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China's Expressways: Connecting People and Markets for Equitable Development





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Foreword

This paper, prepared in response to the Chinese Government's request, examines the institutional and financial arrangements under which the expansion of the Chinese expressway network has taken place. The analysis is based upon dialogue with government agencies at the national and provincial levels, government information and supplemental reports, and a background study commissioned by the World Bank. The core government team was led by the Ministry of Communications (MOC).

The paper was prepared under the leadership of Graham Smith, Lead Transport Specialist and China and Mongolia Transport Sector Coordinator. Members of the China Transport cluster contributed with suggestions, including Christopher R. Bennett, Aurelio Menendez and Alain Dube. Jitendra Bajpai, EASTR Sector Director, provided technical guidance. In addition, the paper benefited from comments received from peer reviewers, particularly Jean-Marie Braun, Robin Carruthers and Clell Harral.

The background paper—*People's Republic of China: China Expressway Retrospective Study*, June 2006—was prepared by W. Greg Wood of Wood International Ltd. It provided a wide range of statistical data and analysis, and reviewed the relevant government policies. These were discussed at a seminar held in Beijing on May 25-26, 2006 that was attended by representatives from MOC, NDRC, several provincial governments, leading Chinese researchers and academics, the Asian Development Bank, and guest speakers from the USA and Japan.

The World Bank team is grateful to the Chinese Government, particularly to the staff at the MOC, for their contributions and support in the preparation of this paper. The team is also grateful to the US Transportation Research Board, the American Association of State Highway and Transportation Officials and the Japan Expressway Holding Agency for participating in the Beijing seminar.



Acronyms

BOT	Build, Operate and Transfer
CATS	China Academy of Transport Science
CHRB	China Highway Research Board
EIRR	Economic Internal Rate of Return
GOC	Government of China
IFI	International Financial Institution
MOC	Ministry of Communications
NDRC	National Development and Reform Commission
NEN	National Expressway Network
NTHS	National Trunk Highway System
PCD	Provincial Communications Department
PDRC	Provincial development and reform commission
RMB	Chinese Yuan (Renminbi)
TPRI	Transport Planning Research Institute
TRB	Transportation Research Board (USA)



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1 China's Achievements in Expressway Development

1.1 Introduction: China's Highway Development

1. China's outstanding achievements in economic growth and poverty reduction over the last fifteen years have been well documented. The major emphasis has been on the development of its infrastructure, particularly transport. All modes of transport have seen their networks expanded, to provide the infrastructure needed to support the broader development goals. Road transport is vitally important and, among the surface modes (excluding pipelines or waterways), has seen its share grow over the last ten years from 45% to 60% in terms of passenger-km and from 24% to 30% in terms of freight ton-km. The road transport system has contributed greatly to China's continuing economic and social development.

2. From 1990 to 2005, during the period of the 8th, 9th and 10th Five-Year Plans, China completed nearly 41,000 km of tolled expressways, the main portion of which comprised the National Trunk Highway System (NTHS). The NTHS will be further expanded to the National Expressway Network (NEN) of 85,000 km. During that period approximately 400,000 km of local and township roads were also improved. Table 1 shows the increase in the number of kilometers for each type of road class. This was achieved by investing upwards of US\$40 billion per year, with about one third of that amount allocated to development of the expressway network.

China has created an unprecedented highway network

Table 1: Highway Network Growth by Technical Classification

Year	Number of km by Road Class ('000)						Non-classified ¹
	Total	Express-way	Class I	Class II	Class III	Class IV	
1985	942	0.0	0.4	21.3	128.5	456.3	336.0
1990	1,028	0.5	2.6	43.4	169.8	524.8	287.2
1995	1,157	2.1	9.6	84.9	207.3	606.8	246.2
2000	1,403	16.3	20.1	152.7	276.7	750.3	186.7
2004	1,871	34.3	33.5	231.7	335.3	880.9	354.8

Source: NDRC Comprehensive Transportation Research Center, October 22, 2005

Notes: 1/ After a road census in 2000 the length of unclassified roads was adjusted

3. This unprecedented expansion in the expressway network was accompanied by the continuing development of intermediate Class I and II roads, under the coordinated efforts of the National Government and the governments of China's 31 provinces, autonomous regions and municipalities. No other country has been able to create such a major enhancement to its national road asset base in such a short period. These public works have helped to develop a



range of supporting skills in financing, management, construction, and operation of roads.

1.2 The Expansion of the Expressway Network

4. The expansion of the road network during the last 20 years was made possible by rapid increases in public funding, both in absolute terms and as a share of the total investment in transport infrastructure (see Table 2).

Table 2: Investment in Transport Fixed Assets

Investment	Year				
	2000	2001	2002	2003	2004
Investment in Transport Fixed Assets (US\$ billion)	41.5	47.7	55.0	61.3	76.1
1. Grouped by Function					
1.1 Ports & Other Coastal Construction	2.4%	3.2%	3.1%	4.9%	5.5%
1.2 Inland Waterway Construction	1.6%	1.3%	0.9%	1.1%	1.2%
1.3 Highway Construction	68.9%	69.1%	72.1%	74.8%	76.3%
1.3.1 Trunk Highways ^{1/}	32.2%	29.7%	29.1%	27.4%	28.4%
1.3.2 Other Road Networks	27.6%	30.1%	32.0%	31.0%	27.7%
1.3.3 County and Township Roads	9.1%	9.3%	11.1%	16.5%	20.2%
1.4 Railways	23.5%	23.2%	21.6%	16.7%	13.7%
1.5 Others	3.6%	3.2%	2.3%	2.6%	3.4%
2. Grouped by Source of Funds (excluding Railways)					
2.1 State Budget	12.4%	15.4%	19.3%	15.5%	14.3%
2.2 Domestic Loans	34.2%	38.4%	41.0%	41.3%	40.4%
2.3 Foreign Investment (mainly IFIs)	3.7%	3.1%	2.7%	2.6%	1.3%
2.4 Self-Financing and Others ^{2/}	49.8%	43.1%	37.0%	40.6%	44.0%

Source: Based on Chinese Highway and Waterway Transport Statistical Yearbook (2005) as reported in Wood (2006) and World Bank data

Notes: 1/ 'Trunk Highways' are predominantly the NEN. However, in a small number of instances the data include Class I and Class II.

2/ This consists of the contribution of provinces, counties, local townships, villages, and the private sector, and debt taken on by the secondary and tertiary levels of government. While there is no hard data on the provincial and tertiary government debt levels for road financing, the authors estimate that debt represents about 60% of that category of investment, which represents a reasonable overall debt to equity ratio of approximately 2:1.

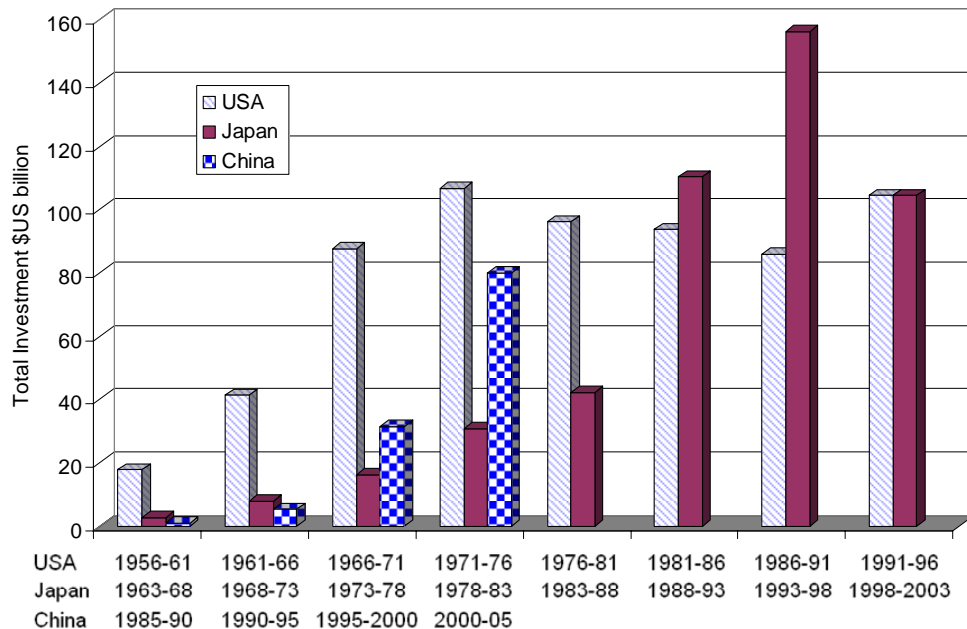
Expressway investment levels parallel the USA and Japan

5. The investment in expressways in China, those to date and planned, parallels the comparable investment already made in the USA and in Japan, and is of the same order of magnitude. Figure 1¹ shows the investments in 5-year periods for the USA, Japan and China at different stages of their network development. Both the USA and Japan developed their national expressways networks over a period of about 40 years; the USA starting in the mid-1950s and Japan a decade later. Both countries started the construction when they had higher per capita income than China, so were better able to afford the investment.

¹ All values are in current US\$, Japanese and Chinese currency, converted to US\$ at the exchange rate prevailing at the time of investment.



China has only 20 years of expressway development history, most of it concentrated in the 15 years since 1990.



Source: Calculations based on Chinese Statistical Yearbook (2005) and other sources as reported in Wood (2006)

Figure 1: Comparison of Expressway Investment Levels

6. China's spending is on the same order of magnitude as that in the USA and Japan when they were developing their expressway networks. In the USA expenditure increased to reach a level of US\$80-100 billion per five years by the late 1960s (the third five-year period) and stabilized in that range throughout the following three decades. In Japan the expenditure was at lower levels in the first 25 years but soared in its seventh 5-year period to around US\$ 150 billion. This was when the Government was using infrastructure investment as a way of bolstering the Japanese economy during the Asian financial crisis of the late 1990s. After that peak the level of expenditure has dropped back to around US\$ 100 billion per five years.

Road asset expansion has exceeded GDP growth to close the infrastructure gap

7. Since 1990, the overall average growth in the Chinese road assets has exceeded the overall growth in its GDP and has helped to close the 'infrastructure gap'¹ that existed at the beginning of the period. Since 1998 total expenditure on transport infrastructure has exceeded 5% of GDP, of which roads have accounted for about 3.5%.²

¹ The 'infrastructure gap' is the difference between the existing road asset base by road class and the asset base required by the economy.

² In 2005 the GDP was adjusted to take into account growth in the service sector, which raised it by 17%. Using this revised GDP level, the road spending was 3% of GDP.



8. Reviewing the experience of the USA in developing their Interstate Highway System shows that while an infrastructure gap exists, the economic return on investment from highways exceeds the comparable private sector rate of return.¹

Box 1: Key Factors Behind China's Rapid Expressway Network Development

There were many factors which contributed towards the rapid development of China's NEN, but five key ones stand out:

- ❑ A clear long-term development plan committed over five-year programs;
- ❑ The simultaneous implementation effort by each of China's 31 provinces, autonomous regions and municipalities;
- ❑ The increasing investment from the central government and the pooling of national and provincial government resources—through their own funds and domestic/foreign debt
- ❑ The greenfield characteristics of most expressway projects, allowing implementation with limited interference with existing networks
- ❑ The availability of a large pool of qualified construction firms and design engineers drawn from former major state owned enterprises to meet the unprecedented demand

1.3 Future Challenges and Opportunities

China has a three-pillar strategy towards road infrastructure development

9. The remarkable achievements over the last fifteen years raise two sets of questions: (i) what key factors allowed for the unprecedented expansion of the high-class road infrastructure; and (ii) what issues need to be addressed to ensure the sustainability of the investments and support the equitable development of provinces across China? These factors and issues can be analyzed under the lenses of a strategy that includes three-pillars, as follows:

- ❑ Strengthening the planning mechanisms to be used in defining the next phase of expressway investments;
- ❑ New financing framework to ensure a sustainable and balanced approach for continuing the network's expansion while maintaining what already exists; and
- ❑ Improved management and operational systems to serve road users and maintain the assets as the network expands and matures.

