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Social cost of railways relative to other modes of transport

Ministry of Railways, China

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Executive Summary

The aim of this project is to examine the methods used for evaluating the social costs of transport, and the way in which such evaluations are used in practice in selected countries. On the basis of this review an approach is recommended for China, estimates made of the social costs of rail and competing modes of transport and suggestions put forward as to how the results should be used as part of an integrated and sustainable transport policy. The project included organizing a brief study tour for a Chinese delegation to Europe.

Social costs of transport may be divided into internal and external costs. Internal costs are those experienced directly by the transport user. These will be taken into account in their decision taking. By contrast, external costs, those imposed on other people, will not be taken into account without government intervention. External costs of transport include noise, air pollution, global warming, delays and part of accident costs, and infrastructure costs where these are not fully charged for.

We first consider European Union transport policy. Concern for external costs is reflected in regulatory decisions (especially emissions levels for various types of vehicle on the different modes), pricing policy and investment appraisal. In particular, the European Union is pursuing a policy of internalising external costs in transport prices (i.e. making the user pay for these costs), although progress in implementing this policy is slow.

We then turn to the use of social cost measurement in three major European countries, Britain, France and Germany. Evidence on the use of social cost estimates from these three countries is considered. It is found that, whilst social cost estimates may sometimes be used for general policy studies and for pricing decisions, their use is not systematic and tends to be confined to particular research studies. By contrast, all three countries make routine use of social cost estimates as part of cost benefit appraisals determining investment programmes and in decisions on individual projects.

The next section describes the methods developed for valuing external costs in European research and outlines typical values. Three broad approaches are described. The damage cost approach values the actual damage done by the physical impact of the externality. It is most appropriate for valuing damage to buildings or crops from air pollution. The willingness to pay approach uses either actual decisions or hypothetical surveys to estimate what people would be willing to pay for the externality to be removed. It is appropriate where the main impact of the externality is a direct effect on the well being of the person affected. Delay, noise and risks to health and safety are valued using this approach. The cost avoidance approach estimates the cost of reducing the level of the externality concerned in the most efficient way possible. It is used where there is a constraint on the overall level of the externality, as is the case for greenhouse gases for countries that are parties to the Kyoto agreement; in that situation an increase in emissions from one source must be offset by a reduction elsewhere in the economy. Results from Europe are used to illustrate the discussion.

Value transfer methods are then used to adjust these costs to Chinese conditions, taking account of factors such as differences in real incomes, in emissions levels of vehicles, in fuels used in electricity generation and in load factors on the different modes. Estimates of the total external costs of transport for inter urban road, rail, air passenger and coastal shipping and inland waterways for freight in China are given in the following tables; congestion is excluded because of a lack of data.

Total external cost of road transport China 2006 excluding congestion (only expressways and national highways)					
In billion RMB	Car	Light duty vehicle	Heavy duty vehicle	Bus	Road Total
Air pollution cost	5	15	42	8	70
Noise cost	2	3	7	2	14
Climate change cost	4	4	10	3	21
Accident cost	16	16	16	12	60
Total	**27**	**38**	**75**	**25**	**165**

Note Climate change costs are based on the central cost value for 2010 (100 RMB/tonne CO2).

External costs of road transport on expressways and national highways in China account for around 165 billion RMB per year even considering only environmental and accident costs. Around two thirds of these costs are caused by freight transport (light and heavy duty vehicles) and one third by passenger transport (car, bus). The highest shares of total costs are caused by accidents and air pollution. We concentrate on these types of roads because of lack of data, and because they are the roads most directly competing with rail. For all roads (i.e. including urban roads, smaller rural roads, etc.), the total external costs would be much higher. Since vehicle mileage on expressways and national highways only account for 6-7% of vehicle mileage on all roads, total external costs of road transport in China might be around 10-20 times higher: around 2,000-3,000 billion RMB per year).

According to a rough extrapolation of congestion costs from limited studies, the annual costs of road congestion in China might additionally amount to around 500 billion RMB per year for all roads.

Total external costs of rail transport in China (national railways) are estimated to account for almost 30 billion RMB per year. The calculations include external costs of indirect emissions from electricity generation. Around 70% of the total rail costs can be attributed to freight transport and only 30% to passenger transport. Again costs arising from congestion or from capacity shortages are omitted.

Total external cost of rail transport China (national railways only) 2006			
In billion RMB	Rail passenger	Rail freight	Rail Total
Air pollution cost	1.1	5.5	6.6
Noise cost	0.2	0.9	1.1
Climate change cost	0.2	1.3	1.5
Accident cost	7.4	11.8	19.2
Total	**8.9**	**19.5**	**28.4**

Note Data also include indirect emissions from electricity generation. Climate change costs are based on the central cost value for 2010 (100 RMB/ton CO_2).

According to the estimates below, the total external cost of domestic aviation in China is around 6 billion RMB/annum. This figure does not include noise cost, however, due to lack of data. The external costs of inland waterways amount to about 16 billion RMB per year.

Total external cost of domestic aviation and inland waterways China 2006		
In billion RMB/a	Domestic aviation	Inland waterways
Air pollution cost	0.25	15.2
Noise cost	n.d.a	-
Climate change cost	5.4	1.0
Accident cost	0.1	-
Total	**5.8**	**16.3**

Note n.d.a. = no data available

Since traffic volume data (e.g. passenger-km and freight tonne-km) for road transport in China is rather weak, the following comparison of average external cost per passenger-km or tonne-km for road and rail transport in China needs to be treated with caution. According to the available data, the average cost per passenger-km in road transport is 0.11 RMB, whereas for rail transport the average cost is around an eighth of this . For air passenger transport, the average costs are between those for road and rail but almost twice the figure for rail. For freight transport, the average costs per tonne-km are 0.25 RMB for road, which is more than twenty times higher than for rail transport. For inland waterways, the average costs are much closer to those for rail than for road, but still almost 50% higher than the rail figure. The much greater superiority of rail over other modes than is found in Europe is mainly due to the very high loads carried by typical Chinese trains.

External cost in RMB per passenger kilometre or freight tonne kilometre		
	Passenger	Freight
Road	0.11	0.25
Rail	0.013	0.009
Air	0.024	N/a
Water	N/a	0.013

For decision taking, it is not the total or average costs that are important, but the marginal costs. For pricing, the short run marginal social costs (SRMSC; i.e. the costs of adding traffic to the existing infrastructure) are relevant, but for investment planning the long run marginal social cost (LRMSC; i.e. the cost of adding traffic when infrastructure capacity is also adjusted) is relevant (arguably in a situation with rapid traffic growth and high investment to match, LRMSC is relevant for pricing as well).The main difference is that LRMSC includes the costs of capacity expansion but not additional congestion, whilst for SRMSC it is the other way round. For pricing purposes it is only the costs not directly borne by the user that are relevant, but for investment planning all costs are relevant. So the figures quoted below include vehicle operating cost and infrastructure costs.

Both in terms of short run and long run marginal social cost, rail is very much cheaper than car or heavy goods vehicle for both passenger and freight transport, suggesting that both in terms of pricing and investment policy a cost minimising approach to dealing with traffic growth will favour rail over these modes whenever this is a feasible alternative. Bus is more competitive in terms of long run marginal social cost, and the scope for making more use of bus, for instance by giving it more priority, should also be considered. It must be said, however, that the comparative costs are dominated by infrastructure and operating costs; the lower incomes in China mean generally that external costs are a less significant part of the overall costs than in Europe, although they may be expected to grow proportionately as incomes rise.

Marginal social costs for road and rail transport (RMB per passenger or freight tonne kilometre)		
	Short run	Long run
Car – expressway	0.93	0.99
Car – highway	1.04	1.21
Bus – expressway	0.43	0.25
Bus – highway	0.28	0.35
HGV – expressway	0.43	0.46
HGV – highway	0.50	0.61
Rail Passenger	0.14	0.20
Rail Freight	0.06	0.07

Our policy conclusions may be summarised as follows.

1. There is a need to develop more detailed social costs estimates for China. It appears that the costs of road accidents and air pollution from lorries, as well as road congestion, are particularly important issues. What is needed is both better physical data, for instance on the volumes of traffic and speeds on individual stretches of road, and China specific estimates of monetary valuations of items such as the value placed on time savings and and on increased safety. Valuation of noise nuisance, including aircraft noise, should be another priority.

2. The analysis needs to be extended to urban areas, where many external costs are likely to be much greater than for inter urban traffic. However, obtaining reliable results for urban areas really needs detailed information on

factors such as traffic flows and numbers of houses affected by different levels of noise and air pollution.

3. External costs should be taken into account both in overall investment strategy and in detailed appraisal of individual projects, using values derived from state of the art techniques. This could be done simply by transferring values from international experience as used in this report, but again more accurate results require the estimation of monetary values for China from specific new studies.

4. China should move towards more efficient pricing. A fuel tax to reflect global warming costs, and more roughly other externalities (whose impacts are less well correlated with fuel consumption), would be a good start, although it is likely that reflecting the high levels of social costs in cities would require some form of additional charge, such as a cordon toll. Obviously the implications of these developments for current levels of tolls on interurban roads would need to be considered.

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Responsibility for this draft is of course solely our own.

1. Introduction

The aim of this project is to examine the methods used for evaluating the social costs of transport, and the way in which such evaluations are used in practice in selected countries. On the basis of this review an approach is recommended for China, estimates made of social costs of rail and competing modes of transport and suggestions put forward as to how the results should be used as part of an integrated and sustainable transport policy. The project included organizing a brief study tour for a Chinese delegation to Europe.

The evolution of rail policy in China is at a particularly important stage, in that rapid economic growth is placing great strains on the capacity of Chinese railways, whilst growth in all modes of transport is leading to concern about the total social cost of the transport system, including congestion and environmental costs. Decisions are needed on the extent to which rail capacity should be expanded to avoid the need to invest in other modes, and how to go about this expansion in terms of planning, funding, pricing policy and appraisal.

Social costs include all the costs imposed by transport, whether internal (i.e. borne by the user) or external (borne by third parties). Internal costs include the costs of providing and operating vehicles and, where the operator is directly responsible for this, the costs of the infrastructure. External costs include congestion, accidents and environmental effects (of which the key ones are air pollution, noise and greenhouse gases) and infrastructure costs where these are not fully charged for. Clearly their magnitude is important to the above decisions.

An advantage of rail transport which is of growing importance in Europe as elsewhere in the world is its lower environmental impact compared with other modes of transport. In the past, the advantage has been seen particularly in terms of noise, visual intrusion and local air pollution. Nowadays, whilst these factors all remain important, the dominant consideration has become energy consumption and greenhouse gas emissions. Rail is also generally regarded as a safer mode of transport than road, and can play a part in relieving the problems of road and airport congestion.

The principal ways in which these advantages may be taken into account are through regulation, pricing and investment decisions. In order for this to happen, however, it is necessary that externalities be quantified and valued in money terms, so that they can enter into the price of the different modes of transport, and be set aside other costs and benefits in appraisal of regulation and of investment proposals.

In an efficiently working market economy, prices indicate the costs of alternative goods and services. Consumers are then able to choose whether particular goods and services are worth the cost, or whether they prefer to choose alternatives. In turn, firms will decide whether to invest in productive capacity on the basis of a comparison between the revenue they can earn from the facilities and the cost of providing them.

However, in the absence of specific intervention, external costs and benefits will be ignored in these decisions. This is because they are inflicted on persons who are not a party to the transactions that cause the costs. The standard textbook solution to this is for governments to quantify and value the externalities and to levy charges or taxes which cause these to be reflected in the price paid for the goods causing them. Such taxes may be used to ensure firms take externalities into account in private investment decisions; in the case of government decisions, the technique of social cost benefit analysis explicitly considers the value of such costs and benefits alongside all other relevant factors.

It is not possible to take social costs into account for any of these purposes without a good understanding of their magnitude and valuation. For this purpose, accounts which bring together the social costs of all modes of transport on a comparable basis have been developed for a number of European countries, and the European Commission has funded projects (in particular UNITE) to develop such accounts Union wide.

This final report covers the following issues:

- an in depth analysis of existing practice by the European Union and selected member states concerning use of social cost information for transport policy,
- an in depth analysis of existing research for the European Union and selected Member States concerning social cost estimation
- the data base collected in China and the methods used to provide a rough estimate of social cost, for rail and competing modes of transport - road, water (for freight) and air (for passenger).
- Conclusions on the relevance of the results for rail policy in China

2. European Union policy

The European Union is a union of 27 member states, who retain autonomy regarding issues which are not deemed to affect the union as a whole (the so-called principle of subsidiarity). Thus in terms of transport policy, laws applying to the union as a whole are only passed relating to decisions which are seen as important in terms of achieving fair competition and economic and social convergence between the member states. These issues include environmental regulation, transport pricing for commercial traffic and investment in key international corridors.

