | 0.4 | 1.1 | 1.3 | 2.4 | 3.7 | 46.7 |
| South Asia | 0.8 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.9 | 1.1 |
| Sub-Sahara Africa | 25.3 | 5.0 | 0.2 | 1.0 | 1.1 | 1.3 | 4.3 | 31.7 |


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| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| Global Road Construction Outlook comparison of results | 2000 Asset value (USD-B) | 2000 PRCS % of GDP | 2000 New construction (USD-B) | 2000-10 Annual "new construction" (USD-B) | 2010-20 Annual "new construction" (USD-B) | 2020-30 Annual "new construction" (USD-B) | 2030 PRCS % of GDP | 2030 Asset value (USD-B) |
| **2. Big 5** | ***582.7*** | ***4.1*** | ***9.3*** | ***36.6*** | ***46.6*** | ***64.7*** | ***3.1*** | ***1 293.2*** |
| China | 88.6 | 1.2 | 2.4 | 15.2 | 23.8 | 37.8 | 2.5 | 630.6 |
| India | 289.7 | 8.7 | 6.2 | 10.6 | 10.8 | 11.9 | 4.0 | 324.1 |
| Brazil | 30.7 | 2.1 | 0.3 | 2.9 | 3.7 | 5.0 | 2.9 | 96.9 |
| Russia | 142.0 | 10.1 | 0.3 | 6.5 | 6.5 | 7.1 | 6.7 | 185.4 |
| Indonesia | 31.7 | 3.8 | 0.2 | 1.4 | 1.8 | 2.8 | 3.5 | 56.3 |
| **3. Developing** | ***353.2*** | ***5.7*** | ***5.0*** | ***15.7*** | ***22.0*** | ***36.4*** | ***4.9*** | ***685.2*** |
| East Asia and Pacific | 28.1 | 2.2 | 0.4 | 2.6 | 4.3 | 6.8 | 3.3 | 116.5 |
| Europe and Central Asia | 133.8 | 13.8 | 2.0 | 5.5 | 9.4 | 13.4 | 10.7 | 260.4 |
| Latin America and Caribbean | 33.3 | 3.5 | 0.9 | 1.9 | 1.9 | 3.9 | 4.3 | 69.4 |
| Middle East and North Africa | 81.4 | 5.0 | 0.4 | 2.9 | 3.4 | 6.3 | 3.8 | 122.3 |
| South Asia | 37.5 | 4.8 | 1.2 | 1.5 | 1.7 | 3.9 | 3.5 | 67.8 |
| Sub-Sahara Africa | 39.2 | 6.3 | 0.1 | 1.4 | 1.4 | 2.2 | 3.9 | 48.8 |
| **WORLD** | ***5 372.5*** | ***9.7*** | ***114.8*** | ***220.3*** | ***245.2*** | ***292.3*** | ***6.1*** | ***7 128.6*** |