10. At the mid-point in the development of the expressway network, it is timely to review the achievements so far, and to identify challenges and opportunities that China is likely to face in the medium term. This paper

¹ Once the infrastructure gap is closed, the return on further investment in highways may fall below the private sector rate and may not even achieve the long-term interest rate threshold.



examines the key factors and issues and concludes with suggestions as to priority actions the Government may wish to consider, and on which the Bank can provide further support.

*The World
Bank supports
China's
investment in
infrastructure*

11. The World Bank supports the Chinese Government's priority to the development of infrastructure as an engine to facilitate and spur economic growth, as well as a way to achieve more equitable development. The Chinese government looks to the World Bank and other IFIs for only a small part of its total road financing needs, but seeks thereby to enhance its access to international best practice in road design and technology, construction and supervision practices, evaluation and mitigation of environmental and resettlement impacts, financing methods, and management approaches.



2 Expressway Planning and Economic Performance

2.1 The Planning Process

China's expressway network has been planned by the national and provincial governments

12. China's expressway network has been planned through the interaction of entities at the central and provincial levels, following an approach that emphasized the objective of connecting all major cities to one another. The process defined the most important cities to be served and the most efficient network to connect them. The current NEN plan has been built upon the previous 1992 "5-vertical 7-horizontal" Expressway Trunk Network and now responds to the so-called 7-9-18 plan (see maps, Annex A). This includes seven corridors radiating from Beijing, nine north-south corridors, and 18 east-west corridors.

13. At the national level, the MOC Comprehensive Planning Department started designing the 7-9-18 plan in 2001, with inputs from other line agencies at MOC, research institutes, and the provincial communications departments (PCDs). International seminars were also organized to collect further inputs from foreign experts and academics.

The plan calls for the inter-connection of all major cities

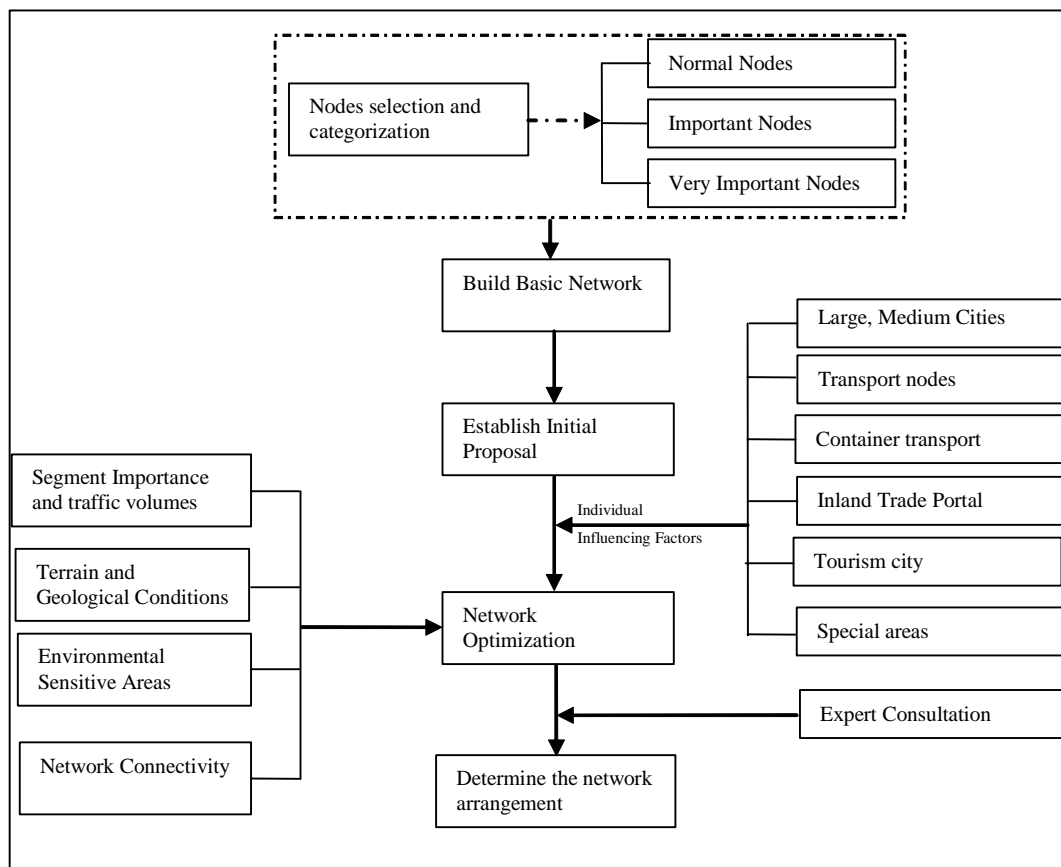
14. The strategy for defining the 7-9-18 plan consisted of combining radial and grid patterns in an attempt to maximize coverage and transport connectivity. Behind this overall strategy, the expressway plan seeks to connect provincial capitals and all the large and medium-sized cities with a population of more than 200,000, serving as facilitator of economic and social interactions as the economy comes to rely more and more on road transport. In prioritizing the selection of cities (nodes) to be connected, the planning process incorporated economic and transport objectives (including trade and container traffic, and tourism needs), giving special consideration to poorer regions and environmental issues (e.g., avoiding environmentally sensitive areas). Figure 2 schematically represents this process.

15. The PCDs, having participated in the overall definition of the 7-9-18 corridors, then define the detailed alignments and designs within the respective provincial boundaries and as a supplement to the NEN the PCDs may add additional local expressway links to meet local needs. This process defines the financing needs and forms the basis upon which the provinces formulate their Five-Year Plans. The inputs to the Plans are prepared by the PCDs two years ahead of the start of a Plan period and require an exchange of views between the PCD and the communications bureaus of the provincial cities. Once a preliminary definition of the investment needs for the next FYP cycle is agreed upon, it is cleared by the provincial development and reform commission (PDRC) in discussions with other provincial departments (e.g., finance and environmental protection). The PCD then shares the proposal with MOC for its review and comments.

16. The revised five-year plan, as cleared by PDRC and incorporating possible comments from MOC, is submitted to the provincial government for approval, or, in some instances, is submitted to the provincial People's Congress through the provincial government for final approval. In this process, MOC's participation is limited to ensuring that the provincial plan is consistent with the national 7-9-18



plan. When disagreements arise in the alignment at the border between two provinces, MOC usually co-ordinates—with support from a reputed design or research institute—to make the proper alternatives analysis and officially communicates the decision to the two involved PCDs.



Source: National Expressway Network Plan, Ministry of Communications, 2004

Figure 2: Planning Process for the National Expressway Network

Implementation is done by the PCDs and the mega cities

17. The implementation of the planned expressways is the responsibility of the 27 provincial communications departments and the traffic bureaus for the four mega cities Beijing, Chongqing, Shanghai, and Tianjin (which have the status of a province). The provinces typically finance 66-90% of the capital cost, through their own budgets and debt. MOC sets policies, standards and provides investment support towards the construction cost.¹ Once the expressways are opened, they are managed through an operating company or other authorized entities. The private sector provides finance on a limited scale through different types of concession schemes.

18. The rapid expansion of the network owes much to this tiered approach: a central entity being responsible for overall planning and standards definition and several concurrent PCDs being in charge of the detailed planning, engineering design and building of the selected roads. The setting of specific provincial

¹ The level of investment support is based on a formula reflecting the length of road and priority given to different regions.



targets under the five-year plans also contributed to the large-scale implementation capacity that allowed the construction of many parallel projects. This capacity was further allowed by the particular financial framework used in the sector, as discussed in Section 3.

The expressway planning process for the next investment stage can be refined

19. While the planning process for the 7-9-18 is commendable for its overall participatory approach, several issues can be highlighted as deserving further emphasis in the next phase of expressway investments:

- ❑ The next investments will likely involve corridors with less traffic demand in areas where construction costs are higher while their social and networking impacts can be greater. This will dictate renewed efforts to strengthen the economic analysis of individual projects to tailor investment levels to expected social and economic benefits. (See Section 2.2.)
- ❑ The 2004 approach for the definition of the 7-9-18—including the participation of city communications bureaus—has helped reduce the possibilities of unnecessary duplication of alignments. Further efforts should be pursued in the scheduling of interconnecting links with municipal road networks, particularly in the areas closer to the more populous urban areas.
- ❑ Further efforts are also needed by provincial highway bureaus to ensure proper coordination with the development of other local networks around the expressway corridors, to make the most effective use of both types of infrastructure. (See Box 2).

Box 2: Where the Expressways Meet the Local Road Network

The World Bank's projects have often found that the weakest aspect of the expressway planning process lies in their interfacing with other roads. In some instances, expressway interchanges have been constructed to an unimproved Class III or Class IV road (see photo to right). In others the locations have been selected without adequate consultation with the local authorities to make sure they are compatible with local plans.



Example of Local Road At Expressway Exit

As the expressway network continues to expand, an inclusive and holistic approach to planning would enhance its development impact on local communities.



2.2 Development Contribution: Macro-view

The expressway network has transformed travel in China

20. Travel in China has been transformed by the NEN. Before 1988, when the first expressway opened to traffic, travel on China's road network was arduous. The roads followed the terrain to keep earthworks and structures to a minimum. The pavement and traffic conditions were poor, so delays were often frequent. Expressways make far greater use of earthworks, bridges and tunnels to follow a more direct route, often significantly reducing the distances traveled and allowing higher speeds. Reduction in travel times, distances and vehicle operating costs have resulted in considerable resource savings for consumers and producers. Table 3 shows some of the trip length savings for a sample of expressways compared to the old roads.

Table 3: Changes in Travel Distances Brought about by New Expressways

Expressway Name	Province	Road Length (km)		Savings Over Old Road	
		New Exp.	Old Road	Km	% of Trip
Xiaoxian	Hubei	243.5	268.4	24.9	9
Tonton	Anhui	116.2	155.0	38.8	25
Shiman	Hubei	105.1	211.8	106.7	50
Haiman	Inner M.	177.0	201.0	24.0	12
Ruigan	Jiangxi	117.0	140.0	23.0	16
Shaanxi III	Shaanxi	109.9	165.0	55.1	33

Source: Own calculations based on World Bank project reports

The network connectivity in the east is having a major impact on logistics

21. The NEN—particularly in the eastern provinces—is now approaching a true network that provides users with a variety of options for travel. Within the past two to three years it has become possible for the first time to drive by expressway all the way from Beijing to Shenzhen, a distance of about 2,800 km. In the eastern provinces drivers are even beginning to have route options, all on expressways, for travel from one major center to another. This is important for long-distance transport of high-value freight, a sector that has been growing especially rapidly in recent years. Just-in-time delivery has become possible, allowing manufacturers and distributors to hold smaller inventories and respond more quickly to changing market tastes. Wal-Mart now relies on its single major distribution center in Guangdong for supplying stores throughout China, a practice that would not have been possible previously. A similar trend was also observed in the USA (see Box 3).

22. In addition, the NEN has a significant impact on traffic safety. Many of the expressways have attracted up to 70% of the traffic that previously used the existing roads. Those lower class roads typically have much higher accident rates than expressways. The diversion of traffic therefore greatly reduces the number and risk of accidents on the existing roads. For example, the Second National Highway (NH2) and Third National Highway (NH3) projects¹ were parts of the important Beijing-Zhuhai expressway. The World Bank's completion reports noted that the number of accidents on the existing road was reduced by two-thirds in

¹ NH2 was comprised of the Xiangtan to Leiyang expressway in Hunan and the Xiaotang to Gantang in Guangdong. NH3 was the Dawu-Quanli and Yongan-Baoxie expressways in Hubei.