Regulation is used in a number of contexts. For instance, there are noise and air pollution standards which all new road vehicles in Europe are required to meet, and there is currently debate on whether to extend this to regulation of the average greenhouse gas emission of new cars. There are requirements regarding noise levels of aircraft and of railway rolling stock. Once the value of the environmental externality is known, the appropriate level of these standards may be determined by comparing the benefits with the costs, taking care to include any indirect effects – for instance, energy consumption standards which reduce the cost of motoring may lead to additional travel, offsetting some of the benefits.

Since the mid 1990s, EU pricing policy has been to internalise externalities in transport prices. Starting with the Commission’s Green Paper 'Towards Fair and Efficient Pricing in Transport' (CEC, 1995), and continuing with the White Paper 'Fair Payment for Infrastructure Use' (CEC,,1998) and the Common Transport Policy White Paper (CEC, 2001), there is a strong emphasis on pricing policy reflecting the full social costs of transport use. But progress in implementation has been slow. The specific approach adopted has been to base charges on short run marginal social cost; that is to say the additional costs of adding traffic to the existing infrastructure. This approach to pricing policy is generally deemed appropriate where capacity is slow to adjust to changes in demand, meaning that surplus capacity exists on parts of the network and congestion elsewhere.

The aim is to use pricing to reflect the social costs of different modes of transport. This may impact in a number of ways – how many motorised trips to make, where to go, what mode of transport to use, and what type of vehicle if the choice is road. For this reason pricing has major advantages over regulation - for instance pricing may lead to a cheap polluting car being chosen by someone travelling low distances in a rural area, but would give a much greater incentives to buy a low emission car to someone covering a lot of distance in urban areas where the cost of emissions is much higher.

Generally, environmental externalities produced by use of the transport infrastructure vary with the type of vehicle, location and time of day. Thus ideally they need to be incorporated into an infrastructure charge (the obvious exception being the effects of global warming, which do not vary with where and when the carbon is omitted, so that a fuel tax proportionate to the carbon content of the fuel is an ideal internalisation instrument). For roads, the ideal way of reflecting costs would be universal electronic road pricing, but this would be expensive to implement; in its absence, second best methods such as simple kilometre based charges, fuel tax and annual licence duty have to be used. For rail in Europe, there is now a requirement that explicit charges are levied for the use of the infrastructure. This has come about because of the policy of opening up the infrastructure to new entrants. For air and water transport, the choice is between adding such charges to port or airport charges, or to air traffic control charges or to fees for using national waterways.

Within the rail sector, short run marginal social cost is taken as the basis for track access charges (Directive 2001/14/EC). Charges may be differentiated with respect to environmental impacts, but this must not add to the average level of charges unless environmental costs are also reflected in charges for other modes.[1] Mark ups on marginal social costs are permitted where necessary in order to finance particular schemes or rail infrastructure in general in the event that the government does not provide sufficient funding for pure marginal social cost pricing to be applied. In the case of electricity for traction, the costs of global warming are internalised to a degree by the inclusion of electricity generation in the European emissions trading scheme; there are proposals to extend this approach to air

1 Note that the Directive also allows Member States to introduce time-limited compensation schemes for the use of railway infrastructure for the demonstrably unpaid environmental, accident and infrastructure costs of competing transport modes in so far as these costs exceed the equivalent costs of rail.

transport and possibly also to water. Otherwise, there are currently no proposals to internalise the costs of environmental externalities for the air and water modes.

For the road sector, following adoption of Directive 2006/38/EC on road charges (amending Directive 1999/62/EC), the European Union allows the introduction of tolls for heavy goods vehicle (lorries) on all roads. Differentiation is possible according to the level of congestion and accident costs and to the environmental performance of vehicles as indicated by the EURO emissions category of the lorry. This differentiation has to be designed in a way that the total revenues from tolls do not exceed the total allocated infrastructure costs, except that a surcharge of up to 25% is permitted in environmentally sensitive areas such as the Alps. This can be used to fund alternative modes of transport.

Switzerland (a non EU country) was the first country to introduce a kilometre based charge for heavy goods vehicles; since Switzerland did not need to follow European legislation, it was able to base its charge on explicit calculations of the social costs of heavy goods vehicles (See Table 1). Germany and Austria have also introduced kilometre based charges on motorways and many more countries are considering doing so. The European Parliament has argued strongly that the overall level of charges should reflect levels of externalities, and further proposals on this, to amend the above Directive to allow full charging of external costs of congestion, noise and air pollution, with any additional revenue to be used for improving the environmental performance of the transport system, were proposed by the European Commission in July 2008. (Costs of climate change are thought to be best internalised through fuel tax and external accident costs through insurance). Charging for the private car is regarded as a matter for individual member states.

Table 1

External Costs of heavy goods vehicles in Switzerland (2000)

	m.euros	m.rmb
Accidents	30	230
Noise	145	1110
Air pollution		
-Health	282	2160
-Buildings	62	475
Nature and landscape	41	314
Climate change	156	1195
Production and disposal of infrastructure, vehicles and fuel	36	276
Other	64	490
Total	816	6249

Source: Presentation by Balmer at Imprint-Net inter urban road group seminar 3.

Appraisal refers mainly to the choice between investment projects but may also be applied to broader policy questions. The point here is to allow for the impact of new transport infrastructure, not just on the mode in question but also on other modes. Thus for instance, the environmental externalities produced by a new rail line will be partly offset by reduced externalities from other modes. It must be remembered however that when new rail infrastructure is provided, not all the rail trips using it would otherwise have used road or air. In Britain it is estimated that around half of the additional rail travel generated by an improved intercity rail service would otherwise have used car, with a load factor of around 2 per vehicle, so that on average an additional rail passenger kilometre takes about 0.25 of a car kilometre off the roads.

As regards assessment approaches for infrastructure, the development of the Trans-European Networks is the most important issue for the European Commission. This is because it is the only transport infrastructure for which there is explicit European funding. At EU-level, methodologies have been developed especially for the evaluation of infrastructure projects in Eastern Europe (e.g. the TINA programme). With the results of the European project HEATCO, there are for the first time harmonised guidelines for Cost Benefit Analysis (CBA) in transport at the European level. These guidelines will set the standard for the assessment of future transport projects in Europe. However, most countries still have their own guidelines concerning CBA in transport including social costs: e.g. the Netherlands (Overzicht Effecten Infrastuctuur, OEI), United Kingdom (New Approach to Appraisal, NATA), Austria (Strategische Prüfung im Verkehrsbereich, SP-V), Finland (Guidelines for the Assessment of Transport Infrastructure Projects in Finland), and Germany (Bundesverkehrswegeplan).

In the next three sections we consider in turn the use of social cost estimates in transport policy in three major European states – Britain, France and Germany. In each case we consider firstly the use of social cost estimates in project appraisal, then the development of accounts and finally pricing decisions.

3. Britain

3.1 Introduction

In Britain, from the second world war until the 1970s, the transport sector was largely owned or regulated by the state. This was the period of most rapid growth of road traffic in Britain, which saw the development of the motorway network. Following the election of the Thatcher government in 1979, extensive deregulation and privatisation of the transport sector took place. Transport planning fell from fashion, and the government sought to make the sector much more market oriented, privatising air, bus and rail sectors and even starting with the process of privatising roads through the 'shadow tolling' approach whereby the government paid private developers for building or upgrading roads in terms of a payment per unit of traffic using them. If the market dictated a rapid expansion of roads and road traffic and a decline in public transport, then this is what would happen.

However, some writers, notably Goodwin (1991), identified the emergence of what he calls the `new transport realism' in the late 1980's. This is the realisation that environmental and budgetary constraints make it impossible to provide for the rate of growth of road traffic that then existed, making a new set of interventions inevitable. A major part of the problem of transport is its very rapid growth. In the passenger sector, the total amount of travel has more than trebled since the early 1950's. This has been partly due to an increase in the number of motorised trips (with a corresponding reduction in walking and cycling), and partly due to a substantial increase in mean trip length. Also notable is the reduction in bus and coach travel over this period. Rail has managed to maintain its volume in absolute terms, and even to increase it substantially in recent years, but has a greatly reduced market share. In the freight sector, there has also been a big rise in traffic, again largely due to increases in average length of haul. Reasons for this include: the decline of bulk commodities and their replacement by high value goods which are distributed over a much wider area; and changes in production and distribution systems emphasising concentration, specialisation and again trading over much wider areas. Road has become dominant, but this time rail has declined substantially in absolute as well as relative terms, though with some recovery in recent years. The rapid growth of water transport was mainly associated with North Sea oil.

The result of these trends has, of course been rapid growth in road traffic, which has quadrupled since 1958. For many years roads policy had been described as ‘predict and provide’ - i.e. predict what the demand will be and provide the appropriate capacity. There is a sound economic argument for following such a policy as part of the 'market' approach to transport provided that pricing policy is appropriate and takes full account of all the costs of road use including environmental effects. However the roads programme came under vehement attack from environmental concerns. At the technical level the Department's cost-benefit analysis programme was subject to a range of criticisms including the failure to take adequate account of environmental factors (whilst these were listed in a framework of effects of schemes they were not valued in the cost-benefit analysis undertaken), the failure to take a strategic view of investment options (what were appraised were mainly small individual stretches of new or improved roads) and the failure to allow for the traffic generating capacity of new roads. The problem was brought home in a particularly influential report from the Royal Commission on Environmental Pollution (1994), and a follow-up report (RCEP, 1997). A further significant factor was the conclusion of the Standing Advisory Committee on Trunk Road Assessment (1994) so that on balance the evidence suggested that building new roads does generate additional road traffic, as had long been alleged by environmentalists but not allowed for in the government's appraisal methodology.

An important part of the 'new transport realism' is an appreciation of environmental constraints, but it is also argued that in purely practical and fiscal terms it would simply not be possible to cope with forecast traffic growth by increasing road space. Congestion would worsen so seriously that alternative policies would have to be sought.

The debate culminated in the publication of a transport Green Paper (DOT, 1996), which accepted that there was a need to pay increased attention to the environmental impact of transport policy and to reduce dependence on the car. Ways of achieving this would include market oriented measures, such as action to reflect better social costs in the prices of transport modes, planning oriented measures such as a presumption against planning permission for further out of town retailing, and switching the emphasis in investment from roads to public transport. It was also accepted that quality improvements were needed in bus services, and that if these could not be secured by voluntary 'quality partnerships' between local authorities and bus operators then legislation may be needed to introduce an element of force.

Not surprisingly, Labour Party transport policy also sought a return to a planned approach Following its election in May 1997, in July 1998 it published a transport White Paper (DETR, 1998). As well as various provisions regarding the planning and regulation of public transport, it announced a new appraisal framework to be applied to government funded transport investment, and the introduction of powers for local authorities to introduce road pricing or a tax on non residential parking and to retain (most of) the revenue to finance other transport measures.

More recently, the government commissioned two influential reports – the Stern report on global warming (Stern, 2007) and the Eddington report on transport's contribution to economic growth and productivity (Eddington, 2006). In a response to these reports in 2007 (DfT, 2007), it committed itself to objectives of maximising the contribution of transport to competitiveness and productivity of the economy, to cutting greenhouse gases from transport as a contribution to meeting overall targets for Britain of reducing greenhouse gases from the economy as a whole by 26-32% by 2020 and by 60% by 2050, to improving safety and security, to improving quality of life and to promoting equality of opportunity. The package of measures to achieve this include doubling the capacity of the railway network, greatly improving the energy efficiency of road vehicles and road pricing to reflect the social costs of transport as well as selective measures to increase the capacity of the road system.

3.2 Project and programme appraisal

Transport projects requiring government funding have long been subject to social cost benefit analysis in Great Britain. The 1997 Labour government pledged itself to introducing a common appraisal framework for all government spending decisions on all modes of transport; the NATA (New Approach for Transport Appraisal) form of appraisal is now used for all projects funded by central government or by local government through local transport plans. These include public transport subsidies as well as investment projects. In the case of the rail sector, almost all passenger services are provided under franchises let by the government which specify levels of service. Decisions about service levels and the infrastructure investment needed to provide them are subject to this form of appraisal, although the government has declared itself against rail closures in the immediate future, so it may be reasonably surmised that the decision to retain the entire existing rail network is political rather than economic. Guidance on the application of the appraisal method and on assumptions and values to be used may be found in:

www.webtag.org.uk

The quantified element of a NATA appraisal is contained in three tables – the Transport Economic Efficiency table, the Public Accounts Table and the Monetised Costs and Benefits Table. The first of these includes user benefits (such as time savings) and impacts on private sector providers (revenues, costs and grants). The argument is that these are the factors which may be valued most reliably. The second examines impacts on central and local government funding, including impact on tax revenues (this can be a substantial negative element for public transport schemes if they divert traffic from highly taxed car travel). The third table adds in not just environmental impacts (greenhouse gases and noise are valued in money terms) but also such important user benefit factors for rail as crowding, reliability and interchange. For the time being values based on the Passenger Demand Forecasting Handbook (produced by the Association of Train Operating Companies on behalf of the rail industry passenger forecasting council) are used for these.