# ANNEX 4.A7

## *Rail Construction Forecast*

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| Global Rail Construction Outlook comparison of results | 2000 Asset value (USD-B) | 2000 RTCS % of GDP | 2000 New construction (USD-B) | 2000-10 Annual "new construction" (USD-B) | 2010-20 Annual "new construction" (USD-B) | 2020-30 Annual "new construction" (USD-B) | 2030 RTCS % of GDP | 2030 Asset value (USD-B) |
| **REGIONS OF THE WORLD** | | | | | | | | |
| **1. High–income/ industrialised** | ***468.5*** | ***1.3*** | ***27.7*** | ***33.3*** | ***36.8*** | ***36.8*** | ***1.5*** | ***900.8*** |
| ***a)* G-7** | ***329.7*** | ***1.4*** | ***21.3*** | ***20.8*** | ***23.3*** | ***23.8*** | ***1.4*** | ***583.2*** |
| United States | 93.4 | 0.8 | 5.6 | 5.2 | 6.3 | 8.8 | 0.8 | 180.8 |
| Japan | 78.5 | 2.1 | 3.1 | 3.2 | 3.4 | 3.7 | 1.7 | 97.8 |
| Germany | 43.8 | 1.9 | 3.6 | 4.0 | 4.5 | 3.5 | 2.8 | 95.9 |
| United Kingdom | 24.8 | 1.4 | 2.0 | 1.8 | 2.0 | 1.6 | 1.6 | 44.9 |
| France | 28.0 | 1.6 | 2.1 | 2.6 | 2.9 | 2.3 | 2.3 | 61.6 |
| Italy | 46.3 | 2.9 | 4.1 | 2.7 | 3.0 | 2.6 | 3.1 | 72.0 |
| Canada | 14.9 | 1.5 | 0.6 | 1.3 | 1.1 | 1.3 | 1.6 | 30.2 |
| ***b)* Other–OECD** | ***111.4*** | ***1.5*** | ***5.6*** | ***10.3*** | ***11.1*** | ***9.6*** | ***1.8*** | ***248.8*** |
| Europe and Central Asia | 84.0 | 1.7 | 4.4 | 8.2 | 9.2 | 7.2 | 2.2 | 194.1 |
| East Asia and Pacific | 22.0 | 1.3 | 1.0 | 1.5 | 1.4 | 1.7 | 1.3 | 39.4 |
| North America (Mexico) | 5.4 | 0.5 | 0.2 | 0.6 | 0.4 | 0.8 | 0.8 | 15.3 |
| **OECD Industrialised** | ***441.1*** | ***1.4*** | ***26.9*** | ***31.1*** | ***34.3*** | ***33.4*** | ***1.5*** | ***832.0*** |
| ***c)* Non–OECD** | ***27.4*** | ***0.8*** | ***0.8*** | ***2.3*** | ***2.5*** | ***3.4*** | ***1.1*** | ***68.8*** |
| East Asia and Pacific | 1.6 | 0.1 | 0.0 | 0.4 | 0.4 | 0.7 | 0.6 | 12.5 |
| Europe and Central Asia | 5.8 | 2.4 | 0.2 | 0.3 | 0.3 | 0.4 | 2.6 | 8.7 |
| Latin America and Caribbean | 10.8 | 1.3 | 0.3 | 0.9 | 1.1 | 1.3 | 1.7 | 26.8 |
| Middle East and North Africa | 0.7 | 0.1 | 0.0 | 0.2 | 0.2 | 0.4 | 0.5 | 6.9 |
| South Asia | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Sub-Sahara Africa | 8.6 | 1.7 | 0.2 | 0.5 | 0.5 | 0.6 | 1.9 | 13.8 |


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| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| Global Rail Construction Outlook comparison of results | 2000 Asset value (USD-B) | 2000 RTCS % of GDP | 2000 New construction (USD-B) | 2000-10 Annual "new construction" (USD-B) | 2010-20 Annual "new construction" (USD-B) | 2020-30 Annual "new construction" (USD-B) | 2030 RTCS % of GDP | 2030 Asset value (USD-B) |
| **2. Big 5** | ***100.3*** | ***0.7*** | ***4.4*** | ***12.2*** | ***13.3*** | ***15.0*** | ***0.8*** | ***322.3*** |
| China | 28.8 | 0.4 | 1.4 | 7.3 | 8.1 | 7.7 | 0.7 | 171.9 |
| India | 19.0 | 0.6 | 1.0 | 1.5 | 1.8 | 2.9 | 0.7 | 52.9 |
| Brazil | 7.4 | 0.5 | 0.2 | 1.0 | 0.7 | 1.3 | 0.7 | 24.3 |
| Russia | 43.6 | 3.1 | 1.7 | 2.1 | 2.3 | 2.6 | 2.3 | 64.1 |
| Indonesia | 1.6 | 0.2 | 0.0 | 0.3 | 0.3 | 0.5 | 0.6 | 9.0 |
| **3. Developing** | ***62.6*** | ***1.0*** | ***1.9*** | ***3.5*** | ***3.4*** | ***6.3*** | ***0.9*** | ***119.7*** |
| East Asia and Pacific | 3.5 | 0.3 | 0.1 | 0.5 | 0.6 | 1.1 | 0.5 | 18.3 |
| Europe and Central Asia | 30.5 | 3.1 | 1.1 | 1.3 | 1.4 | 1.6 | 1.6 | 39.8 |
| Latin America and Caribbean | 5.3 | 0.6 | 0.1 | 0.4 | 0.3 | 0.8 | 0.8 | 12.6 |
| Middle East and North Africa | 9.0 | 0.5 | 0.2 | 0.6 | 0.5 | 1.5 | 0.7 | 23.4 |
| South Asia | 4.1 | 0.5 | 0.1 | 0.3 | 0.2 | 0.9 | 0.7 | 13.0 |
| Sub-Sahara Africa | 10.3 | 1.6 | 0.3 | 0.4 | 0.4 | 0.5 | 1.0 | 12.6 |
| **WORLD** | ***631.4*** | ***1.1*** | ***34.0*** | ***49.0*** | ***53.5*** | ***58.1*** | ***1.2*** | ***1 342.8*** |

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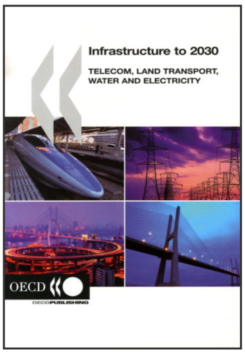


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