Hunan (NH2) and Hubei (NH3). Guangzhou's NH2 section reported a 40 percent reduction. The issue of road safety is further discussed in Section 4.3.

Box 3: Fifty Years of the US Interstate Highway System

July 29, 2006, was the 50th anniversary of the day when the U.S. Congress passed and President Eisenhower signed into law the Federal-Aid Highway Act that allocated US\$25 billion to pay for 90% of the 66,000 km US Interstate Highway System, then called "National System of Interstate and Defense Highways". For this purpose, Congress levied a 3% federal tax on gasoline and diesel fuel consumption. Congress subsequently expanded the network to include other routes and new states (Hawaii and Alaska).

Recent reports on this milestone have highlighted the importance of the interstate highways for the US transportation system. Among the reported benefits one stands out: it made the US distribution system of people and goods more flexible. This flexibility has benefited manufacturers, especially in the lagging regions of the South. It is highlighted as one reason for a thriving Southern-based automobile industry (BMW in South Carolina; Mercedes in Alabama; Honda in both Carolinas, Georgia and Alabama; Toyota in Tennessee, Alabama and Kentucky), as well as the location decisions of today's big box retailers—Wal-Mart (Arkansas) and Home Depot (Georgia)—and distribution firms—FedEx (Tennessee).

The expressway investments have benefited inland cities

23. Reduced land transport costs between inland cities and coastal mega-cities and seaports—and from there to overseas markets—promote the development of inland firms in two ways: through lower cost of inputs delivered to the inland factories, and the higher net revenue from their sales to the external markets. The inland cities' improved access to markets attracts new firms, creating more competition and eroding existing monopolies. It also offers economies of scale and greater rewards to innovation. Highly skilled labor becomes more willing to move to the inland cities, enhancing their level of technology (Limao and Venables, 2001).

24. To test this theory against the experience of Chinese inland provinces, several researchers have tried to demonstrate the additional value added (e.g. provincial GDP) attributable to investment in roads. Some, notably IFPRI (2005), have succeeded in showing a strong correlation between investment in roads and increases in provincial GDP. However, efforts to isolate the roads' impact from that of other contributory factors—in developed and developing countries—are open to question, because of the paucity of relevant data and lack of rigorous baseline studies¹.

25. In addition, investment in one province can have a spillover effect on other provinces. Road investment in the central provinces provides both a push

¹ To strengthen the understanding on the specific impacts of roads on economic development, MOC may want to promote use of more rigorous methods of impact evaluation among the academic and consulting communities. This will require the monitoring of GDP growth and other indicators, not only in targeted provinces enjoying large investment in roads but also in 'control' areas with far less road investment and, ideally, experiencing similar endowments of other possible contributory factors.



and a pull effect on the adjacent western and eastern provinces and results in the best overall net economic effect. While investment in the eastern and western provinces tends to stay local, investment in the central provinces benefits all regions.

26. Research has shown (Luo, 2005) that the net economic impact in terms of poverty alleviation from road transport investment improves as the investment moves toward the western provinces in China—by a factor of ten over investment in the eastern provinces. However, in terms of return to the rural economy, investment in the central provinces has a higher impact than an equivalent investment in either the eastern or western provinces.

The expressway developments have created new institutions and skills

27. The expressway program has helped develop a range of skills including consulting, planning, financing, managing, constructing and operating roads. As China embarks on the next stage of development of the road system through the 11th Five Year Plan, the skills and knowledge developed over the past 15-20 years will be important in helping to continue the development of an environmentally sensitive, socially responsible and sustainable road system that serves the needs of the economy. For this vision to be realized, there is a need to update engineering design standards to suit the local conditions, traffic levels and weight of vehicles, to keep trained people involved, and to develop construction quality procedures reflecting lessons drawn from previous projects.

2.3 Economic Performance: Micro-view

IFI projects have generally given high economic returns

28. Most International Finance Institution (IFI) projects have surpassed the minimum acceptable Economic Internal Rate of Return (EIRR) level of 12%. EIRRs estimated at the project appraisal stage were clustered in the range 15-30%, with some exceeding 30%. However, EIRRs estimated one year after the road opened showed quite wide variations compared to the appraisal estimates. In the majority of cases the post-opening estimate was lower than the appraisal estimate, but still clustered in the healthy range of 15-25%. This vindicates the confidence shown by the National Government in promoting the rapid expansion of highways.

29. Projects not involving IFIs may sometimes have higher EIRRs compared to IFI projects, but in a few cases they appear to have over-estimated traffic and under-estimated cost, resulting in overly optimistic EIRRs¹. Moreover, decisions were made to invest in some roads that, at the time, may not have warranted investment at the standard of a full expressway: two separate carriageways, grade-separated interchanges, and limitation of access throughout. These investments have been made in consideration of their potential future social and networking benefits.

30. In both IFI and non-IFI financed projects, various outcomes explain the difference between the pre- and post construction estimates. The most common have been: (i) overly optimistic traffic growth and diversion projections; (ii) changes in the design; (iii) delayed completion of adjoining expressway sections; and (iv) opening of parallel roads not previously taken into account. Each link,

¹ It should be noted that the EIRRs are often calculated in isolation for the specific project and therefore do not fully reflect the network connectivity benefits arising from the investment. Were these to be incorporated there could be different results.



being part of the wider network, often does not realize its full potential until a large portion of the related corridor is substantially complete. In sum, the economic results have been positive, but with a decreasing trend as the newer investments move into areas with more limited demand and, sometimes, more difficult terrain.

For the future network development improved demand estimation and alternative analysis is important

31. The key lessons learned from both IFI and non-IFI funded projects for consideration in the next phase of the expressway expansion program are: (i) focus on improved demand estimation methodologies, including the impact of higher or lower toll rates on demand; and, (ii) emphasis on the analysis of a full set of alternative options, including not only different alignments but also the possibilities of phased construction. The latter might be particularly important when the demand estimates show a relatively long ramp-up period of low traffic volumes, and must take into account the adequate analysis of the costs of the alternative technical options. In all, these methodological approaches call for a rigorous life-cycle analysis of alternative alignments and phased options, taking into account levels of traffic demand that would vary depending on toll levels and competing parallel routes.

2.4 Prospects for the Next Phase of Highway Expansion

China is planning major investments in its road networks

32. The first phase of the NEN is now essentially complete. During the current 11th Five-Year Program (FYP) and upcoming 12th and 13th FYPs, a further 45,000 km are planned to be constructed. Major investments in the local road networks are also planned. Current targets and timetables call for all villages in the eastern and central provinces and all towns in the western provinces to be connected to the road network with an all-weather road by 2010 and all villages in the western provinces by 2020. The vision is to develop a balanced road network to support equitable growth. While a relatively complete network has developed in the eastern provinces, many of the major western cities, and some central ones, lack high-grade highway connections to the central and eastern cities.

33. Measuring the specific contribution of road investments to the development of each region is a major challenge. So is the question of how the distribution should be balanced to achieve maximum development impact. This challenge is compounded by the fact that the inter-provincial roads (largely expressways and Class I roads) provide benefits that go beyond the boundaries of a province. An analysis of key indicators across regions, however, can help provide a sense of achievements to date and the overall direction of future investments.

The expansion of the expressway network to poorer regions creates a new set of challenges

34. While the national expenditures in road assets have been reasonably balanced across road classes (see Table 1), the indicators across regions lead to the following conclusions:

- ❑ The most prosperous provinces exhibit higher levels of utilization of the higher-class roads, as shown by the values of GDP per km, imports and exports per km, or the number of highway vehicles per km.
- ❑ As more and more people in the less developed regions buy a car for the first time and the distribution of goods comes to rely more on trucking, the need for additional road infrastructure will become more pressing.



- ❑ Regions with fewer good roads also tend to have lower economic indicators—without a clear causality implied by the numbers. Consequently, they have limited revenue capacity to meet the future investment needs. The situation can only be corrected by further support from the central level.
- ❑ Further efforts must be made to improve the quality of the connections of villages and counties outside the main corridors of the higher-class roads, so as to facilitate their access to economic and social opportunities.¹

35. The emerging need is to balance the continued investment in expressways as the network matures, against the demands for investment in other parts of the network so that the road development is balanced by road class and by region to achieve equivalent levels of economic return from all investments.

36. Despite the very large investment made in the road sector, a road access gap persists and varies both by road class and by geography. In general, rural roads lack funding and capacity. To adequately support both the development and the maintenance of rural roads, requires financial support from municipal, provincial, and national levels.

¹ This is a conclusion also reached in the report "Trade and Logistics in East Asia: A Development Agenda," June 2003.



3 Financing Approaches and Opportunities

3.1 Financing Needs for Sustainable Asset Management

It is essential that China adopt an 'Asset Management' approach to protect its infrastructure investments

37. The investments in road infrastructure over the last 15 years have created a large stock of highway assets that require their proper upkeep and management. Both an appropriate financial framework and modern asset management approaches must now be reinforced to ensure the sustainability and economic serviceability of the constructed assets. Increasingly, this requires that decisions regarding budget allocation for roads address the proper balance between (i) routine and periodic maintenance, (ii) rehabilitation and reconstruction, and (iii) further capital investment in new roads. This balance, with an increasing share on maintenance as the network expands and matures, is paramount to ensuring that the large sums of resources invested in the road network are used in a sustainable manner.

38. A standard estimate of the annual cost of road maintenance is 2.5% of the asset value.¹ This is widely used in economic assessments of road operating costs in IFI feasibility studies. It is also the recommended level of funding for road maintenance suggested by the European Union. In China, this level should be relatively easy to achieve for those jurisdictions with road asset value below 40% of GDP, but may pose difficulties for jurisdictions above 40%.²

Most provinces are under-investing in road maintenance

39. A key source of road maintenance financing so far has been the annual "road maintenance" fee paid by all road vehicles to the province in which they are registered. The fee is nominally earmarked to cover road maintenance. However, MOC allows up to 20% of the revenue collected to be spent on road construction, although anecdotal evidence suggests that some provinces use more than 20% for construction. The total revenues from the road maintenance fee were estimated for 2004 and compared to 2.5% of the road asset base. Figure 3 shows the results for each province. It can be noted that for only a few provinces the current level of revenue is adequate for maintaining the asset base. The funding shortfall is most pronounced in the poorer provinces. This shortfall is leading to a maintenance backlog.³

40. The relative shortage of maintenance revenue in most provinces, combined with the large financing demand for NEN construction and other roads, particularly those in rural areas, will exacerbate the difficult financing situation. This calls for renewed efforts in strengthening the planning and programming capacities in each province to make best use of the available funds to cover a balanced distribution between new investments and maintenance.

¹ The asset value is the estimated current replacement cost for each road class.

² Wood (2006) indicates that for long-term sustainability, the ratio of asset value to GDP should be in the target range of 20 to 40%. Above this range it is difficult for the economy of the jurisdiction in question to generate enough funding from users to maintain the assets.

³ Several provinces anecdotally confirmed the general validity of the findings. In Hubei recent research (HPCD, 2003) suggested that the current maintenance funding was only some 25% of what was required, compared to the World Bank estimate of 38% suggested in Figure 3.