For freight, the key user benefit attributes are:

- journey time
- reliability
- frequency
- security

There is less evidence on their valuation than for passenger attributes but a recent study (Freight user benefits) is to be found on the DfT website (www.dft.gov.uk).

Adjustments are made for optimism bias (the measured tendency for costs to be underestimated and revenue over-estimated, particularly at early stages of project development), and benefit cost ratios are then calculated.

A particularly important factor to consider is the benefit from diverting traffic from road, which arises because road vehicles are not paying their full marginal social cost of road use. In the absence of a full multi-modal model, this may be estimated by applying diversion factors to discover the impact on traffic of changes in rail patronage, and then applying values to represent the difference between the saving in external cost and the tax revenue for the type of road and the time of day in question. These are based on research in Sansom et al (2001).

For rail freight, the current view of the Department of Transport is that this is a commercial business, and benefits to freight users should not count in the appraisal. However, benefits from diverting freight traffic from road are estimated as for passengers and used in appraisals including appraisals of grant schemes designed to transfer freight from road to rail. Values for 'sensitive lorry miles', which are lorry miles for which there is deemed to be a social benefit in diverting them to rail, are to be found on the DfT website.

This quantified appraisal is reported within a wider framework including various non quantified social, environmental and wider economic aspects. The complete list of costs included under the environmental objective comprises:

- Noise
- Local and regional air pollution
- Greenhouse gases
- Landscape
- Townscape
- Biodiversity
- Historic resources
- Water environment
- Physical fitness
- Journey ambience

Whilst only noise and greenhouse gases are currently routinely valued in money terms, research is continuing on extending this to other categories of environmental costs, particularly air pollution and landscape.

A review of the appraisal process (the NATA refresh exercise) is currently underway. A key issue in this review is whether to include estimates of wider economic benefits, such as increased productivity through improved accessibility to other firms' customers and workforce and reduced market distortions through local or regional monopoly power.

An example of an appraisal undertaken using this methodology is given in Table 2. This is an appraisal of a scheme to attract more containers to rail by increasing the loading gauge so that large containers can be carried on standard wagons, rather than requiring special wagons with reduced capacity and higher costs. For this type of scheme, the reduced external costs of carrying the traffic by rail rather than road are a major part of the benefits, and turn a financially unprofitable project into one that is socially very beneficial.

Table 2 Appraisal of a scheme to attract containers to rail by increasing loading gauge (Britain)

Revenue	+512
Operating Cost	-471
Investment Cost	-100
Developer Contribution	+10
Financial NPV	-49
External Benefits	
Reduced road	
Congestion	+260
Accidents	+24
Noise	+33
Local air quality	+15
Greenhouse gases	+17
Road wear and tear	+42
Other	+77
Total	+468
External Costs	
Rail Environmental Costs	-43
Loss of Road taxes	-108
Total	-151
Social cost benefit analysis NPV	+268

Note Benefits are shown as positive values; costs as negative. All values are expressed relative to the capital costs (which are given a value of 100) because of commercial confidentiality.

3.3 Social cost account information

Accounts for calculating social costs of transport for Great Britain are not produced on a regular basis. There used to be specific accounts produced for the road sector to inform the setting of taxes on heavy goods vehicles but these were abandoned many years ago. Data on physical measures, such as emissions and energy consumption for the transport sector, are produced annually but no money values are attached to them.

Transport social cost accounts covering all modes of transport were produced for Britain (as well as the rest of Europe) for 1998 as part of the UNITE project, and the government commissioned a further study based on the same methodology to find the total and marginal social cost of transport by road and rail (Sansom et al, 2001). The results in this document informed the subsequent debate on transport pricing as discussed in the next section, as well as contributing to appraisal.

3.4 Transport Pricing

In Britain, charging for the use of roads has traditionally been by means of an annual licence fee plus fuel tax, with tolls on some bridges and tunnels. A more sophisticated system using electronic road pricing was first recommended as long ago as 1964 in a report issued by the then Ministry of Transport as a way of dealing with the problem of congestion (the Smeed Committee report, Ministry of Transport, 1964). Road pricing was considered periodically as a way forward for major cities, especially London, over the ensuing years; in particular the results of a major study for London were published in 1997 (Government Office for London, 1997). But it was almost 40 years after the Smeed report, in February 2003, that the first road pricing scheme in Britain designed specifically to deal with congestion problems in Central London was introduced. It comprises a daily charge, initially £5 but now £8, for driving on central London streets. This has generally been seen as a success, having reduced traffic and congestion more than was generally expected without apparently serious side effects on the London economy (TfL, 2006), although it has been criticized particularly for having very high administration costs relative to its benefits (Prud'homme and Bocarejo, 2005).

In the meantime, interest in road pricing at the national level has grown. Through much of the 1990s, the British government had pursued a policy of increasing fuel tax in real terms each year (the so-called fuel duty escalator). In the year 2000, this resulted in protests, including blockading of oil refineries by a small group of road hauliers. In the aftermath of this protest, the fuel duty escalator was abandoned and fixed annual charges on heavy goods vehicles reduced. This development may have inclined the government to look for alternative ways of charging for the use of roads.

A study commissioned by the Department of Transport, Environment and the Regions was published by the Institute for Transport Studies at the University of Leeds in 2001 (Sansom et al, 2001). This showed that with the development of modern techniques and vastly improved databases it was possible to estimate the marginal external cost of road use at a fairly fine level of detail in terms of vehicle type, road type, location and time of day/week. The Commission for Integrated Transport (CFIT, 2002) took the argument further by publishing a study which went the next step and estimated the implications of a national road pricing scheme, whilst a further study of this was commissioned by the Independent Commission on Transport (Glaister and Graham, 2003). Finally the Department for Transport (DfT) published its own feasibility study of national road pricing in 2004. This found that marginal social cost pricing nationally would yield benefits of £10.2b in 2010 with net revenue of £9b after allowing for a reduction in fuel duty. Congestion would be greatly reduced with an overall fall in traffic nationally of 3% (9% in urban areas). A revenue neutral option was examined, which would give three quarters of the benefits of full Marginal Social Cost pricing, but overall traffic would increase by 2%. A system with a limited number of rates per kilometre varying by time of day could capture most of the benefits, but using simple charges which did not vary with distance or time of day gave much lower benefits. DfT reports great uncertainty about the costs of the Global Positioning System based technology that would be needed for national road pricing on all roads , suggesting this figure would lie in the range £10-27b to set up and £2-3b p.a. to run even without any allowance for optimism bias. However, it is expected that this figure will fall over time, both because of technical progress and because much of the technology needed for it may be installed in vehicles anyway for other purposes (such as transport information systems). Conurbation wide microwave based systems (which really on tags on the vehicles and beacons by the side of the road for London and seven other urban areas would cost £800m to set up and £720m p.a. to run.

The first proposal to introduce a national road pricing scheme was put forward in 2001 and was for heavy goods vehicle only. There are some particular issues relating to heavy goods vehicle charging. Firstly, the wear and tear and environmental costs they cause are very significant, and vary strongly with characteristics of the vehicles such as axle loads, as well as the nature of the roads on which they drive. It is impossible fully to reflect these differences through annual licence duty and fuel tax. Moreover, there is the particular problem of vehicles entering the country from other countries with much lower taxes, which can then compete at an unfair advantage. The proposal was to levy a distance based charge, varying between motorways and other roads, on all heavy goods vehicles, compensated by a refund of fuel duty. However, the scheme had been criticised as too expensive for what it achieved (McKinnon, 2005) and in 2005, when procurement of the technology was at an advanced stage, the government cancelled the scheme, stating its intention to postpone heavy goods vehicle charging until it could be part of a national system for all vehicles?.

Whilst the government initially reacted favourably to the report on national road pricing, it seems subsequently to have become more cautious, with various statements from Ministers that a national scheme was 10 years away, or indeed might never be needed. The government has however introduced a Transport Innovation Fund to fund local authority packages of measures that include developing road pricing proposals. In November 2005, seven local authority areas were selected for the first round of funding under this scheme. These include three major conurbations (Greater Manchester, Tyne and Wear and the West Midlands) and four other areas (Cambridgeshire, Durham, Shrewsbury and the Bristol area). Thus it now appeared that the next attempt would be to extend road pricing to more of the congested urban areas, with proposals for a national scheme confined to the distant future.

However, local opposition has led many of these local authorities to withdraw their proposals. Some, including Manchester and Cambridge, still pursued them, but following a heavy defeat for the Manchester proposals at a local referendum, the chances of an immediate extension of road pricing in Britain now look slim.

For other modes there is no explicit environmental pricing. For rail, access charges are based on extensive research on marginal wear and tear and congestion costs, but it was considered inappropriate to charge environmental costs when these are not charged for on roads. For air, there is a departure tax, and it is intended to switch this from a charge per passenger to a charge per aircraft movement to better align it to environmental costs. There is also the prospect of air transport being included in the European carbon trading scheme – producers of electricity for rail traction already are. There has been no serious discussion of charging for environmental costs of water transport, which for Britain is mainly coastal or international shipping.

3.5 Evaluation and conclusions

For Britain then it may be concluded that environmental arguments have played an important part in the debate on transport policy, including decisions about road building, support for rail and other public transport and fuel taxes. However, this debate has not usually centred on explicit estimates of the social costs of transport; so transport accounts giving social costs of transport are not produced on a regular basis. Money values of social costs do enter directly into appraisal of all transport schemes requiring government funding. Such money values have also been computed in a number of studies informing the debate on pricing, and in particular road pricing, although they do not directly determine the level of charges for the use of roads, and at present prospects for an extension of road pricing in the near future look bleak.

4. France

4.1 Introduction

Transport policy in France has tended to emphasise government planning rather than the role of the market, and liberalisation has proceeded more slowly than in other major European countries. In the rail sector, infrastructure has been placed in a separate company from train operations, but both are still state owned, and the infrastructure company (RFF) subcontracts day to day operations as well as maintenance and investment to the train operating company (SNCF). New entry has been limited to the freight sector, where it is now permitted in compliance with European law. Whilst there are privately owned urban public transport operators and toll roads, they operate under franchises from central government (also local?) rather than as part of a market solution.

Interest in social cost began in France in the early 60's, when the need for a means to prioritise transport schemes became obvious due to the scarcity of funds vis-à-vis the needs of infrastructure development (especially in the road sector at that period). Then was established the first Cost Benefit Analysis (CBA), and for its implementation it appeared that information on monetary costs of transport was needed as well as monetarization (placing of monetary values) of non-marketable goods, and more precisely travel time savings and value of human life. From that period on, rules on Cost Benefit Analysis were issued and regularly updated (about every five years), and these rules contained much data related to social costs. These rules were focused on road investment at the beginning, but progressively extended to the other modes. They became compulsory for all modes, and were designed to allow for inter-modal comparisons.

Another impulse towards social cost information was given by the intention to link information on the transport sector to the rest of the economy by building national accounts for transport embedded in the overall national accounting system. Then the "Commission des Comptes de Transport de la Nation" (CCTN) or "Committee for transport national accounts" was created which issued a yearly report giving a lot of information on the transport system (prices, costs, quantities) embedded in the national accounting system. The information was used first for strategic orientation based on macro economic information and second for developing macro-economic models focused on transport. The CCTN was from the start multimodal. It covered equally all modes, but dealt mainly with quantity data (traffic) and financial flows between the transport agents. It first produced information on monetary costs, and dealt with non monetary cost only about 15 years ago.

Both initiatives had a legal support. CBA was prescribed by a law of 1982[2], and the CCTN was set up by a common decision *(arrêté)* taken by the ministry of transport and the ministry of finance. CBA guidelines are issued by the ministry in charge of

[2] The Loi d'orientation des transports intérieurs (Law of orientation of domestic transports)

transport and are generally based on the recommendations of committees[3] which provide the general directions and the main estimates of unitary social costs. The CCTN approves the yearly report which is prepared by the economic division of the ministry of transport. It is composed of experts, representatives of the transport trade unions, professional organisations and administrative CEOs. All are named by a decision of the ministry of transport.