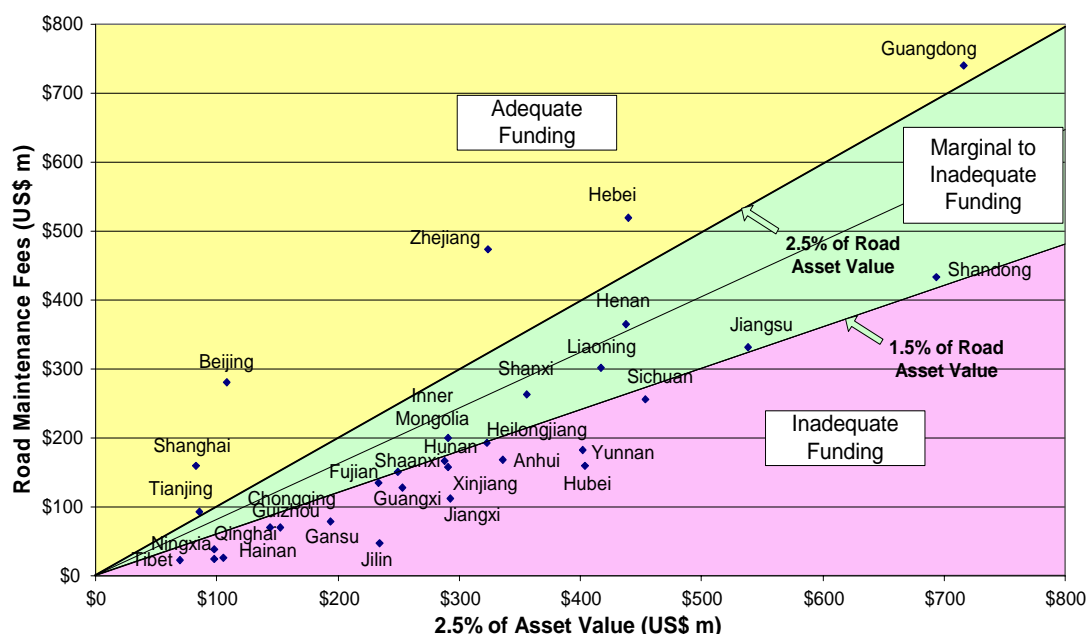


Figure 3: Availability of Maintenance Funds by Province

There is a need to improve maintenance planning and execution

41. Most PCDs have not built up a complete database for detailed road conditions and traffic volumes. Therefore, data collection and methodologies for maintenance programming and asset management need to be improved so that maintenance practices are based on the actual network's needs. In addition, although many PCDs have corporatized the previous own-account maintenance units, the productivity of these companies still needs to be increased. Acknowledging this situation, the MOC has stepped up efforts to improve road asset management practices and priority setting. Simultaneously, many PCDs and highway bureaus are exploring the option of contracting out the maintenance of roads to independent firms.

3.2 Financing Challenges for the Next Investment Phase

42. Assuming the average cost of one km of highway at US\$5 million¹, the total cost for the next phase of the NEN construction will be on the order of US\$225 billion. If spread evenly over 20 years, this would mean that around US\$11 billion will be required to build 2,250 km of new expressway every year—about half the current rate of construction, but they will likely go faster. With the construction of NEN to be largely completed by 2020, the construction and financing demands will be heavy over the next 15 years.

The NEN has been financed mainly by domestic loans and debt

43. Domestic loans and other forms of debt have been the predominant mode of financing road development (see Table 2). The National Government's share of

¹ In the early years of the NEN construction the costs were on the order of US\$2-4 million/km, but as the network has expanded it is entering more demanding terrain with correspondingly higher construction costs.



total investment has been at about 15%, or by 2005 about 0.5% of GDP. The expenditure on the NEN over the past five years from all sources has averaged 1.2% of GDP¹.

44. By comparison, between 1956 and 1985, when the USA was creating the 85,000 km of the Interstate Highway System, the federal government contributed 90% of the total cost, representing 1.3% of GDP in 1960 to 3.3% in 1980. The balance was provided primarily by state user fees. By the mid-1980's, when many of the urban bypasses were being built in the USA, the percentage of GDP represented by the total expressway program from all sources had reached about 3.7%.

45. Presently, in China, there is strong commitment to a local roads development program from researchers, investment banks, IFIs and senior policy organs of the National Government. The consistent view is that the investment in local road capacity will spur development of rural areas, thus reducing both the rural-urban and the inter-regional inequities, particularly between eastern and western provinces.

The financing of local road improvements will present a challenge

46. While the commitment to the local road development program is widespread, the financing of the program will rest largely on the shoulders of the provincial and county jurisdictions. The required financing will be similar in magnitude to the development of the NEN prior to 2002. But unlike the NEN, these non-revenue-earning roads are unlikely to attract bank debt under present practices. They will effectively require about RMB 75 billion (US\$10 billion) annually in capital contributions from the provinces and local governments.

47. The western development of the expressway system, together with the rural access needs, creates a financing challenge for the sector, especially for the poorer provinces. Many of the major western cities remain unconnected to the high-grade highways of the central and eastern cities. An important part of the remaining work to finish the basic NEN aims at completing network connectivity. However, the traffic volumes are low and there will be insufficient fiscal revenue to cover the capital and operating costs for many years.

The NEN in eastern provinces is financially viable, but western provinces face a funding gap

48. China is therefore facing the situation where the eastern portion of its expressway network, with its high traffic flows, will have sufficient income to attract debt and even private equity, whereas the central and western portions will have insufficient revenue to cover debt service and on-going maintenance costs. The financing gap is estimated at \$1 billion per year (RMB 8 billion), spread over 13 provinces. Options open to the National Government to balance out the profitability of the expressway system include: (i) attracting debt and private equity to revenue-earning roads so that government contributions can be concentrated on socially desirable but non-revenue-earning roads, (ii) establishing a national toll financing mechanism for redistributing income to poorer western provinces, and (iii) implementing a fuel tax. Each of these options—not mutually exclusive—will be considered in turn below.

¹ This was the original valuation GDP before the statistical adjustment made in 2005.



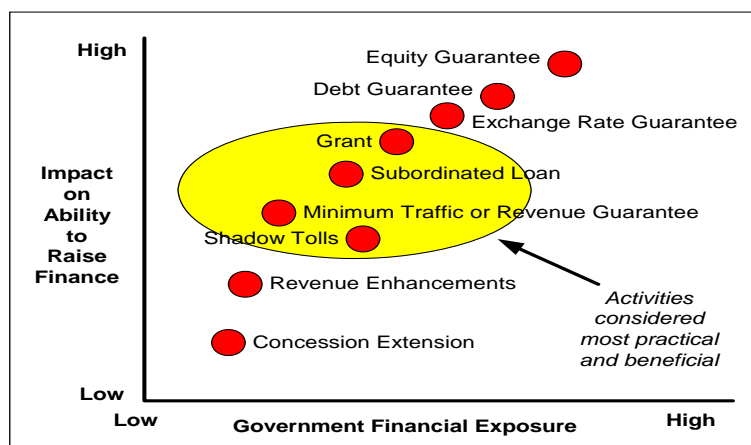
3.3 Private Financing and Public/Private Partnerships

The private sector can make a useful contribution to financing infrastructure

Private sector financing can free public funds for use on non-revenue earning parts of the network

49. International experience of private financing of roads has shown that the private sector can make a useful contribution to advancing financing resources, but there are many limitations. Since it takes several years before most roads generate a positive net cash flow, private equity normally requires a high return on capital. Privately raised debt also costs more than public borrowing, as the lenders are usually at a disadvantage in terms of scale, information, and control over key risks. Putting together private financing also takes longer and the transaction costs can be large. Off-setting these disadvantages, the main merits of private participation are that it can deliver more efficient and innovative management. Furthermore, by adding to the total pool of funds available for road construction, in exchange for future toll revenues, it can free up current public funds for use on non-revenue earning parts of the network. As noted by Meyrick (2006), if the private financing option is systematically compared with the cost and timing of fully public financing (the so-called 'public finance comparator', a concept first applied in the UK), the responsible government entities can more accurately assess the net benefit of private financing.

50. Expressways benefit not only their own users (who pay tolls) but also users of the parallel roads that become less congested (who do not pay tolls). This can lead to situations where the predicted financial return to private investors is below their threshold but the economic return to society is above the public target rate. In such circumstance there is an argument for blending public and private finance. A range of public/private participation mechanisms available to governments is shown in Figure 4. Provinces may want to consider some of these, especially those in the central range which promise a reasonable impact without exposing the government to high financial risk.



Source: Fishbein and Babbar (1996)

Figure 4: Options for Private Sector Support

51. The nature of risks and their allocation between the government and the private parties need to be examined on a case-by-case basis. In the early days of private investment in China, the investors reduced risk by creating joint ventures with the local PCD, thereby often ensuring preferential treatment and high-level official support. As the process moves toward more competitive bidding and



transparency, the private sector will likely seek a level of profitability lower than what has been the case to date, but with corresponding less risk. Public/private partnerships can serve this need.

3.4 Tolls Rates and Collection Method

Tolls are the main financing mechanism, but these are high by world standards

52. Tolls are the main mechanism for financing expressways and, as shown in Figure 5, tolls in China have been set at levels similar to or higher than equivalent tolls charged in many developed countries.¹ This is due to the fact that the percentage of public investment is relatively low and that loans are a high portion of the total investment. More importantly, the affordability of tolls² in China is among the lowest in the world (see Figure 6). In many cases, low traffic on expressways has been caused by the resistance of travelers to pay the set toll.

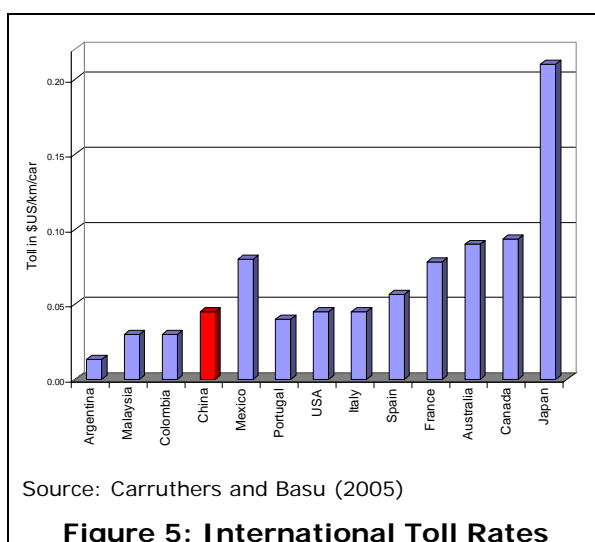


Figure 5: International Toll Rates

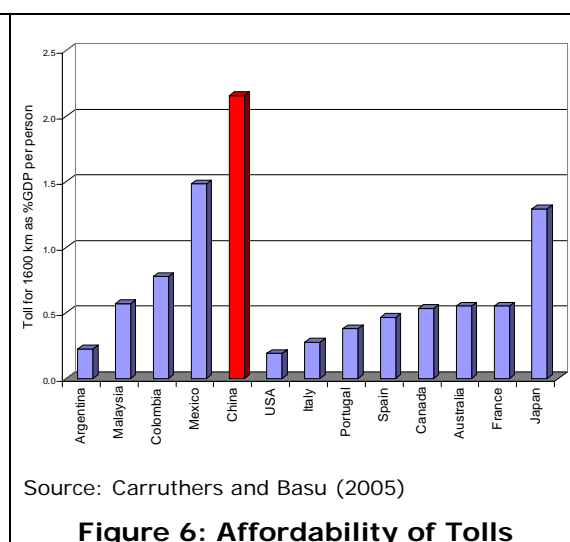


Figure 6: Affordability of Tolls

53. However, even with the relatively high tolls, traffic volumes show that the share of trucks on toll roads is increasing and has now reached (on average) 40% of the traffic stream.³ This is quite a high percentage for average traffic and reflects the relatively low private car ownership and use—and strong competition from railway and air for long-distance passenger travel. The increase in the percentage of trucks suggests that trucks are no less likely to use the expressways than are other vehicles. This is in spite of the recent trend towards charging weight-based tolls (see Box 4). Where high tolls suppress traffic, they affect all types of vehicle users, including trucks.⁴

¹ Germany is now charging trucks an average of about US\$0.15/km. This compares to the average for China for heavy goods vehicles of US\$0.12-0.21/km.