This organization is unique, no other sector has so developed social accounts, and for instance the main estimates of environmental costs of pollution, noise etc come from transport studies, as well as estimates of the value of human life. These estimates are now established taking into account the large number of studies at the European level taking into account the differences in income and in geographical structures of the European countries; they also take into account the international scientific literature on each subject, as appears clearly from reading the CCTN's reports.

France also contributes to the research in this field; its main contributions are presently focused on air pollution, the discount rate and global warming. It is developing also specific estimates of monetary costs for instance in railways, infrastructure costs and operation costs.

There is a debate as to whether external benefits, as well as external costs should be taken into account in the case of transport, for instance in the form of economic benefits over and above the simple reduction in transport costs brought about by a scheme. The official doctrine in France, though acknowledging external benefits, does not take them into consideration, at least until now.

4.2 Project and programme appraisal

Project and programme appraisal procedures are not unambiguously defined, though they have three phases: the master plan, the medium term planning and the implementation of each project.

The master plans are usually updated about every 15 years, though this period is not statutory. They are designed through rough CBA and assessments of more qualitative considerations: environmental strategy (this point leads to an increase of rail investments vis-à-vis road as rail is more environmental friendly than road), or land use (increase of investment in remote areas); but these qualitative considerations are subjective, and not necessarily consistent between projects.

Medium term planning does not follow a precise procedure, except for the investments in regions which are subsidized by the State and for which every 5 years, a list of schemes is made with the indication of how the State and the Région will share the financial burden. These investments bear mainly on secondary road and rail networks. For large investments such as new high speed rail lines, the

[3] Of which the most recent ones are "Transport : pour un meilleur choix des investissements" 1994; « Transports, choix des investissements et coût des nuisances »2001, « le prix du temps et la décision publique » 2005, « Le coût du carbone et les décisions économiques » forthcoming 2008

prioritization of the schemes comes from the decisions of the ministry, based on CBA and on political considerations.

When the decision to build new infrastructure has been made, the process of implementation goes through a lot of public hearings which are accompanied by economic studies, impact studies, environmental studies; the outcome can be technical changes in the project, in order to make it more in line with the results of the public hearings, or postponing implementation due to strong opposition to the project.

These procedures apply to all modes, but especially to road and rail. Their implementation and the use of CBA are less important in seaports, and even less in airports, where financial considerations are paramount. Guidelines are established in order to set out how CBA should be implemented. These guidelines are regularly updated, about every 5 years. The structures of these guidelines are as follows: a general approach is outlined, and more precise rules are established according to this approach, one for each mode. The last general outline dates back to 2004; it was updated twice in 2004 in order to take into account more recent results on external effects and on the discount rate.

CBA heavily relies on social costs estimates which are major inputs to the calculations. We elaborate on this point by illustrating it in the case of a rail project. The economic appraisal is intended to assess the desirability of the scheme for the whole country. It takes into account not only the benefit to RFF (the infrastructure company) but also the effect of the project on the other agents: SNCF (the main train operator), the users, the neighbours of the link, and the users of other modes.

- SNCF (and the future competitors when competition is introduced) is impacted on as its revenues and costs will change: its patronage will increase and its revenues too; but its costs will also increase, both operating costs and infrastructure fees. The CBA should include the change in profit for SNCF
- The users of the new line save time and this advantage has to be taken into consideration through the value of travel time savings. Some users, who are diverted from road to rail, enjoy better safety which should be included in the CBA.
- The neighbours of the track will suffer from environmental damage (noise, air pollution). Similarly CO^2 emissions will change.
- The other modes will be impacted on: for instance, the operators of airlines may suffer from a decrease of patronage, and their profits will decrease.

The sum of these effects provides the yearly benefits of the scheme for the country; this yearly benefit is compared to the cost, and the economic net prevent value is calculated. This may differ very greatly from the financial return; for instance two new high speed line have recently been reappraised to check the financial and social rates of return they offer. In the case of the LGV Atlantique, the ex post financial rate of return was estimated to be 4.1% and the social return 8.1%. For the LGV Rhone-Alpes, the ex post financial rate of return was 6.1% and the social rate of return 10.6%.

In order to calculate these annual benefits, it is necessary to know the following items which are the components of the social cost:

1. First the monetary costs and prices of the various transport modes at stake.
2. Second the value of some non market goods such as travel time, reductions in accident risk and the value of improved reliability of travel time.
3. And third, the monetary values of external effects such as air pollution, noise and global warming,

All these values are fixed by the previously quoted guidelines, which strictly determine the values used by the analyst.

The first category, monetary costs and prices, are estimated by the Ministry of Transport and by RFF, and the CCTN also gives rough information on them. They raise difficult problems in the case of rail, coming from the combination of imperfect competition, of the practice of yield management and secrecy on prices and costs from the operators. Imperfect competition implies that prices differ from costs to an extent which depends on the market power of the operators, in contrast to road haulage where competition ensures that prices are equal to costs. Due to the secrecy policy of the operators, which do not reveal their costs for fear that the competitors or the regulator could make use of them, it is very difficult to know the costs. Prices could be more easily estimated through statistical observation; unfortunately the efficient yield management policy of SNCF and its air competitors makes this observation very difficult.

The second and third categories, concerning non-market goods and external effects, are fixed in the guidelines on the basis of the reports of *Commissariats* (Commissions) which are appointed one or two years before the updating of the rules and whose task is to make general recommendations in these fields. Recent commissions dealt with the following items:

- the report “*Commissariat general du Plan*” 2000 dealt with the value of time, statistical value of human life, noise, air pollution, and global warming.
- The report “*Commissariat general du Plan 2004*” dealt with the value of the discount rate, which was previously fixed at 8% and which the report lowered to 4% (with a decrease after 30 years. It set the cost of public funds at the level of 0,3%????)
- A forthcoming report *“conseil d’Analyse Stratégique 2008*” will update the shadow cost of carbon in keeping with the new knowledge in this field.

4.3 Social cost accounts

Social costs accounts are one of the subjects of reports of the *Commission des Comptes de Transport de la Nation*. This commission was created in 1958 and modified in its role and its composition by several texts, the most recent one being the decree n°92-918 of 2nd of September 1992. According to this decree, its aim is [4] “to gather the data and information describing the transport activity production and use; it should allow the transport sector to be placed in the framework of the national economy. It should more precisely contribute to estimates of the costs and benefits of the various transport modes and the role of public sector in funding these activities”

A bill passed in 2002 stipulates that[5] the Commission publish every year a report which assesses:
- the economic and social results of the transport sector.
- the financial flows, especially concerning the public sector, related to the sector
- the results obtained in comparison with the means used
- the capital stock of the sector

As this brief review shows, these accounts are closely linked to the general national accounting economic framework; they give some place to social costs, but they deal more extensively with some other aspects, and they fall short of covering the whole range of social costs.

4.4 Transport Pricing

Transport pricing is one of the fields of application of social costs evaluation. In France this possibility has been scarcely used, and the reason is that public opinion is not in favour of pricing instruments. For instance discussion about road pricing is very limited, much lower than in the UK or in northern Europe, and even less than in another Latin country, Italy. The uses of social costs for transport pricing are rare. For instance France enjoys a large use of toll motorways, but this toll is solely set in order to raise money.

A noticeable fact was in the past (from the 70’s) the “*taxe à l’essieu*” (axle-load tax) which was established in order that lorries pay the damages they cause to the roads; this tax has also taken into account congestion and safety costs. It did not included the environmental costs, a point which is understandable as they were not acknowledged at the time the tax was created. When environmental costs became an issue, they were not included in this tax; now the tax has been cancelled.

Social costs are presently partly used in rail infrastructure charges. These infrastructure charges are not derived from economic calculations involving social costs. Nevertheless the spirit of the infrastructure charges directly comes from social costs consideration: these charges were first based on the marginal costs; of infrastructure but have been increased to improve cost recovery, and differentiated in order to reproduce the assumed congestion costs of the rail network.

[4] « *Elle a pour but d’assurer le rassemblement, l’analyse et la publication des données décrivant les activités de production de services de transports, ainsi que l’utilisation de ces services par les différents agents économiques. Cette description doit permettre de situer l’activité de transport dans l’économie de la nation. Elle contribue notamment à l’évaluation des coûts et résultats économiques des différents modes de transport et de la participation des pouvoirs publics au financement de ces activités.* »

A future probable use of social costs in transport pricing can come from global warming concerns, which are very important in French public opinion. The question of a possible CO^2 tax is on the agenda, and sooner or later a carbon tax will be implemented, hopefully based on the economic calculations of the CO^2 value.

4.5 Evaluation and conclusions

On the whole it appears that France has shown strong interest in social costs estimation, including their regular production for the transport sector accounts. But in terms of application, their regular use is solely in project appraisal. The use of social costs information for pricing is very limited, due to poor political support. There is a big gap between the perception of the environment by public opinion and the results of social costs calculations. With the values currently published, the impact of environmental costs and benefits on project appraisal is small, often negligible, while it would be important in pricing.

5. GERMANY

5.1 Introduction

Up to now, the German transport sector has been largely owned and regulated by the state. The German constitution defines that the major transport infrastructure (motorways and federal roads, the rail network of the national rail company DB and the major inland waterways) are in the ownership of the Federal Government. The general approach of German transport policy has been more interventionist than market-oriented, with a move towards more market orientation in the recent decade.

The huge destruction of Germany during the Second World War implied a priority of infrastructure investment and reconstruction afterwards, in particular of the road and rail network. Besides, transport policy in the first decade after the Second World War was characterised by state interventions and strict regulations such as restrictions of market entry (concessions for road hauliers, public service obligations (PSO) of DB with regulated fixed tariffs which were not cost-covering). This was followed by subsequent adjustments towards more market orientation in the 60s. Examples are a clearer distinction between public service obligations on the one hand and the obligation of DB to operate on entrepreneurial principles on the other hand, and the change from regulated tariffs to the opportunity for rail companies, road hauliers and inland waterway shippers to suggest tariffs for approval. The continued deterioration of DB's situation which was manifested in further losses of market shares and an increase in state subsidies[5], and increases in the negative effects of road transport, such as increased accident rates, led to a new policy program, the so-called Leber-Plan (named after the then-transport minister Leber). This program included, apart from investment measures and a ban on road transport for 28 types of bulk goods, a first attempt to charge heavy goods vehicles (defined as those with more than 4t load) with an additional, pay-load related tax, the so-called Leber-Pfenning. This instrument was introduced with the aim to shift road freight to rail and was terminated after a 3 year period[6]. The further worsening of the situation, but also the policy developments at EU level led finally to a cautious move of German transport policy towards more market orientation. This includes

- the rail restructuring process, introduced in 1994,
- open access to the rail network for all rail companies on payment of access charges,
- first PPP projects in the road sector,
- the abolishing of market restrictions and tariff approvals in road transport,

[5] Subsidies from the Federal Government increased from DM b. 0.36 in 1960 to DM b. 2.8 in 1966.
[6] After this period it was decided not to continue with this type of instrument but to reform the vehicle tax towards a scheme which increases progressively with weight and axles.

- the introduction of a distance-based HGV charging scheme for using German motorways,
- the intended part privatisation in autumn 2008, (now postponed due to the situation in financial markets).

Concern about the social costs of transport have been playing a role in Germany since the 80s. This has manifested itself in two ways: First, estimates of the social costs of transport as unit values such as value of time estimates (VOT), unit costs for accidents, noise, air pollutants and greenhouse gases have been introduced in the benefit-cost analysis for project appraisal in the Federal Masterplan on Transport Infrastructure Development (FMP). They have official status and are continuously developed. Second, several national though not official governmental studies have emerged, mostly conducted on behalf of environmental organisations such as the Federal Environmental Board (Umweltbundesamt UBA, see for example Huckestein and Verron 1996, Teufel et al. 1991, UBA 2007) and rail lobbying groups (Planco 1990, for the most recent one see INFRAS et al. 1997 on behalf of Allianz pro Schiene). The advent of these studies has been changing the political climate towards considering the environmental effects of transport, rather than providing direct quantitative inputs to taxation and charging. Up to now, an official consensus on an estimation method has not been achieved.