² Carruthers and Basu (2005) defined the affordability of tolls as the toll paid by a private car traveling a distance of 1,600 km, expressed as a percentage of the income of the occupant of the car. Figure 6 is from this source.

³ Over the period 2002-2004 the truck share of traffic on toll roads rose from 32% to 38%, whereas on other roads the average remained stable at around 30%.

⁴ The impact of high tolls on trucks was recently addressed in Sichuan, which reduced truck tolls by some 38% in December 2005. Since 2003 Sichuan has also exempted all trucks carrying fresh agricultural and husbandry products from paying tolls.



A national toll policy should be considered to help finance road infrastructure in less developed provinces

54. In order to meet highway needs, there is a need to reallocate tolls from high revenue areas to low revenue areas. This is already happening in some provinces. In order to finance network expansion to the central and western regions where traffic levels are expected to be low, China may consider the options of a national toll policy. Its main objective would be to divert a portion of the toll revenue from the mature highways to the development of lower-volume and non-remunerative roads in less developed provinces. The approach would be to bridge the revenue shortfall until the debt has been retired on all roads.

55. The toll road development in many countries, particularly in Europe, was made possible by using this approach. For example, in both Japan and France cross-subsidy of this kind was seen as a critical means of supporting the development of the network.

56. In China, the National Government has contributed part of the capital costs for constructing the NEN—estimated at about \$3 billion in 2004. (Most of this is funded from a tax on vehicle purchases earmarked to MOC.) The collection of part of the toll from all expressways can therefore be viewed as the dividend payment on the equity that the National Government initially invested. The government can then decide where to re-deploy these funds independent of the toll roads that generated them.

57. There are 13 loss-making provinces which require about \$1 billion per year of additional revenue to finance their highway investments (Wood, 2006). This is equivalent to one third of the National Government's contribution to expressway financing, and about one tenth of the toll revenues collected by the profitable provinces. A transfer of this magnitude from either source could be justified as a national contribution to the development of high impact roads with low financial returns.

Tolls should not be eliminated once the debt has been repaid

58. The recently adopted regulation to eliminate toll collection on roads which have repaid all loans needs to be reexamined.¹ There are several arguments for doing so. First, the justification for charging tolls is strongest on congested roads, where the toll is a useful pricing instrument for rationing the scarce road space to those who value it most—and mature highways are the ones most likely to be congested.² Second, the revenues from such roads can readily be redistributed to poorer regions as suggested above. And third, they could be used to fund road maintenance, which is currently significantly under-funded (see Section 3.1).

59. The introduction of a national toll policy could be an opportunity to improve the overall efficiency of the system. It could: (i) offer users consistency in the way they pay for use of the expressways; (ii) reduce the frequency with which users have to make payments; (iii) reduce the incentives to stay on the old roads; and yet (iv) allow separate toll road companies to continue receiving the revenues earned on their roadways.

¹ The regulation has not been implemented. There are several instances of toll roads continuing to collect tolls after the construction debt has been paid, the Beijing Airport Expressway being the most widely recognized.

² When tolls are used for congestion pricing, they should be controlled by the entity in charge of operating the transportation network, not by the expressway company or by the concessionaire. The income from congestion pricing should be used to develop new highways as alternative routes or for public transportation.



There are benefits from adopting electronic toll collection

60. With a common system for electronic toll collection,¹ provinces and provincial toll road companies can generate more revenue while saving road users time.² Three options for electronic toll collection are: (i) transponders or smart cards; (ii) GPS-GSM; and (iii) vignettes (see Annex B). The first two retain the principle that the further you drive, the more you pay. This has the merit of disciplining use of the road network, especially if they also make heavier vehicles pay more in accordance with their actual weight (as distinct from registered weight). The most viable option for China is to implement a system based on smart cards (stored value cards) which will work with or without transponders.

Box 4: Tolling by Weight in China

At least ten provinces have implemented goods vehicle tolls which vary depending upon the weight of the vehicle. This can help to both control overloading and to recoup some of the investment costs arising from overloaded vehicle damage, though it needs to be complemented with effective control measures (see Section 4.2). To be truly effective, the additional toll—actually, in the nature of a fine—should be set at a level that matches the cost of repairing the additional damage caused to the road pavement and structure. Unfortunately, this is not as yet done.

As an example of this mechanism, in Hubei the standard truck toll is set at RMB 0.08 per ton per km. This applies up to the point where the vehicle is 30% overloaded. Above that point the toll rates for the overload portion increase to RMB 0.16/t/km for up to 60% overloading, RMB 0.24/t/km for up to 80% overloading, RMB 0.32/t/km for up to 100%, and RMB 0.4/t/km for more than 100% overloading. In Henan similarly trucks overloaded less than 30% pay the standard toll; from 30 to 50% the toll is doubled; from 50 to 100% it is tripled. Above 100% the truck is not allowed on the expressway and must be unloaded.

3.5 Fuel Charges

Users' charges from fuel taxes can help raise revenue

61. Users' charges from fuel taxes offer a complementary mechanism for raising revenue to finance the development of the road network and road maintenance. Most countries have adopted charges from fuel taxes, as they are efficient to collect and provide a tariff which reflects the distance traveled, and thus road use.

62. In 1999 the State Council authorized the government to prepare and implement a fuel tax. However, it has still not been adopted—except in Hainan. Compared to the present annual fee on commercial vehicles earmarked for road

¹ The implementation of electronic toll collection will vary depending upon local circumstances. Where traffic volumes are low, the need is much less than on heavily trafficked roads where transponders eliminate the need to stop. However, from the efficiency point of view even if the provinces are not prepared to implement such a system, a commitment to follow a common approach within the province, and preferably among provinces, should be made.

² As an example of the benefits, Al-Deek, et al. (1997) found in the USA that by using electronic toll collection transponders with a dedicated lane, the measured capacity tripled, the service time decreased by five seconds per vehicle, the average queuing delay decreased by one minute per vehicle, the maximum queuing delay decreased by 2.5–3 minutes per vehicle, and the total queuing delay decreased by 8.5–9.5 vehicle-hours per morning peak hour for the lane.

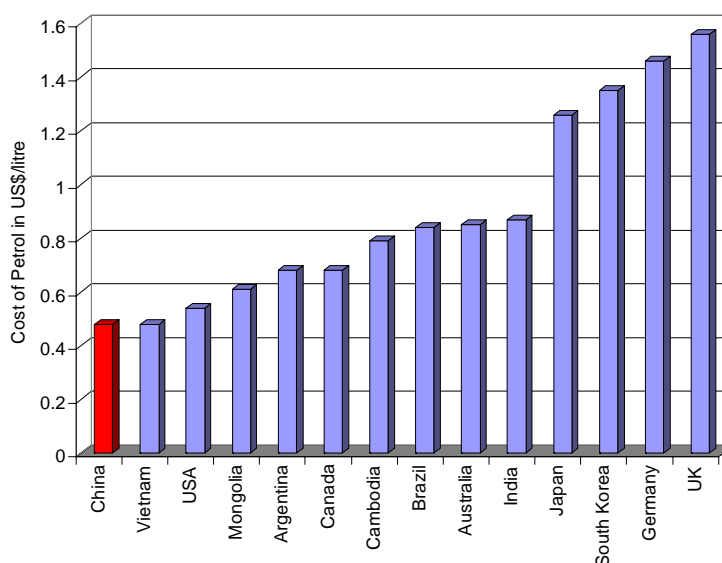


maintenance, a surcharge on fuel has the advantage that it is variable with vehicle use, so that those who drive more pay more, and the rate can be set at a level that reasonably reflects the cost elements that vary with vehicle use: road wear and tear, congestion and emissions. Such a charge creates incentives for a more efficient use of vehicles and reduced pollution. It is also very efficient as an instrument to generate the revenues necessary for the adequate maintenance and development of the road network in a manner commensurate with the deterioration and needs of the road network.

China's fuel price is low by international standards so there is scope for a fuel surcharge to be allocated for the upkeep and development of road assets.

63. If the Chinese government decides to cover all categories of road maintenance expenditure from a tax on fuels, the with-tax price of fuel would be about 30% higher than the mid-2006 pump price. In contrast, an increase to three times its mid-2006 price would cover both maintenance and planned road construction.

64. The price of fuel in China is low on a world scale, even relative to most other Asian countries—as shown in Figure 7. For example, Japan and South Korea both charge more than double the Chinese price for their fuel. The price differential reflects the use of fuel taxes as a source of general revenue of the state in many countries.



Source: Based on data from Metschies (2005)

Figure 7: International Comparison of Fuel Prices

A fuel tax should be implemented gradually with exemptions for farmers

65. Any fuel tax should be implemented gradually, and with exemptions or rebates for farmers and rural areas.¹ The international evidence suggests that the economy can adjust to a higher price for fuel, especially if the new tax is offset

¹ The exemptions or rebates for farmers and rural areas would be consistent with the recent policies of the National and some provincial governments to relieve farmers' burdens and promote the rural economy. In 2003 some of China's coastal and central regions started cancelling farmers' taxes and fees. In 2004 the National Government made a commitment to gradually cancel farmers' taxes and fees in five years which led to the National People's Congress in 2005 cancelling the 'People's Republic of China Farmers Tax Ruling beginning January 1st, 2006.



by the elimination or reduction of other taxes. In the transport sector, behavior is likely to change and so will vehicle technology and its use. But behavioral and technological change will be gradual. If a fuel tax increase of 1% per month is implemented, then the price of fuel could double in about six years. At the same time the economy would be adjusting to that gradual increase and limiting the negative impacts.

66. An in-depth analysis of the overall financing requirements for simultaneously continuing expressway construction at current levels, upgrading of rural/local road networks, and having adequate maintenance, is beyond the scope of this paper. Nonetheless, the previous sections clearly identify the need for comprehensive toll and fuel charges policies that can allow the appropriate financing and allocation of investment needs across provinces (since poorer provinces do not have the financial means to meet their investment needs), between road classes, and to ensure adequate resources for the maintenance of the substantial road asset base constructed over last 15 years. The participation of the private sector in selected projects, and the commercialization of maintenance activities, should also help to further improve the value for money in both road construction and maintenance.



4 Management and Operational Challenges

4.1 Enhancing Expressway Operations

67. To ensure seamless movement of goods and people along the expressway network, there is a need to re-examine the current framework for managing and operating the expressways.

Institutional strengthening and technology deployment can promote seamless transportation services

68. As the NEN developed, a very large number of toll road companies were created, provincially owned, but with varying degrees of independence from the provincial governments. The resulting fragmentation of the expressway network among many companies has created the situation where users often have to pay tolls repeatedly even on short trips, and where the toll rates vary from one stretch to another, except in those provinces which have adopted unified tolling rates and electronic toll collection.

69. In China, the PCDs have control of all publicly financed expressways.¹ These expressways are managed by operating companies or separate divisions of the PCDs. In some provinces the toll income is mainly used for payment of the principal and interest of the loans, and the remainder used to cover the costs of maintenance, staff salaries and operating expenses. In other provinces, the pool income allows for revenues to be distributed across the provincial network as needs arise and also permits consistent tolls to be set throughout the province. However, not all provinces have adopted this structure.

70. As discussed in Section 3.4, the adoption of electronic toll collection within a province—and even better between different provinces—would result in further efficiency gains and increased safety to both the users and the toll road operators.

4.2 Truck Overloading

Truck overloading is very common and detrimental to the road assets

71. The Chinese Highway Law (Clause 49) requires that the “Axle load mass of vehicle running on highway shall conform to technical standard of highway engineering” and “any vehicle excessive to limits of load ... shall not be run on roads, bridges, tunnels or auto ferries” (Clause 50).² Unfortunately, vigorous competition pushes carriers to rely on overloading to ensure a profit. As shown in Table 4, which is from a study in Anhui province, truck overloading is rampant.