5.2 Project and programme appraisal

Social cost estimates have been used for a long time in project appraisal within the FMP (see BMVBW 2003). This requires consideration of the costs and benefits listed in Table 3. The following elements are valued in money terms:

(i) Values of Time

Values of time (VOTs) are applied in quantifying and monetarising time savings arising from investment projects. They refer to time savings in non-commercial transport (e.g. commuting to/from work, education, shopping, leisure – all of them considered in benefit component NE) and to time savings in commercial and business transport (cost reductions for vehicle operation which contain amongst others the time-dependent costs of passengers including the time costs of occupants in passenger cars and buses on commercial trips - considered in the component NB2). VOTs were obtained from WTP studies[7]. The project appraisal within the FMP 2003 uses a VOT of € 3.83 per person/hour[8].

[7] The current FMP 2003 uses results from studies which were conducted for the former FMP 1992 and which were adjusted at 1998 prices (the price base used for the FMP 2003).

[8] Obtained from a VOT of € 5.47 per person/hour which is reduced by a 30% threshold up to which travel time savings are not perceived.

Table 3: Components of benefit-cost analysis used in the Federal Masterplan on Transport Infrastructure Development in Germany

Cheaper transport (NB) NB1 Cost reductions for vehicle provision and maintenance NB2 Cost reductions for vehicle operation NB3 Changes of costs due to transport shifts
Maintenance of transport infrastructure (NW) NW1 Renewals of transport infrastructure NW2 Maintenance of transport infrastructure
Increase of transport safety (NS)
Improvement of accessibility of destinations (NE)
Regional benefits (NR) NR1 Employment effects from the construction of transport infrastructure NR2 Employment effects from the operation of transport infrastructure NR 3 Support of international relationships
Relief of environmental burden (NU) NU1 Reduction of noise NU2 Reduction of pollutants NU1 Reduction of separation effects
Impacts of induced traffic (NI)
Improvements in the accessibility of seaports and airports (NH)
Non-transport related functions (NF)
Investment costs (K)
Source: BMVBW 2003b.

(ii) Accident costs

The social costs of accidents considered in the project appraisal of the FMP include production costs (medical costs etc.), resource costs (production losses), costs of suffering and grief, loss of production in non-market sectors (e.g. in households) and material damages. They are evaluated by accident rates and accident unit costs differentiated by severity of the accident.

(iii) Noise costs

Unit costs for evaluating noise are based on a willingness to pay (WTP) study conducted for the former FMP from 1992 on behalf of the Federal Environmental Board UBA (see Weinberger et al. 1991). The evaluation distinguishes between noise emissions within built-up areas and outside built-up areas by different dB(A) targets. For built-up areas, reductions of noise costs are considered in project appraisal if in the reference situation an emission target of 37 dB(A) at night is exceeded (based on WTP studies which show that below this noise reductions are not perceived) and if the difference of noise emissions in the planning and the reference case are more than 2 dB(A). The procedure for extra-urban areas uses noise emissions targets of 59 dB(A) for recreation and reservation areas and 64 dB(A) for other areas.

For rail projects, a noise bonus of 5 dB(A) is applied which leads to a noise emission target of 42 dB(A) at night. This is justified by older studies indicating that rail noise is perceived as less annoying than road noise.

(iv) Air pollution costs

The project appraisal considers the costs of global warming, damages to vegetation, damages to human health (cancer), other damages to human health and damages to buildings. Pollutant emissions are based on specific energy consumption and emission factors, for rail differentiated by diesel and electric traction, for road differentiated by vehicle categories, road types and traffic density. Urban emission is estimated with concentration figures for typical roadside housing types and by considering average wind speeds.

Global warming costs are evaluated at € 205 per tonne CO_2, a value which is required to reduce CO_2 emissions in 2050 by 80% compared with the level of 1987 using the cost avoidance approach[9]. The valuation of costs caused by all other air pollutants is based on damage cost approaches, considering impacts on human health, buildings and vegetation.

(v) Severance effects

Reductions of waiting times for pedestrians to cross roads are evaluated with the VOTs used in the valuation of time savings

5.3 Social cost accounts

Germany has a long tradition in accounting for infrastructure costs and revenues from charges and taxes to recover these costs. The first methodological work was conducted in 1969 (BMVBW 1969) and followed by frequent inter-modal studies

[9] The technical costs to achieve this climate goal were estimated in a bandwidth between € 163 and €205 per tonne CO_2. In order to consider the effect of greenhouse gases other than CO_2, the upper bound was chosen.

covering road, rail, inland waterways and airports commissioned by the transport ministry (Enderlein 1978, 1980, 1983, Enderlein and Rieke 1987, Enderlein and Kunert 1990, Enderlein and Link 1992). Even though there has been an academic debate about the extension of these accounts to genuine social cost accounts (see for example DIW 1987) and despite the advent of several studies on the external costs of transport (Huckestein and Verron 1996, Teufel et al. 1991, Planco 1990, UBA 2007, INFRAS et al. 2007) no consensus on official social cost accounting, based on an agreed methodology and frequent updating procedures, has been achieved.

The most recent social cost figures for all transport modes in Germany were elaborated within the EU funded project UNITE (Link et al. 2002). Some refinements of methodology and input data for specific cost categories can be found in the GRACE project (Link et al. 2007).

5.4 Transport Pricing

Unlike countries such as Italy, France or Spain, Germany has no tradition of road tolling. For a long time, the interventionist, non-market oriented approach of German transport policy has used taxation rather than pricing. Traditionally, transport infrastructure has been considered as a public good provided for free. However, since the middle of the 1990s pricing instruments have been introduced in the transport sector, and environmental concerns have led to changes in energy taxation. Within the context of this report, three types of taxation/pricing instruments are relevant: 1) The eco-tax, 2) Rail track charging, 3) heavy goods vehicle charging on motorways.

The so-called eco-tax, introduced in 1999 is a general instrument of environmental taxation for all energy products, i.e. not restricted to transport. It is based on the "double dividend" concept. This concept includes the idea to internalise external environmental costs and to use the tax revenues generated for reducing social security contributions. In 2004, revenues from the eco tax amounted to € bill. 18.1, out of which € bill. 16.0 were fed into the pension system. Several studies were conducted before the introduction of the eco-tax, most of them dealing with the economic impacts. There has been no official study to estimate comprehensively the social costs for each sector as a direct input for defining the level of the tax.

Rail track access charging[10] was introduced in Germany in 1994. Several access charging schemes had been in use, all of them based on the principle of full cost recovery of infrastructure provision, maintenance and operation. By this definition, external cost components are generally excluded. However, there are some elements considered such as congestion (considered via a utilisation factor for the tracks), and delays (considered in an incentive scheme within which delays caused

[10] Access charges are charged for providing the tracks (including passing- and crossing tracks and the tracks within stations) as well as for operating the network and compiling the time table. The use of marshalling yards and peripheral facilities (such as cleaning of trains etc.) has to be paid by special access charges defined in an additional price framework.

by the rail companies and DB Netz are evaluated at €0.1 per minute). The charge level is defined by DB Netz, and there is no official study based on an agreed methodology to determine these charges.

In 2005, a km-based HGV charging scheme for using German motorways, applicable for all goods vehicles with a maximum gross vehicle weight of more than 12 tonnes, has been introduced. In accordance with the EU tolling directive, the charge considers the costs of constructing, maintaining and operating motorways including the costs of charge collection. External cost components such as accidents, environmental costs and congestion costs are excluded. The charge is differentiated by the number of axles and emission classes. Currently a proposal for further differentiating the charge by emission classes is under discussion. This means that environmental concerns will be taken into account but, as for rail track access charges, there is no direct link to social cost estimates. The charge level was defined based on a study commissioned by the transport ministry (Prognos et al. 2002).

5.5 Evaluation and conclusions

In Germany, social cost estimates are mainly used in project appraisal. Even though there is a long tradition of accounting for infrastructure costs and revenues from taxes and charges, official comprehensive social cost accounting which includes all components of social costs, does not exist. The use of pricing instruments was introduced in the mid-90s with rail track access charging and was followed in 2005 by the introduction of HGV charging for the use of motorways. However, the charges have no direct link to social cost estimates and were introduced rather with the aim to cover infrastructure costs. However, both rail track access charges and HGV charges allow social cost concerns to be addressed through differentiation of charges and this could be further developed by the inclusion of social cost components.

6. Social cost estimation

6.1 Introduction

We have seen in the previous sections of this report that there is a strong interest in the social costs of transport both at the European level and within member states. In some cases this has led to estimation of transport accounts showing all costs, including external costs, and revenues for the transport sector, and to discussion of including these costs in the determination of transport prices. But the routine use of these costs in all the countries considered is limited to investment appraisal, although even in this the extent to which costs are valued in money terms varies between countries.

There has been extensive research on the estimation of social costs in Europe at EU and at national level. Many studies have been carried out including:

- EU Research projects of several framework programmes to estimate external costs (such as UNITE, ExternE, GRACE, etc) need years??
- European programmes to standardize methods for appraisal, such as CAFE CBA and HEATCO.
- EU consultancy projects on external and infrastructure costs, particularly Marginal costs of Infrastructure use – towards a simplified approach, CE Delft, 2004.
- National research projects and studies on external costs (particularly for the UK, the Netherlands, Switzerland, Austria, Germany).
- Estimates of external costs by other international bodies (such as by UIC, ECMT).
- EU-proposals to standardize marginal cost estimation (High level groups).
- EU-Networking projects to discuss pricing instruments (CAPRI, IMPRINT-EUROPE. IMPRINT-NET).

Evidence on social cost estimation from many of these studies has recently been synthesized in the form of a handbook for the EU by the IMPACT project. This handbook is available on line at:
http://ec.europa.eu/transport/costs/handbook/doc/2008_01_15_handbook_external_cost_en.pdf

6.2 Overview of approaches

Social costs of transport include costs borne directly by users, such as the operation of vehicles, which are known as internal costs, and costs imposed on others, or external costs. The principal external costs are the provision and maintenance of infrastructure (where this is not the responsibility of the agent undertaking the transport itself), congestion, accidents and environmental costs.

Some elements of social costs, for instance infrastructure construction costs, may be taken directly from the financial costs, assuming market prices reflect social values (if not then shadow prices must be used). For externalities such as safety and environment, however, no market prices exist.

There are three different approaches for valuing externalities:

1. Damage cost approach: where a certain amount of damage is caused which must then be put right. In this case the cost is a direct financial cost, for instance of maintaining and renewing the infrastructure or of repairing buildings.

2. Willingness to pay approach, which looks at the willingness to pay or to accept compensation of consumers for the benefit or cost in question. This is used where there is a direct impact on consumers' wellbeing; for instance to obtain values of time or of accident risk, using either stated preference (based on hypothetical choices administered by questionnaire) or revealed preference (examining actual choices which reveal the value sought) techniques.

3. Avoidance cost approach: costs to achieve a certain target level of pollution. This is used where politicians have adopted a binding constraint on the level of pollution acceptable, so that any increase in one sector must be offset by reductions in another. This is most often used for greenhouse gases.

Each approach is relevant for some elements of social cost. Sometimes the costs or benefits in question are traded directly in markets, for instance if crops are damaged by pollution, healthcare costs are incurred or output lost through time off work. In these cases, the damage costs approach is appropriate.

In other cases, such as the disamenity (nuisance) effects of noise and air pollution, where the costs themselves are not traded in any market, markets may be found in which individuals reveal their willingness to pay as part of the price they pay for a good which is traded in markets. For environmental effects, the most popular market to use in this way is that for the purchase or rent of accommodation. For instance, houses with lower levels of noise or air pollution, and higher visual amenity, will sell/rent for a higher price; that price difference reflects the present value of the stream of additional benefits such a house will offer. Thus the approach is to undertake statistical analysis of large samples of house prices in order to find the impact of environmental variables on the price.

The approach has problems however. Firstly, the change in house price represents a stream of benefits over time, but the appropriate discount rate that should be used in summing them is unknown. From this point of view, if there is a sufficient market for rented property, rents are easier to use. Secondly, house prices will only reflect people's perceptions of environmental quality. Thus environmental impacts which directly affect amenity, such as noise and visual intrusion, will be more accurately measured than more indirect effects, such as the impact of air pollution on health. Indeed some forms of pollution may not be perceived at all.

An alternative approach to environmental valuation is to rely on hypothetical surveys. These can ask about issues such as a willingness to pay to avoid health risks, which might otherwise not be perceived. The disadvantage of this is that, if faced with a hypothetical question, people may not answer accurately, either because they do not give the issue sufficient thought, or because they perceive an advantage in deliberately distorting their answer (for instance if they perceive questions about noise nuisance as presaging plans to build a motorway close to their homes and for which they will not be adequately compensated, then they may wish the authorities to value noise at an inaccurately high level). Carefully designed surveys which give respondents hypothetical choices between realistic options but with no obvious incentive to distort their answers can minimise these problems.

For indirect effects such as health effects, the lack of knowledge of the consequences of the pollution of the general population mean that it is better to use scientific evidence to try to predict the effect, and then to value the risk of ill health or loss of life itself. This approach – known as the impact pathway approach – has been much used in European research.

Most difficult of all valuation problems is that of global warming. Whilst there is much research on the ultimate consequences of global warming, these are subject to great uncertainty. On the other hand governments do reach political decisions on the levels of greenhouse gas emissions that are acceptable and sign up to achieving them. Thus for the transport sector, if these constraints are indeed binding, then the cost of more greenhouse gas emissions from transport is not more global warming but more action to reduce greenhouse gas emissions elsewhere. Whilst the cost of this is still not easy to quantify, this is much easier than forecasting the long term consequences of global warming.

In any case, of course, data on the physical impact is needed. Speed flow relationships, accident risk models, emissions factors and dispersion models are examples of the sorts of relationships needed to predict the physical impacts before they can be valued in money terms.

6.3 Value transfer procedures

For China, studies of values of externalities are scarce, and indeed often the data on physical impacts does not exist. Thus it will be necessary to rely heavily on value transfer methods to transfer European experience to China. These methods have been extensively studied in Europe, but of course the transfer to China is much more extreme in terms of changes in factors such as incomes, population etc

Unit values (e.g. cost per traffic unit such as vehicle km) are the basis for calculating the values for the various traffic situations, modes, types of vehicle and countries. European research projects have derived such default values for average Western European situations. In order to transfer these values to other countries, a value transfer procedure is needed. The following procedure is recommended for the different cost components:

- Willingness to pay: In order to consider the different income and price levels, f willingness to pay or to accept compensation values should be multiplied by the ratio of the real GDP per capita at Purchase Power Parity exchange rates in China to that in the country for which the original estimates were made. This assumes that willingness to pay is proportional to real income. There is some evidence that this is a reasonable approximation for most cost elements.

- Infrastructure cost: Cost elasticities (the percentage change of cost from a one per cent change in traffic, which can be roughly interpreted as the percentage of costs that are variable) show a reasonable degree of consistency across European countries, although the situation in China may be rather different, The percentage of costs that is variable may be multiplied by average cost to obtain an estimate of marginal cost.
- Supplier operating costs: there is no reasonable way of transferring this, which must be estimated directly from local data.
- Accidents. Local data on risk by type of vehicle and type of infrastructure are needed.
- Noise: a crude transfer may be made by grouping areas of different population densities and background noise levels, as these are the main determinants of the amount of additional nuisance created by additional road traffic. .
- Air pollution: Consideration of specific fleet emissions characteristics and population density as being the main factors influencing the impact of additional traffic.
- Climate change: Use of specific emissions factors or of energy use.

6.4 Evidence Available

This section provides an overview of the evidence for different cost categories, based on recent European studies.

6.4.1 Infrastructure Costs

The particular issue relating to infrastructure costs that has commanded most European research is the variability of maintenance and renewal costs with traffic volume and characteristics. The results of work carried out for the GRACE project on infrastructure costs, particularly that reported in Deliverable 3 (www.grace-eu.org) is briefly outlined below. A series of case studies was carried out with the aim of estimating a series of cost elasticities for each transport mode.

a) Road – Cost Elasticities

The elasticity of cost with respect to output (or cost elasticity) can be shown to equal the ratio of marginal cost to average cost (or more roughly the proportion of total cost that is variable with output). Thus if the elasticity and the average cost are known, the marginal cost may be very easily estimated.

The table below summarises the estimated elasticities in the GRACE case studies. These were obtained by carrying out regression analysis of costs against measures of traffic volume using data for individual sections of infrastructure in the country concerned. The principal difficulty with this approach lies in getting data at this level of disaggregation. The average elasticity estimated is always below 1, showing that not all costs are variable with output. The pattern that the elasticity decreases as we move towards short-term measures (i.e. from renewals to maintenance to operation) is here clear. However, the effect of increased traffic on the elasticity is less clear.

None of the studies have been able to clearly verify which types of traffic drive the cost. Contrary to the rail sector, these road studies need to rely on rather rough measures of traffic. The output variable distinguishes only between vehicle classes, for example passenger cars and heavy goods vehicle (HGV), and does not include any more sophisticated weight information. The correlations between these aggregate output variables are strong and usually an *a priori* decision has to be taken on which of them to include. However, thanks to the correlation the elasticity (but not the average cost) may be similar between different output variables. It appears that for renewals plus maintenance an elasticity of the order of 0.5 may be appropriate. It is generally considered that the 4th power rule may be used to derive wear and tear values for different types of vehicle. This is based on empirical tests and concludes that on average damage to pavements is proportional to the fourth power of the axleweight of each axle passing over it.

	Elasticity	**Output Measure**
Renewal (R)		
Germany R	0.87	HGV km
Poland R	0.57	All traffic
Sweden R paved	0.72	HGV km
Sweden R gravel	0.68	HGV km
Sweden duration model	0.039DE	HGV km
Renewal (R) and Maintenance (M)		
Sweden R+M	0.58	HGV km
Poland R+M	0.48	All traffic
Maintenance(M) and Operation (O)		
Poland M	0.12	All traffic
Sweden O	(0.05)	All traffic
Sweden O winter	(0.007)	All traffic
Sweden O paved	(0.03)	All traffic
Sweden O gravel	(-0.09)	All traffic

Note: DE=Deterioration elasticity
Table 4 Road cost elasticities, Source: GRACE Deliverable 3 (www.grace-eu.org)

b) Rail – Cost Elasticities

A similar approach was taken to rail infrastructure costs. Marginal cost is below average cost in all studies of rail infrastructure maintenance and renewal costs. The elasticities are in the same range for all measures and in the range of 0.2 and 0.3 for the econometric models. However, a separate study for Indian Railways (Singh, 2008) yielded a much higher elasticity of the order of 0.5, which may reflect a higher elasticity for densely used systems with a lot of heavy freight traffic, and thus be more appropriate for China.

	Elasticity	Output measure
Renewal		
Sweden (duration)	0.109	gross tonnes freight
	0.146	gross tonnes Passenger
Maintenance and Renewal		
Sweden	0.302	Gross Tonnes
Switzerland (A+B)	0.265	Gross Tonnes
Maintenance		
Sweden	0.204	Gross Tonne
Switzerland (A)	0.200	Gross Tonne
UK (model V)	0.239	Gross Tonne
Switzerland (part of A)	0.285	Gross Tonne
Operation		
Sweden	0.324	Trains

DE=Deterioration elasticity; GT=Gross Tonne
Table 5 Rail elasticities Source: GRACE Deliverable 3 (www.grace-eu.org)

c) Other modes

GRACE produced a model of short and long run airport costs as a function of aircraft movements using world data on airports, results of which are reproduced in Annex 1. It also examined short run marginal infrastructure costs for water transport, but found these to be trivial except for wear and tear on lock gates.

6.4.2 Supplier Operating Cost

Supplier operating cost estimation was examined by UNITE Deliverable 6 (www.its.leeds.ac.uk/projects/UNITE), and the favoured approach was an accounting one, which divided costs into those varying with time, distance run and peak vehicle requirement. The study looked at several case studies and results of the Lisbon and Swedish examples are reproduced in Annex 1.

6.4.3 User Cost, Accident and Environmental Cost

In the case of congestion and accident costs, it must be recognised that some costs are internalised already through being borne directly by users. The external cost of congestion is the delay to other users caused by extra traffic. This may be found using speed-flow relationships, and will differ with the type of vehicle, the type of road and the existing traffic volume. The external costs of accidents is the increased risk to other users as well as costs (such as health service or police) borne directly by the state, to the extent that these are not paid for through insurance. The increased risk to other users is a controversial issue. Most European countries have experienced both increased traffic and reduced risk, but this may be caused by other factors such as safer vehicles, better roads and legislation on drink driving and the wearing of seatbelts. However, even allowing for these factors, time series regression still provides some evidence that the risk may actually reduce as traffic increases and speeds drop. However, it appears that there is an increased risk to walkers and cyclists in towns from increased traffic, and to these and other road users from the increased severity of accidents caused by additional heavy goods vehicles.

For congestion, accident and environmental cost, the recent European study IMPACT provides an overview of the unit values per unit of damage (input values) and per vehicle-kilometre (output values, expressed in marginal cost figures). The unit values given for Germany can be adapted to other countries through a value transfer procedure as described above. The most important input values are given below (all values in €$_{2000}$, if not otherwise indicated):

Value of time:

Sector/purpose	**Unit**	**Car/HGV**	**Rail**	**Bus/Coach**	**Air**
Passenger transport	€$_{2002}$/passenger, hour				
Work (business)		23.82		19.11	32.80
Commuting, short distance		8.48		6.10	*
Commuting, long distance		10.89		7.83	16.25
Other, short distance		7.11		5.11	*
Other, long distance		9.13		6.56	13.62
Freight transport	€$_{2002}$/ton, hour	2.98	1.22	/	n. a.

Table 6 Recommended values of time in passenger and freight transport (EU-25 average).
Source: IMPACT (2008) . – Original source: HEATCO (2006a), .
* Values presented by HEATCO (70% of long distance values) have been removed, because short distance air transport (below 50 km) does not happen.

Values of time for passenger transport not in working time are based on extensive research using both revealed and stated preference methods to investigate what people are willing to pay to save time, using contexts such as mode choice. Given actual or hypothetical choices between modes, a model is estimated which explains the choice of mode in terms of journey time, fare and other factors such as comfort. The relative value of the coefficient on journey time to that on cost gives the willingness to pay to save time.

For journeys in working time, it is assumed that the wage rate (plus an allowance for the overhead cost of employing labour) represents the value of the time savings to the employer. The Value of Time in commercial transport contains all components of a full cost calculation including vehicle provision, personnel, fuel and second-order effects on customers.

- Value of statistical life:
    - Accidents: 1.5 M EUR/fatality

- Value of life years lost due to air pollution:
    - chronic effects: 50,000 EUR/fatality
    - acute effects: 75,000 EUR/fatality

The value of a statistical life and of a life year lost are derived from revealed and stated preference studies of what people are willing to pay to reduce the risk of death or injury, using similar methods to those described above in the case of the value of time.

- Air pollution costs: value per tonne of emission:
    - PM2.5 (values for Germany): urban metropolitan: 384,500EUR/tonne, urban: 124,000 EUR/tonne, rural: 75,000 EUR/tonne
    - PM10 (values for Germany): urban metropolitan: 153,800 EUR/tonne, urban: 49,600 EUR/tonne, rural: 30,000 EUR/tonne
    - NOx (values for Germany) : 9,600 EUR/tonne
      Value for EU-25 : 4,400 EUR/tonne
    - NMVOC (values for Germany): 1,700 EUR/tonne
      Value for EU-25 1,000 EUR/tonne
    - SO2 (values for Germany) : 11,000 EUR/tonne.
      Value for EU-25: 5,600 EUR/t

These values use the above value of a life year lost, together with evidence on the impacts on health using the Impact Pathway Approach, which involves predicting the emissions, their transformation and deposition, and finally the physical impact this has. They also include evidence on damage to crops and buildings of air pollution, but it is the health effects (e.g, the risk to lose life years) that dominate. Evidence exists on numerous relationships between concentration of different pollutants and the incidence and severity of various forms of disease, particularly of the heart and lungs.

- Noise costs

Noise costs are estimated using the house price approach described above. A value in the range of 0.09-0.11 % of per capita GDP per DBA p.a. is recommended. Thus it is necessary to predict how many houses experience increased noise and by what level. Obviously this approach only values noise at home; to the extent that there are also noise costs at work, school, when at places of recreation or simply in the street, these are not usually included in the estimate.

- Climate change costs:

	Central values (EUR/tonne CO2)		
Year of application	Lower value	**Central value**	Upper value
2010	7	**25**	45
2020	17	**40**	70
2030	22	**55**	100
2040	22	**70**	135
2050	20	**85**	180

Table 7 Recommended values for the external costs of climate change (in EUR/tonne CO2), expressed as single values for a central estimate and lower and upper values. Source: IMPACT Handbook, op. cit.

Climate change costs were determined after reviewing a range of studies examining both damage costs and avoidance costs. Damage costs have been estimated in a number of studies, but as they involve examining impacts worldwide for a hundred years or more they are obviously very uncertain. Where countries have adopted binding targets for greenhouse gases, then – as explained above – the marginal cost of measures to meet that target may be taken as the cost of additional greenhouse gas emissions from the transport sector.