Truck overloading seriously reduces pavement life

72. International research has shown that pavement damage due to loading is proportional to the axle load, raised to the fourth power (Chinese government manuals on pavement design use the power 4.35). This means that heavier vehicles cause greatly increased rates of pavement damage, as shown in Figure 8.³ If all individual axle loads are below the design limit, the road would reach its

¹ The law does not apply to expressways sold to private companies or floated on the stock market.

² HPCD (2005) indicates that the maximum axle load limits are set by the MOC at 10 t per single axle, 18 t per double axle and 22 tons per triple axle. The maximum loads permitted for vehicles (including trailers) are: 2 axles-20 t; 3-30t; 4-40 t; 5-50 t and 6-55 t.

³ As an example of the implications of overloading on pavement damage, the data in Huang, et al. (2005) indicate that approximately 8.5% of the two-axle trucks sampled carried over 20 t on the rear axle, with the highest load 25 t. This 8.5% resulted in 45% of the total pavement damage. 25% of the two-axle trucks carried over 16 t on the rear axle. This resulted in 85% of the pavement damage.



design life. However, excessive loading will significantly reduce the pavement's life. For example, HPCD (2005) reports that increasing the loads from 10 tons to 13 tons reduces the life of the pavement from 8 years to 3.9 years.

Table 4: Truck Overloading on Expressways in Anhui Province

Statistic	Truck Type			
	2-Axle	3-Axle	Semi-Trailer	Truck-Trailer
% of trucks overloaded	60	76	77	91
Average overloading (% of registered tonnage)	141	206	172	258
Maximum overloading (% of registered tonnage)	669	600	650	553

Source: Hang, et al. (2005)

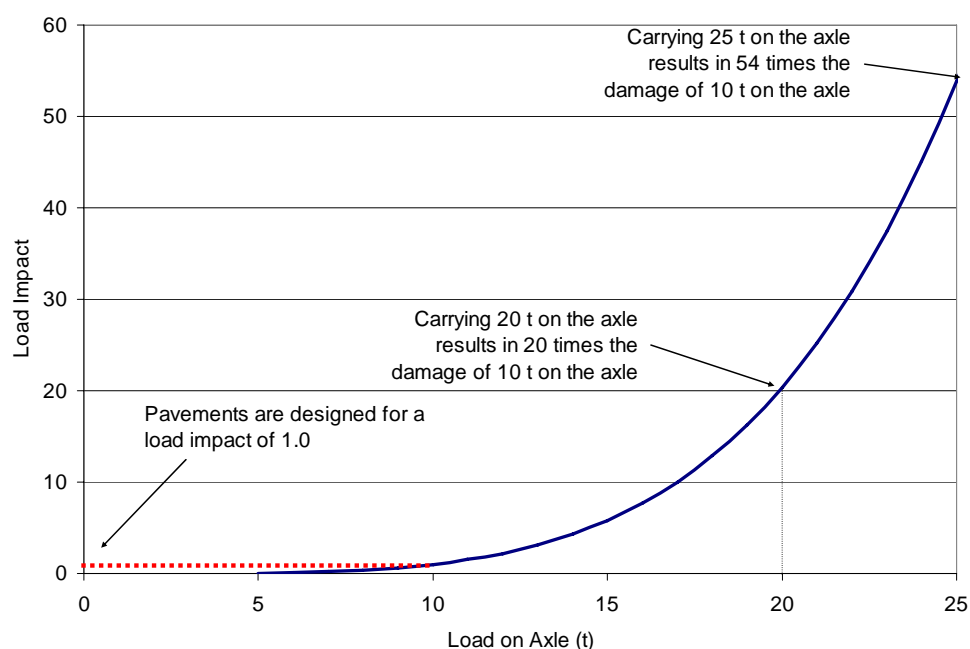


Figure 8: Impact of Overloading on Pavement Life

73. Some Chinese expressways designed for 15 years have required reconstruction after only 5-7 years.¹ Bridges have also been seriously damaged by vehicle overloading. The annual economic cost of overloading to the Chinese economy was reported by HPCD (2005) to be over US\$ 3.5 billion.

Overweight enforcement and penalties are inconsistent

74. Enforcement of axle load regulations is the responsibility of the provinces and the municipalities. The commitment to enforcement varies among provinces, and also seems to vary over time. A major enforcement campaign was organized nationwide in the summer of 2005, which achieved a notable reduction in

¹ It must be noted that shortened lives are not only due to the prevalence of overloading but also sometimes due to lapses in construction quality control.



overloading in the short term. However, the sustainability of these results after the campaign ended is uncertain. Similarly, the penalties are inconsistent. For example in some instances trucks are forced to offload the goods¹, in other cases fines are levied, while in some cases a higher toll is imposed (see Box 4).

75. Overloading control is also a challenge in other countries and addressed in different ways. A summary of overloading enforcement in North American and Europe is given in Box 5. The successful implementation of an enforcement program depends on a number of factors including:

- ❑ The technology adopted for enforcement must be readily available at a reasonable price;
- ❑ There must be strong incentive to implement overload controls and regulations;
- ❑ It is an area with potential corruption so adequate supervision and controls are needed;
- ❑ Enforcement must have a random nature so truck operators cannot plan to avoid them;
- ❑ The weight limit should preferably be adjusted to climate conditions;
- ❑ Controls should be implemented over a timeframe that allows for the industry to adjust gradually;
- ❑ The implementation of regulations needs to be supported with information campaigns to raise awareness and training programs.

76. An increase in overloading enforcement limited to expressways may lead to a drastic shift of overloaded vehicles to the adjacent road network, which is often less able to carry these vehicles due to lower design standards. Hence, a consistent nation-wide policy towards the enforcement of axle load limits, on all road classes, should be considered, with sufficient financing for enforcement.

77. Traffic safety would benefit from axle load limit enforcement. Overloaded trucks are over-represented in accidents in mountainous areas. For example, when the Xiaotang to Gantang expressway opened in 2003 there were some 80 accidents with over 20 deaths on the long (3-4 km) down slope sections, even though the maximum gradient of 4% was not unusually severe. Overloading and the poor condition of the vehicles were among the primary causes of these accidents (World Bank, 2005). Overloading, and many old vehicles, leads to trucks traveling at very low speeds on the expressway—often on the order of 30 km/h. This creates a major speed differential with fast moving cars and thus a large number of rear-end collisions².

Pavements need to be designed for actual traffic loads and should be stronger

78. In addition to enforcement, China's pavement design procedures need to be reviewed. International experience shows that relatively small extra investment by highway providers will enable road users to save transport costs several times larger. Currently, pavements are designed based on the single axle design load of 10 tons, not the actual expected traffic loading. This design practice is far from optimum and has contributed to very large losses to the

¹ For example, in Inner Mongolia overloading on the Class II and below network is the responsibility of municipalities. Trucks are forced to unload excess material in specific discharge areas and this material becomes the property of the municipality, who auction it. Profits are used for road maintenance.

² It is recognized that the fault of such accidents are not only the trucks. Car drivers themselves often speed and show poor lane discipline.



Chinese economy through premature pavement failure, even more so due to construction quality issues (see Box 6). Enforcement will be more effective if axle load standards are raised consistent with revisions in truck dimensions, and pavements' load carrying capacity.

Box 5: Overloading Enforcement in North America and the EU

In **North America (USA and Canada)**, transport controls are governed by a series of transport regulations that cover several aspect including the load limit, driving time and distance controls, and the type of materials the vehicle is allowed to carry. Such regulations are usually implemented by police or a specific government unit. Medium and heavy freight vehicles (usually above 5 tons gross weight) are tested randomly on the network via various types of weight stations or mobile control units. Large expressways usually have permanent static weight stations and weigh-in-motion (WIM) installations. Vehicles are also required to undergo specific state/provincial inspections on a recurrent basis for safety and emissions controls. In some area, weight limits are adjusted to take into consideration the pavement structure strength during specific season. For example, in Canada, load limits are lowered during the spring thaw to minimize damage to the pavement structure. With the advent of stronger truck axles, the transport industry is lobbying for increased axle loads. Today, most North American pavements also experience higher freight volumes, higher tire pressures and different axle load configurations than those that they were initially designed for. This has led to the preparation of new pavement design guides.

Most **European Union (EU)** countries adopted similar regulations before joining the EU. The new European Transport Policy for 2010 now establishes goals to improve traffic safety and efficiency which would require extended safety control measures for heavy good transport on roads. To achieve these objectives, a significant increase in police personnel will be needed, which is not practical. The EU is therefore experimenting with fully automatic integrated road controls that would include: automated overload control of wheels, axles, trucks and trailers. Already, some countries such as the UK are testing WIM systems linked to automatic vehicle detection system. This would see overloaded vehicles have their licence numbers automatically analyzed and using the vehicle registration database, the owners can be automatically issued with violations.

4.3 Traffic Safety

*Expressways
have reduced
accidents*

79. Due to their high design standards and separation of vehicles from non-motorized traffic, expressways tend to be safer for traveling than other road classes. The diversion of traffic from local roads to expressways has contributed towards traffic safety improvements. However, there still are issues that need to be addressed.

*Effective
implementation of
the 2004 National
Road Safety Law
holds great
promise*

80. Traffic safety is a multi-sector activity, so it requires good co-operation between the expressway operators, the Public Security Bureau (traffic police) for enforcement, emergency services for responding to incidents, and education



departments for improving the behavior of drivers and other road users. In many provinces there is good co-operation among the sectors, but improvements can still be made through better implementation of the 2004 National Road Safety Law.

Box 6: Construction Quality

Since the first expressway was constructed, China has developed a strong skill base in the areas of design, consulting and contracting. However, there are still ongoing issues with regard to construction quality. Poor construction quality leads to premature failures and incurs higher costs, especially in the medium-long term, which can affect the financial viability of the expressways. Some pavements have failed in less than 3 years.

There are four principal factors behind the construction quality issues:

- ❑ There has been a great deal of pressure on many expressway projects to complete the construction in as short a time as possible. Construction periods are set very low in contracts, irrespective of the difficulties of the project and with limited provision for changes should problems be encountered. Contractors have often been pressured to finish early, although recent MOC guidelines go some way towards addressing this problem.
- ❑ The technical specifications were not strong enough, particularly with regard to the quality of materials. This has recently improved and MOC has issued tighter specifications for expressways, but more needs to be done, especially in the area of testing.
- ❑ Contractors are often constrained with how they approach the project and often are forced to follow the instructions of the client. This affects their initiative, limits their ability for innovations and improvements in efficiency, ultimately affecting the quality of the works. The full and strict application of FIDIC regulations would help this issue.
- ❑ There is a lack of clarity in the roles and responsibilities of the client, the engineer and the supervision teams. The client often takes too many decisions, rather than relying on the engineer and supervision teams.

The achievements of China in improving their construction quality should not be downplayed. Significant improvements have been made since the start of the NEN program. However, more needs to be done. Stricter application of FIDIC regulations and a change in the sharing of responsibilities between the various parties should lead to more responsible contractors, engineers and supervisors and thus, better quality roads.

81. Multi-sector co-operation is particularly important when it comes to tunnel safety. As the NEN expands into more mountainous terrain, the frequency and length of tunnels increases. Some new expressways have over 20% of the road length in tunnels, with some super-long tunnels of 8 km or more. Dealing with tunnel incidents requires: (i) proper designs for monitoring and control equipment, tunnel lighting and ventilation, and emergency facilities; and (ii) efficient emergency operations.



Tunnel safety is becoming more important and China needs to adopt international best practices

82. In recent years tunnel safety has drawn increased attention, especially after the Mt. Blanc and Gotthard tunnel fires in Europe. China has not updated its standards to reflect these developments. Few tunnels take advantage of the latest techniques in monitoring and control equipment. For example, since tunnel incidents are so infrequent, using computers to monitor videos and automatically identify incidents has been proven to be more efficient than manual video monitoring. The current Chinese lighting and ventilation standards do not guarantee successful evacuation in the event of a fire.