More detailed results with output values for all cost categories are to be found in Annex 1.

6.5 Values of environmental externalities by mode

Using examples from the Impact handbook, Table 8 shows the relative environmental costs for road, rail and air passenger transport based on German conditions. Note that the units are eurocents per vehicle or train km; in the case of trains, the data relates to a typical German train, which on average carries around 100 passengers but certainly has a capacity more than double that. It is clear from these examples that electric trains have major advantages over diesel trains, and petrol cars over diesel cars. Beyond that, the other crucial issue is load factors. For instance, an urban electric train carrying one hundred passengers has only a fifth of the environmental impact per passenger of a single occupancy petrol car; in the case of diesel trains, a much heavier load would be needed to produce a significant advantage for rail. The position of rail relative to road is slightly less advantageous in inter urban markets, but rail – and especially of course with electric traction – is very much superior to air over the sort of distances for which the two compete.

Table 8

Environmental Costs for Passenger Transport (2000 eurocents per vehicle/train km) based on German conditions

	Noise (daytime)	Air Pollution	Climate Change	Up and Down Stream	Total
Petrol car					
Urban	0.76	0.17	0.67	0.97	2.57
inter urban	0.12	0.09	0.44	0.65	1.3
Diesel car					
Urban	0.76	1.53	0.52	0.61	3.42
inter urban	0.12	0.89	0.38	0.45	1.84
Electric train					
Urban	23.7	0	0	24.8	48.5
inter urban	20.6	0	0	15.9	36.5
Diesel train					
urban	23.7	144.8	11.4	13.8	193.7
inter urban	20.6	90.7	8.6	10.3	130.2
Air (200 seat, 500 km journey)	120	42	124	142	428

Note Climate change effects from electricity generation are included in 'up and downstream effects'.
Source: IMPACT (2008)

Table 9 provides the comparison for freight. A mean load for a German freight train is of the order of 480 tonnes (or at least 15 times that of a typical hgv), but varies greatly with the commodity carried. Again, with electric traction rail will have an enormous advantage over road at any reasonable load, but for diesel the advantage is more marginal. Water also has advantages over road, and is competitive with diesel trains.

Table 9

Environmental Costs for freight (2000 eurocents per vehicle/train km) based on German conditions

	Noise (daytime)	Air Pollution	Climate Change	Up and Down Stream	Total
HGV					
Urban	7.01	10.6	2.6	3.1	23.31
inter urban	1.1	8.5	2.2	2.7	14.5
Electric train					
Urban	23.7	0	0	44.4	68.1
inter urban	20.6	0	0	44.4	65.0
Diesel train					
Urban	23.7	366.8	28.9	34.8	454.2
inter urban	20.6	305.8	28.9	34.8	390.1
Water	0	89	8	8	105
<250 tonnes					
1000 – 1500 tonnes	0	254	23	22	299

Source: IMPACT (2008)

It is worth noting that, even though environmental externalities are seen as an important reason for favouring rail transport, in European conditions road congestion poses a greater external cost. Thus, to the extent that rising congestion is not offset by increased road capacity, dealing with the problem of congestion is another important factor favouring rail over road in European conditions. In an ideal world, congestion costs would be reflected in charges for the use of roads. If it is not, then there is a case for reducing rail infrastructure charges below the level of the costs additional rail use imposes to offset the underpricing of road. Similarly reduced road congestion as well as environmental pollution are important factors in making the case for rail investment in Europe.

7. Methodology for Social Cost Estimation for China

7.1 Introduction

In all three European countries reviewed in earlier chapters, social costs of transport play an increasing role in transport policy. Looking at history, the main drivers were the increasing concern for environmental problems, the increasing capacity problems (congestion) and the need for infrastructure investments (motorways since the late 50s and 60s, railways since 1980s). The main focus is on road and rail transport, due to its importance, public ownership and competitive situation. Compared to that, social costs have played a minor role in policy debates for air and water transport, although with increasing concern about global warming and about the impacts of airports and ports, this is changing.

In all three countries social cost information is relevant on two levels. On a general level, social cost information has helped to make the environmental costs and benefits more visible and influential. The monetarization of environmental costs and external cost estimation have stimulated discussion of efficient pricing and investment and favour environmental charging and modal shift policies towards railways. The relevant information (such as social cost accounts or specific marginal cost figures for road and rail track pricing) is however not routinely provided and mainly based on specific research studies.

On a specific level, social costs are very relevant for project appraisals. Until now, the main application of social cost information is the cost benefit analysis for the appraisal of road and rail infrastructure programmes and projects. In all three countries, CBA approaches are standardised in infrastructure planning, based on methodological guidelines on how to estimate and consider social costs such as infrastructure, time and congestion, accident and environmental costs. Although there are differences with regard to estimation procedures and values proposed, the approaches are comparable. In strategic (midterm) planning procedures, the consideration of social costs might favour investments in the rail sector due to their lower specific accident and environmental costs. In detailed project planning, environmentally optimised variants will perform better.

For China, the most immediate use of social cost data would be to inform overall investment policy towards the different modes of transport. However, valuation of social costs should in due course play a direct role in project appraisal and in pricing decisions for the different modes of transport. The latter is a particular issue given the lack of a fuel tax in China, which is the most simple and obvious way of internalising the costs of greenhouse gas emissions, as well as providing a rough and ready way of handling other forms of air pollution.

For investment policy and project appraisal, the most relevant measure of social cost for China is long run marginal social cost (LRMSC) – that is, the social cost of carrying more traffic on the mode in question when infrastructure is expanded in line with demand. However, for pricing purposes, short run marginal social cost (SRMSC) – that is the social cost of carrying more traffic on the existing infrastructure – may also be relevant. For pricing policy, division of costs into internal and external is important, internal costs are already borne by the user so it is only external costs that need to be reflected in taxes and charges.

In this chapter, we set out the methodology we use to prepare estimates of the total average and marginal costs for rail and its principal competitors in China. For road we concentrate on expressways and national highways as competitors to rail, so all data where possible should refer solely to these two types of road. For air, it is domestic passenger services that compete most with rail; for water, it is coastal shipping and inland waterway transport of bulk commodities.

7.2 Data availability

The estimates of unit social costs are mainly based on the cost factors identified within European research programmes (IMPACT, HEATCO). These factors are adapted to China taking into account the differences between China and Europe, such as income level, emission factors, population, transport volumes, accident rates, etc..

The main source of information was a broad range of transport data provided by the Chinese consultant (Wu WeiPing). Additional transport data from China are taken from the official database of the National Bureau of Statistics of China. Economic data for China and Europe are taken from the World Economic Outlook of the International Monetary Fund (IMF). For the estimation of the social costs of transport in China, the following data is relevant: emission data, transport volumes, accident statistics and economic data.

For road and rail transport, data availability is sufficient for the calculation of unit social unit costs for China. However, there is some data missing, for example fuel consumption data of motorcycles. Therefore, for motorcycles no unit costs can be calculated. Looking at inter-urban traffic, this is not a major problem as motorcycles do not play a major role. For urban transport, motorcycles are much more relevant and would therefore have to be considered. However, the general policy in China is currently to reduce the number of motorcycles as quickly as possible because of their high accident rate.

Data about emission factors of domestic aviation and inland waterways are also missing. According to our Chinese partners, there are no such data available in China. Therefore, unit cost data for domestic aviation and inland waterways can only be derived from European values by a simple value transfer procedure; given the similarity of the aircraft and vessels used in China and in Europe, we do not see this as a major problem.

Concerning transport volume data, there is no data available that is differentiated by vehicle category and fuel type. However, these data can be calculated using the mileage data and the estimated average load factors for those categories provided to us.

Tables with all relevant input data used in producing the estimates for China are shown in the appendix

7.3 Methodology and value transfer procedure

For the estimation of social costs of transport in China existing cost factors of European research studies are taken and adapted for China, taking into account differences in income levels, currency, fuel consumption and emission factors, accident rate and population density as recommended in section 6.3 above. Unit social costs are given for the following five cost categories: air pollution, noise, climate change, accidents and congestion.

Air pollution costs
The unit values from the European project IMPACT (Handbook on estimation of external costs in the transport sector, IMPACT 2008) are the basis for the calculation of the external cost factors of air pollution in China. The IMPACT values in turn, stem from the research projects HEATCO (2006a) and CAFE CBA (CAFE 2005).

The calculation of air pollution costs of transport in HEATCO and CAFE is based on the so-called Impact Pathway Approach. Since air pollution costs are a core external cost category, there is a considerable number of studies on the methodology available.The Impact Pathway Approach is now the best accepted approach for air pollution cost calculation. The methodology is based on three major steps. First, air pollution exposure of the population is calculated on the basis of emission, transmission and exposition data. Secondly, the physical impact of this air pollution exposure on humans (health effects such as myocardial diseases), ecosystems and materials (e.g. buildings) is calculated on the basis of dose-response functions known from scientific studies. The third step involves the valuation of these adverse effects in monetary terms, which finally leads to the external costs of air pollution. The following figure shows the most important steps of the Impact Pathway Approach.

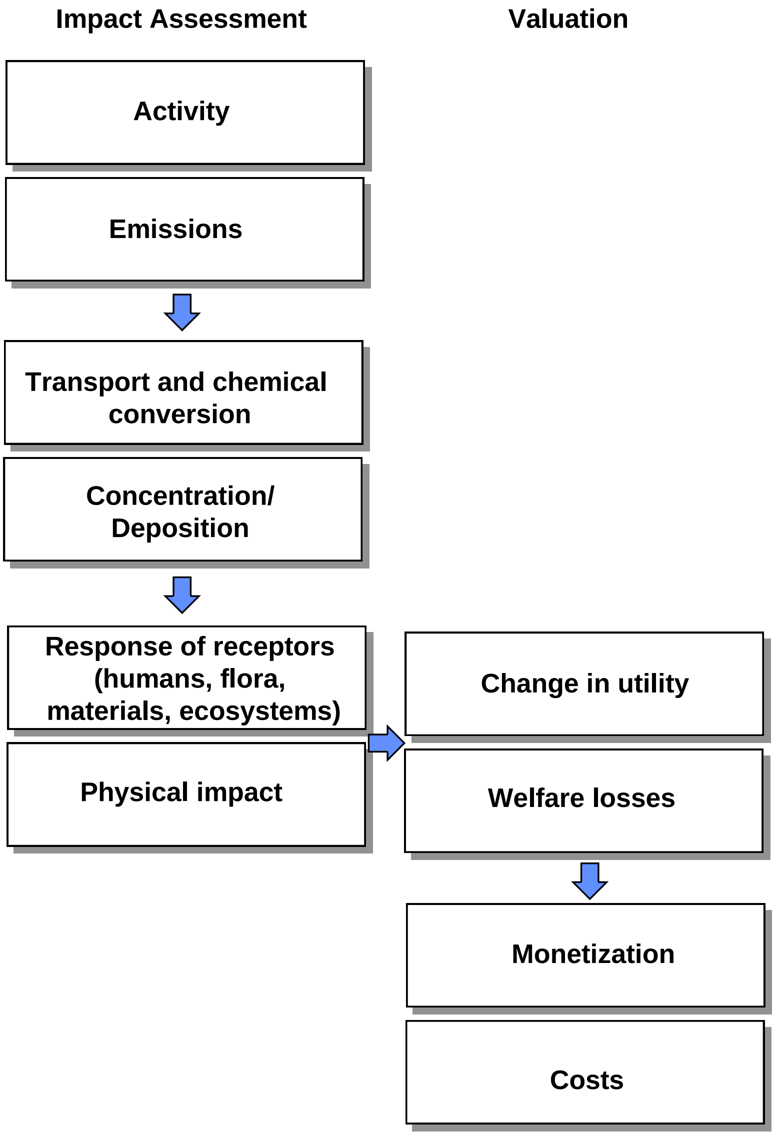

Figure 1 The Impact Pathway Approach for the quantification of external costs of air pollution. Source: HEATCO 2006.

The cost factors from IMPACT are also based on the Impact Pathway Approach and are expressed as costs per unit (tonne) of air pollutant for European countries. These cost factors need to be adapted to China. Since the dose response functions for air pollution are approximately linear, there is virtually no difference between average and marginal costs.

The adaptation of the cost factors to China comprises the following steps:

1. Value transfer: Adaptation of the values given per tonne of pollutant in EUR 2000 prices to Chinese Yuan Renminbi (RMB) 2006 values, using

   a) the RMB/EUR exchange rate (2000) for the currency conversion,

   b) the GDP per capita, adjusted for purchasing power parity, for taking into account the difference in purchasing-powerof consumers between China and the European countries and

   c) the GDP deflator from China between 2000 and 2006 for considering the inflation during this period.