83. With emergency operations involving the expressway operator, the traffic police, the fire service, the local ambulance service and the road administration department, a joint emergency co-ordination group needs to be established. The group should undertake regular drills to ensure a timely response. CPC (2006) indicates that currently on average it takes 30 minutes to respond to tunnel incidents, against the recommended international value of 5 minutes.

China's geometric design standards need updating

84. The expressway geometric design standards have to be updated to reflect recent findings, especially in the area of traffic safety. For example, accidents are caused by: (i) the standard approach of altering the gradient on long downgrades approximately every 900 m (experience has shown that this leads to loss of control accidents since truck drivers, often with overloaded trucks, need to constantly readjust their speeds); (ii) inadequate protection of users from roadside obstacles; and (iii) poor design of interconnecting roads and crossroads.

4.4 Truck Regulations

85. There is competition in China between road and rail transport, with railways offering cost savings of 40-60% over trucks for long shipments (> 700 km). As in other countries, road transport has advantages over rail for high-value and/or urgent cargoes. However, the trucking industry suffers from many inefficiencies which could be improved through a change to the policy and regulatory environment. Some of the issues are:

- ❑ No clear procedures and qualifications for obtaining a 'national' license for cargo trucking;
- ❑ Local protectionism (e.g. cities may not allow outside trucks to enter or collect return loads without tedious city-specific licensing and registration);
- ❑ Multiple licensing requirements (e.g. for different business segments, new branch offices, etc).
- ❑ Absence of a competitive market offering trucking services (e.g. too many manufacturers rely on their own fleets which results in inefficient utilization);
- ❑ Poorly designed and equipped warehouses which increase inventory losses and impede efficient inventory management; and,
- ❑ Difficulties in enforcing cargo liability.

86. There is a need to improve the regulation of the trucking industry, particularly with regard to discouraging and inhibiting provincial and local protectionism. A vibrant and competitive trucking industry will help ensure that the full benefits of the NEN are realized.



4.5 China's Transport Skill Base

The NEN development has created a range of skills in the transport sector

87. Over time the development of the NEN has created a range of skills in China's transport sector. The Chinese contracting industry has matured and is capable of undertaking large and complex projects both within and outside China. However, the sector capacity can be improved further by strengthening its skills base in a number of areas:

- ❑ Road investment decisions are not made based on the full range of investment tools available, such as multi-criteria analysis or sophisticated cost-benefit analysis. Often, alternatives are only considered in a cursory manner and they do not always consider thoroughly the local development plans. The increasing complexity of the economy needs to be reflected in the approach to road planning, including mitigation of environmental impacts and resettlement.
- ❑ Construction supervision can be strengthened to improve the quality of works. The IFIs no longer systematically require provinces to hire international consultants for general construction supervision. However, there are still opportunities for improving the performance of Chinese companies further, for example through the adoption of ISO 9001 or similar certification for firms.
- ❑ Management of expressways should aim to meet the international standards. In particular, while China has abundant experience in construction, there is a limited understanding of 'asset management' principles and techniques.

China's contractors have been much more successful outside of China than its consultants

88. China's contractors have already proved themselves to be successful outside of China. If Chinese institutes and consulting firms wish to expand internationally, they need to undergo a transformation in their work practices. Currently, many operations exactly follow MOC or other established guidelines or local practices, even if they are not entirely appropriate. If the system allowed more flexibility in adapting to local circumstances, and interpreting guidelines in a creative fashion, the organizations would develop skills that would allow them to compete in the international market.

89. Within the positive overall assessment, it is important to note that there exist regional differences. Managerial capacities of provincial—and local—governments in the less developed western regions are more limited than those in the more prosperous eastern provinces. Twinning arrangements and other effective means need to be adopted to disseminate good management approaches across the provinces.

90. With the accelerated development of China's transportation network a full set of service industries has also emerged. These include private trucking companies, freight forwarding companies, roadside facility operators, consultants, contractors, equipment suppliers, toll road operating companies, design institutes, researchers and vehicle manufacturers. The emerging service industry is beginning to look like the transportation industry of many developed countries.

91. It may be timely to consider how all the organizations, agencies and companies involved in the provision of road transportation can work together to improve the performance of the road transport system. Formal means of communications and partnerships need to be developed to allow transportation professionals and agencies to share knowledge, enable local practitioners to



interact with central agencies, and in general improve sector practices and standards.

92. One way of achieving this is through the creation of a national organization which would facilitate discussion and research on key technical issues and sector policy. The involvement of government would create a vertical link as well. Such an organization would need strong support from the national, provincial and municipal governments, as well as from the parties involved in the transport sector.

A 'Highway Research Board' would be a good way to bring together the road transport community

93. The Transportation Research Board (TRB) of the USA represents a model. The TRB within the US National Academy of Science has been effective in bringing together sector agencies, government and research communities to address the emerging technical and policy issues. It is well respected throughout the world for its contribution towards the transport sector. The establishment of a China Highway Research Board (CHRB), or something similar, with founding members representing a wide cross-section of the road transport community, would provide an excellent catalyst or 'incubator' for technical problem solving, innovation and the dissemination of knowledge in the transport sector. Box 7 presents some principles for establishing a CHRB.

Box 7: Setting up the China Highway Research Board

From the outset the CHRB should be based on defining principles. These could include:

- The Board is open to all road transport professionals;
- It is financed by contributions from members;
- Members pay according to their means;
- The Board targets transfer of technology and research within China and internationally;
- It establishes standing committees on key issues and the management of committees rotates to ensure input of new ideas;
- It holds an annual conference; and
- It publishes research and policy papers based on committee input.

As a starting point for the discussion that could contribute to the establishment of a CHRB, the Executive Director of the US Transportation Research Board attended a workshop in Beijing in May, 2006, at which he outlined the ways in which the TRB functions and how those lessons might be useful to the further development of the Chinese road system. He also discussed in general the concept of twinning to link the beginning of the CHRB to the TRB as a way of sharing experience and assisting in the further development of ideas, organization and funding of the CHRB.



5 The Way Forward

5.1 Key Policy and Operational Actions

China seeks to develop a sustainable and balanced transport network by 2020

94. The Government of China is committed to developing a sustainable and balanced transport network. Besides an additional 45,000 km of expressways over the next 15 years, major investments in local roads are also planned. By 2010 all villages in the eastern and central provinces and all towns in the western provinces are planned to be connected by an all-weather road to the network, and by 2020 all villages in the western provinces likewise. The priority of the government to invest across road classes and across provinces is well justified.

95. To achieve these ambitious physical targets, this paper has highlighted three strategic areas of action under the second phase of investments in the expressway network: (i) road planning and evaluation of investment impacts; (ii) financing; and (iii) management and operations. The priority actions are summarized in Table 5, along with their expected effects.

Planning Roads and Evaluating their Impacts

The greatest impact on poverty reduction and growth will be through a regionally differentiated investment strategy

96. A geographically differentiated strategy for expressway expansion holds promise for high impact on poverty reduction and equitable growth as summarized below:

- ❑ **Eastern provinces:** The existing network approaches completion, road capacity expansion will be essential where traffic volume warrants. Due to their high traffic levels, these provinces have potential to attract private finance on a competitive basis from domestic and international bidders.
- ❑ **Central provinces:** The focus of central provinces should be on completing network connectivity. A careful review would ensure that the economic returns from the selected investments are high and based on sound estimates of traffic. If traffic levels are not high enough to justify the investments, then either the investment should be delayed or the engineering design criteria should be adapted to attain a better balance between capacity and demand.
- ❑ **Western provinces:** The focus of western provinces should be on accessibility, which calls for a balanced investment program in expressways and other road classes. The objective is to enhance the investment environment and to promote the regional economy. This will be achieved through better network coverage and connection to the eastern and central provinces. Investments should be screened to ensure that the economic return justifies the investment. This screening will need to ensure that the social and network connectivity benefits from the investments are considered so that the economic and social benefits are maximized. To avoid costly investments up front, the potential for staged construction may be considered.

The MOC needs to be actively involved in the NEN

97. The National Government through the MOC has played a pivotal role in developing the NEN. It needs to continue in this role, especially in ensuring sustainable development and management throughout the country. This role includes improvements to planning methodologies, updated standards—especially



for pavements—and the establishment of a community of professionals for the exchange of views and experiences, and the ensuing development of a knowledge base.

Financing

There is a need to increase financing for maintenance and operations

98. On the basis of rough estimates and figures in other countries, it appears that around 3% to 5% of provincial GDP should be adequate to cover maintenance needs and expansion of capacity commensurate with expected traffic growth¹. However, the share of funds for maintenance must increase, given that the total network length has grown substantially, parts of it are now more than ten years old, and many roads are deteriorating faster than planned because of premature pavement damage. The maintenance and operation needs estimated for 2005 are \$5-6 billion, compared to total spending on roads in 2004 of about \$58 billion (Table 2), but those needs will grow faster than GDP.

99. The lower categories of roads, to which the Government has attached high priority, will also warrant increased funding.

New funding sources will be required

100. The two objectives—funding maintenance at a growing level that will stay ahead of road deterioration, and the priority now being given to improving low-category roads—will require new funding sources. Both maintenance and rural access related activities are less amenable to borrowing as a source of financing. Firstly, maintenance and operation are not normally financed by debt, as they are recurrent costs. Secondly, the Class III and lower roads do not lend themselves to tolling, making them hard to finance by debt. Whether local governments are legally allowed to guarantee loans for such roads needs to be clarified; and systems to discipline borrowing with indirect guarantees from local governments need strengthening.

101. Of equal concern is the imbalance among provinces in their ability to raise the necessary funds. As shown in Figure 3, some thirteen provinces may currently have difficulties in affording proper maintenance. Without radical corrective measures the situation will only worsen, and at an accelerating pace.

The regional imbalance in funding calls for some form of fiscal redistribution between provinces

102. The regional imbalance can be addressed through mechanisms to redistribute funds from richer parts of the country. However, fiscal powers are so decentralized from the National Government to the provinces, that they leave few options for fiscal redistribution from province to province.

103. Chapter 3 of this paper presented three options, not mutually exclusive, for financing road budgets from sources other than borrowing, and to effect redistribution: (i) private financing and public/private partnerships, (ii) pooling of toll revenues through organizational integration of toll road companies, and (iii) the levying of a tax on fuels.

104. Financing of expressways in the richer provinces is relatively attractive to private investors (Section 3.2). To a limited extent this can free up public funds for redeployment to socially desirable roads in poorer areas. Transparent, competitive procedures for selecting private partners and for allocating risks between the public and private parties would ensure efficiency gains from private financing.

¹ By way of comparison, the US was spending about 3.7% of GDP on the interstate and other federal roads in 1980, aside from all other local road expenditure plus maintenance.



Table 5: Recommended Framework for Action

Strategic areas	Key recommended priority areas for action	Expected results
Road planning and evaluation of their impacts	Pursue redistribution of resources across road classes and across provinces from the central level to take into account the different financial capacity among, and within, provinces	Balanced development of road infrastructure
	Renew efforts to strengthen economic analysis to tailor investment timetables and design to expected economic and social benefits, including improved demand estimation and analysis of alternative options (in terms of alignments and phases)	Optimization of investments
	Update engineering standards, especially those for pavements in line with evolution of truck fleet characteristics (weights and dimensions)	Better tailoring of investments to local needs & economic truck loads
	Coordinate scheduling of expressway investment with interconnecting urban and local/rural road networks	Maximized use of road networks
Financing approaches	Explore alternative mechanisms for engaging the private sector, evaluated against public finance comparator	Enhanced efficiency in road investments and management
	Establish a national or provincial toll financing mechanism and improve efficiency in collection through electronic systems	Sustainable financing in line with increasing traffic demand, with potential for redistribution across provinces and road classes
	Implement in a gradual manner a fuel surcharge to address increasing financing needs for maintenance and the continued expansion or upgrade of investments across road classes	Sustainable financing with potential for geographic redistribution, and better price signals to road users
	Renew efforts to strengthen data collection, programming methods, and capacities at the provincial level to help maximize use of resources for maintenance in light of increasing needs for sustainable road asset management	Proper upkeep of large stock of recent road investments
Management and operations	Rationalize the organizational and financial set-up for the operation of publicly-owned expressway links within each province (following directives set by National Government)	Comprehensive management of expressway network, allowing for cross-subsidization (based on specific operational and maintenance needs)
	Design and implement a comprehensive overloading control approach (enforcement, toll levels in line with degree of overloading) that avoids diversion of traffic while penalizing overloading in line with the incremental cost for the damages to road pavement	Preservation of road assets and lengthening of the life of pavements
	Discourage or inhibit provincial or local protectionism in the trucking industry	More efficient trucking industry and greater traffic levels
	Improve engineering quality-control procedures learning from past experience	Higher quality of construction works
	Renew efforts for effective implementation of the 2004 National Road Safety Law, including the required inter-agency coordination	Enhanced overall road safety and reduced fatality rates
	Update standards for tunnel operations to incorporate updated monitoring and control designs and equipment	Enhanced overall road safety and reduced fatality rates
	Update expressway geometric design standards to reflect experience gained through road safety audits and the analysis of traffic accidents	Enhanced overall road safety and reduced fatality rates
	Enhance skills and analytical methods on cost-benefit analysis, construction supervision, and expressway operational management	Continued improvements to highway sector management and research skills base
	Establish a community of professionals for the exchange of views and experience among organizations, agencies and companies involved in the provision of road transportation infrastructure and services	Improved horizontal dissemination of knowledge, promotion of innovation



105. A national toll policy to redistribute toll revenues to poorer regions should be examined (Section 3.3). An integrated tolling system across expressway companies and concessionaires can also help improve the efficiency of travel for users, leading to higher overall revenues.

Current toll rates should not be raised

106. Current toll rates should not be raised, as they are already high. There is a need to review the existing toll levels to assess the extent to which they are discouraging traffic from using the expressways. The recent trend towards charging trucks by weight can complement the renewed efforts in enforcing axle load limits.

A fuel surcharge can help bridge the funding gap

107. Around the world the most common source of funding for the local road network's development and maintenance is a surcharge on fuel consumption (Section 3.4). This surcharge should be allocated for the upkeep and development of the network, in a manner commensurate with the needs, and can be implemented gradually, with exemptions or rebates for farmers and other rural inhabitants to reduce its impact.

Management and Operations

108. Operational rationalization of the operational set-up of provincial expressway companies can further improve travel and management efficiencies within each province.

The truck overloading problem needs to be aggressively tackled

109. A consistent and effective approach to the problem of truck overloading is urgently needed. International experience suggests that, since the transport costs incurred by road users are several times larger than the construction and maintenance costs incurred by highway agencies, a solution allowing heavier axle loads than China's present limits, while adhering to safety standards and building stronger pavements, will yield a large net benefit for the economy.

110. At the same time, better control of construction quality would enhance pavement lives and reduce the maintenance burden.

There are opportunities to further improve road safety

111. The continuing high rate of fatal traffic accidents stresses the importance of fully implementing the 2004 Road Safety Law. Tunnel safety will require particular attention, as the number of long road tunnels in China is growing. Recent disastrous fires in road tunnels in Europe have shown the need for special contingency planning and coordination measures. A review of highway geometric standards is equally warranted to make roads safer.

112. MOC can play a leadership role to foster the development of skills related to roads and road transport, both within the different levels of the government and in the design institutes and consulting firms that serve the sector. The founding of a national organization or coordination mechanism comparable to the US Transportation Research Board holds great promise for disseminating information and encouraging the development of professional skills.

5.2 Potential Areas of World Bank Support

113. A new Country Partnership Strategy to guide the World Bank's support to the Chinese economy over the period of the 11th Five-Year Plan was agreed with



the Government and approved by the Bank's board of directors in May, 2006. With respect to roads it endorses the above priorities and foresees continued lending in support of strategic investments—on both the NEN and rural roads—with high development impact, as part of a broader infrastructure program. In so doing the Bank will provide support in strategic areas that bring innovation, exchanges of international practices, and strengthening of government capacity—at the central, provincial and local levels—in the planning, programming and management of road infrastructure.

There are many opportunities for innovation and capacity building under IFI financed projects

114. In line with the priority actions listed in the previous section, areas where innovative concepts are likely to be incorporated in future road projects will include:

- ❑ planning, programming, and management methods and skills at the provincial and local levels;
- ❑ measuring and analyzing the economic and social impacts of road interventions to create a knowledge base for further improvements in planning and programming approaches;
- ❑ promoting alternative approaches for the private sector participation, particularly contracting mechanisms for road maintenance;
- ❑ assessing the range of potential financial resources to enhance the use of the road network while maintaining its asset value; and
- ❑ strengthening road and tunnel safety policies, operational and institutional practices, including the range of interventions undertaken by highway agencies, traffic police, emergency medical services, and those responsible for public awareness campaigns.

115. At the national level, the Bank can assist the MOC in designing and establishing a country-wide sector information base that would allow central entities to monitor the performance of the expressway and high-class networks.

116. The Bank can also offer international experience to address sector externalities, such as road safety, HIV/AIDS, environmental and social impacts.

117. The Bank aims to continue its role as a knowledge sharing bank in partnership with others including the Asian Development Bank and other development agencies active in China.



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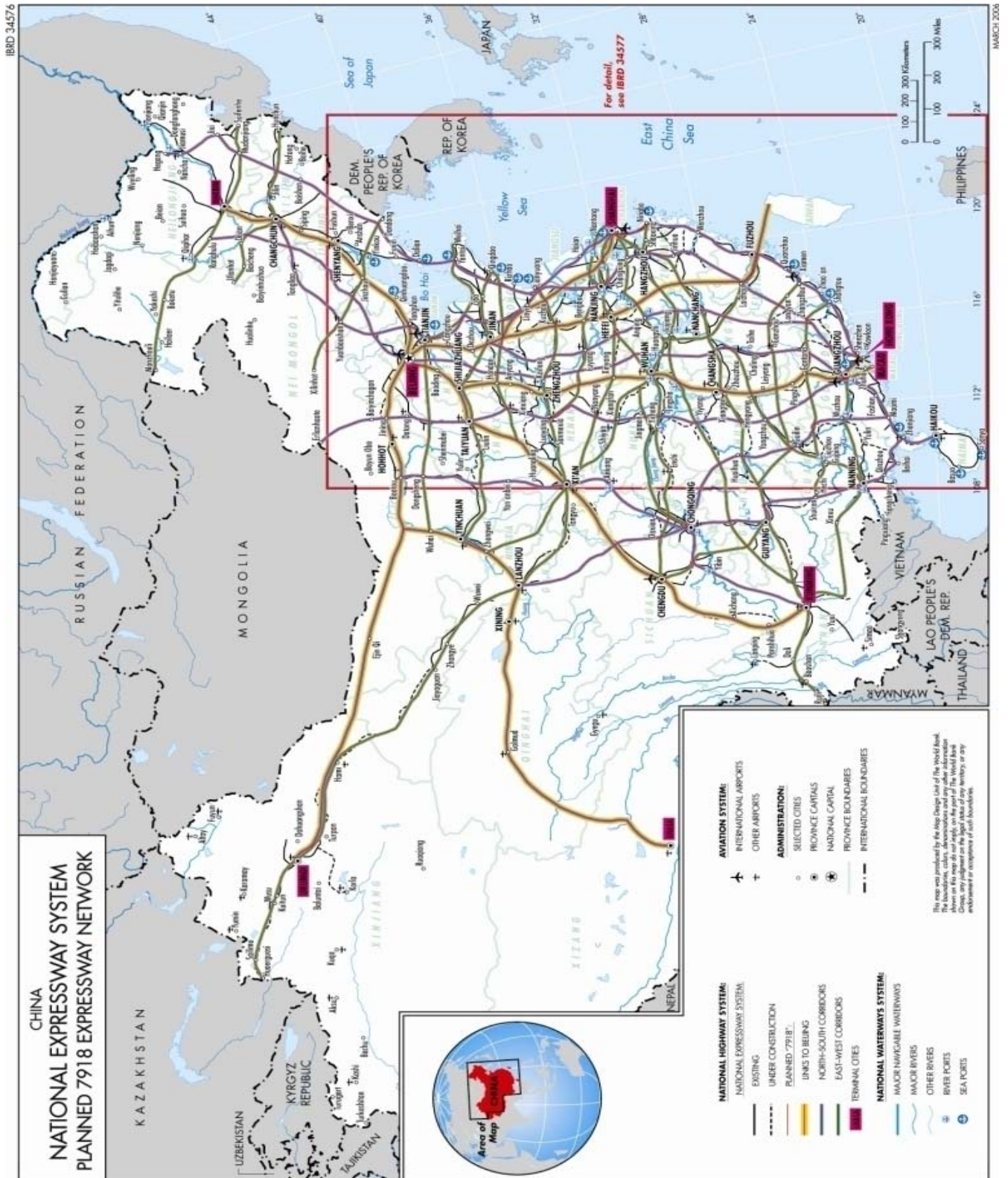
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Annex A: Maps





China's Expressways: Connecting People and Markets for Equitable Development





Annex B: Comparison of Electronic Toll Collection Approaches

Option	Advantages	Disadvantages	Summary
Transponder/Smart Card Based System	<ul style="list-style-type: none"> ❑ Commonly used. ❑ Technology is off the shelf. ❑ Can be customized to deal effectively with the weight/distance issue. ❑ Card readers and transponder readers can be installed on existing toll booths. ❑ Cards could be sold through commercial outlets like phone cards or value could be increased by mobile phone money transfer. 	<ul style="list-style-type: none"> ❑ Standards would need to be set nationally and implemented provincially. ❑ A revenue sharing pool system would need to be established. ❑ Significant installation of new hardware would be needed at most toll stations. 	This option is attractive and perhaps offers the best potential for application in the future across all provinces. However, implementation is not simple and significant effort would be needed to fully implement this kind of system. The advantages of moving this direction are clear and persuasive, but the effort would need to be led by a collection of provinces and companies who clearly see the benefits to be derived from a standardized approach to tolling and collection.
GPS/GSM System (Global positioning system coupled with mobile phone).	<ul style="list-style-type: none"> ❑ Economically Efficient. ❑ Non traffic distorting. ❑ Capable of national operation. ❑ Technology is proven and can be implemented on a national (or provincial) level by private companies. 	<ul style="list-style-type: none"> ❑ Currently used only for trucks. ❑ Constitutes a major change for Chinese provinces. Requires installation of hardware or payment of cash or credit for each truck. ❑ Significant new roadside and truck-based hardware is needed. 	The system offers many advantages but is not likely to be a practical option for Chinese roads for some time. The coordination necessary among companies and provinces is beyond what is likely to be feasible for some time.
Vignette System (Payment in advance for unlimited use of roads in given period)	<ul style="list-style-type: none"> ❑ Simple to administer using the same approach as used for phone cards. ❑ No net loss of revenue by provinces or companies, as tolls collected are remitted to companies directly according to the previous year's traffic carried. Can be targeted to only trucks. ❑ Allows for administrative simplicity at company level and efficient use of trucks across network. 	<ul style="list-style-type: none"> ❑ Frequent users benefit at the expense of infrequent users. ❑ Weight-based but not distance-based. Some advantage for trucks to overuse the system. This could cause negative effects on congested roads. ❑ May be resisted by provinces as an infringement of their authority. 	So far used only in small countries. Questionable if appropriate for a country as large as China.



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