2. Chinese emission factors: Calculating unit costs per vehicle-km from the above-mentioned values per tonne of pollutant, using specific emission factors of transport in China (gram of pollutant per vehicle kilometre for different vehicle categories, based on Table A2 in Annex 1. These emission factors also take into account different fuel consumption and vehicle weights in China compared to Europe.

3. Spatial structure (population density): For the valuation of emissions of particulate matter unit costs are differentiated by spatial density, i.e. urban metropolitan areas, urban regions and rural areas. Differences in population density in urban areas between Europe and China have not been accounted for since no data was available. Intuitively, one would expect the population density in metropolitan areas in China is higher than in Europe, which would lead to higher air pollution cost factors. A short comparison of population densities in ten major European cities with ten major Chinese cities did not support this hypothesis, however. Contrariwise, average population density in European cities was clearly higher than in Chinese cities. However, this difference may stem from different definitions of urban areas. Since these data are not validated, we did not take into account potential differences in population density in the following calculations of air pollution costs.

4. Other factors which may influence cost rates, but not considered are: life expectancy, climatic conditions.

For domestic aviation and inland waterways there is no emission or fuel consumption data available. Therefore, the cost factors are simply quantified by a value transfer process using the first of the steps described above .

For rail transport, indirect emissions from electricity generation also lead to external costs (due to air pollution and climate change). Cost factors for indirect emissions of rail transport are calculated on the basis of European values from IMPACT and the specific power mix in China with 83% of power generated by fossil energy sources (coal and oil) in 2006.

Noise costs

For calculating unit costs for transport noise in China, the values recommended in the IMPACT project for different population density (urban, suburban, rural) and daytime (day vs. night) can be taken as base values (Euro-cent per vehicle-km).

The original source of these values is the study from INFRAS/IWW (2004). The values represent marginal costs. Since the impact of an additional vehicle is decreasing with increasing background noise, marginal costs are generally below average costs.

The valuation of marginal noise costs in INFRAS/IWW 2004 is based on the willingness to pay for more silence and the avoidance of negative health effects. Marginal costs are estimated for different population exposure situations (rural, urban, suburban) and for night and daytime using a model environment and varying transport volumes incrementally. Using a standard noise exposure model for road and rail traffic the incremental changes of noise exposure can be calculated and finally evaluated. Only exposure at home is considered.

The adaptation of the cost values recommended by IMPACT to China is done with the same value transfer procedure as described above (air pollution costs), using the exchange rate, GDP per capita (PPP adjusted) and a GDP deflator.
Differences in population density in urban areas between Europe and China have not been accounted for since no data was available from our Chinese partners (for details see above: air pollution costs).

Climate change costs

The climate change costs are based on the recommended cost values per tonne of CO_2 from the IMPACT study, where it is recommended to take different values for the short term and long term. The long term climate change cost factors suggested in the IMPACT study focus on global, long term effects and are in line with up-to-date studies on damage costs. These long term factors can also be used for China, since they are *global* damage cost factors. Because these are global values, no value transfer procedure is necessary. The values are simply converted from EUR to RMB using the exchange rate.

For the short term unit costs, the European values from the IMPACT study cannot be taken for China, since these short term factors are based on avoidance costs for European countries to meet Kyoto targets and China has no Kyoto targets. Therefore, estimations about the actual short-term damage cost in China are chosen as cost factors per tonne of CO_2 for the short term. This data is based on a German research study on climate damage cost (Kemfert, DIW 2005).

On the basis of the cost values per tonne of CO_2, the unit costs per vehicle-km are calculated by multiplying them with Chinese emission factors for CO_2 (grammes CO_2 per veh-km for different vehicle categories). The emission factors take into account different fuel consumption and vehicle weight in China compared to Europe.

For climate change, the cost function is complex, however as a simplification, marginal damage costs can be assumed to be similar to average costs.

Accident costs

The unit values from the IMPACT study for different network and vehicle types are the basis of the calculation (EURct/veh-km). These IMPACT values in turn, stem from the research project UNITE (2003).

The methodology applied in UNITE is shown in the figure below. It is also a damage cost approach calculating the cost of an additional accident at certain traffic volumes.

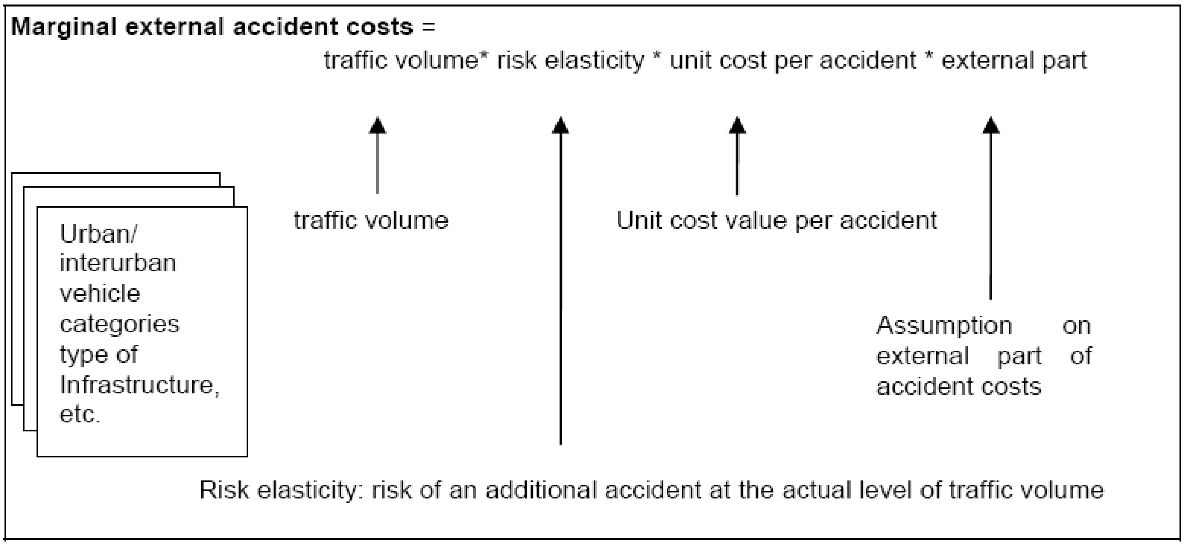

Figure 2 Approach for the calculation of marginal accident costs. Source: IMPACT 2008.

The unit values from the IMPACT study are adjusted to China in two steps:

1. Accident rate adjustment: The risk of traffic accidents differs between countries, which has an influence on the specific accident costs per veh-km. Therefore, the average fatality rate (number of killed persons) per pkm is taken as an indicator of the different risk in different countries. The adjustment of the IMPACT cost factors for European countries is done according to the following algorithm:

$$\text{unit value China (EUR/vkm)} = \text{unit value Europe (IMPACT)} \times \frac{\text{road/rail fatality rate (per pkm) China}}{\text{road/rail fatality rate (per pkm) Europe}}$$

2. Value transfer: Adaptation of the values given in EUR, 2000 prices to Chinese Yuan Renminbi (RMB), 2006 values using

a) the RMB/EUR exchange rate (2000) for the currency conversion,
b) the GDP per capita, PPP adjusted, to take into account the differences in purchasing-power-parity (PPP) between China and European countries and
c) the GDP deflator from China between 2000 and 2006 to consider the inflation during this period.

Other factors influencing cost rates, but not considered are: life expectancy, injury rate, type of injuries.

Congestion costs

The cost factors for congestion recommended in the IMPACT study (EUR/veh-km) for different area and road types are used as base values. These factors represent the external part of marginal social costs or external costs of congestion at optimal traffic levels (considering the traffic reaction due to pricing signals).
.
The estimation of congestion costs follows the basic approach of valuing the time losses based on speed-flow characteristics (interurban road transport) and bottleneck and queuing functions (urban road). The following figure shows the steps for the measurement of unit congestion costs (marginal congestion costs for specific traffic situations).

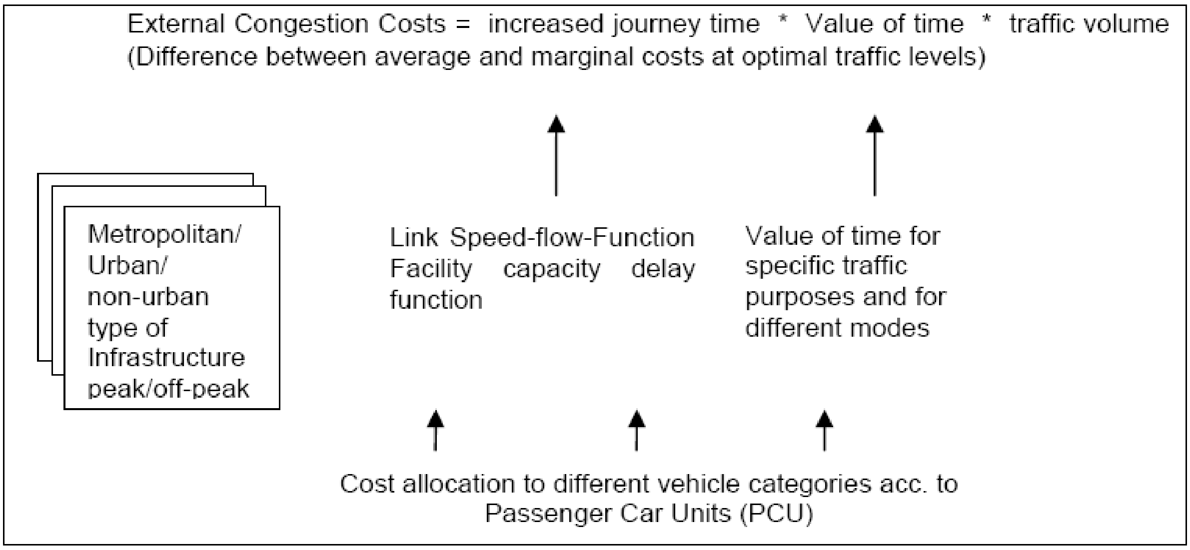

Figure 3 Approach for the calculation of marginal congestion costs. Source: IMPACT 2008.

The unit congestion costs from the IMPACT study are transferred to China with the same value transfer procedure as described above (air pollution costs, noise costs), using exchange rate, GDP per capita (PPP adjusted) and GDP deflator.

Additionally, the input data for the value of time (value of travel time savings) based on the HEATCO study (and also recommended in the IMPACT study) are calculated considering the value transfer procedure from Europe to China as described for unit accident costs above. Of course, Chinese value of time data for transport participants would be more reliable than adapted cost factors from Europe, since differences in the use of transport modes and vehicle types (e.g. cars used only by well-off population groups) would be better reflected. Unfortunately, no empirical Chinese evidence for the value of time is so far available.

7.4 Results: unit values and cost factors for China

The full results of the calculations for China are given in annex 1; a summary of total and average external costs by mode and estimates of short and long run marginal social costs for road and rail are given in the next chapter.

8. Social Cost Estimates for China

In this chapter we first present our estimates of the total and average external accident and environmental costs of transport in China before then presenting our estimates of the short run and long run marginal social costs (SRMSC & LRMSC), including the external accident and environmental costs and also other costs such as infrastructure and operating cost.

8.1 Total and average external accident and environmental cost

In this section we present a very broad estimation of total and average social cost of transport by mode in China. The calculations are based upon the methodology outlined in the last chapter and the detailed data given in Annex 1. Because of missing input data, total cost estimates for domestic aviation and inland waterways are incomplete.

For air pollution, climate change and accidents, it can be assumed that average costs are similar to marginal costs. Therefore, total costs are calculated by multiplying the cost factors per vehicle-km and the corresponding mileage (vehicle-km). In some cases it was necessary to make assumptions about the share of mileage of different areas (metropolitan, urban, rural) (see Table A6 in Annex 1). For climate change the calculation of total costs are based on the central unit value for 2010.

For noise costs, the marginal costs are below the average costs, since as an area becomes noisy, so the impact on perceived noise levels of an increase in noise emissions falls. Therefore, for calculating total costs, average noise costs need to be estimated based on marginal costs as described in the chapter above. Data from total external transport cost calculations for European countries (e.g. INFRAS/IWW 2004) indicates that the average noise costs are at about the same level as the marginal noise costs in urban areas. Therefore, the urban noise cost factors are taken as average costs and multiplied by mileage data to get total costs. .

For congestion costs, there is no opportunity for a simple estimation of total costs based on marginal cost factors. Therefore, a direct calculation is not possible. However, a rough estimation has been made on the basis of a Chinese study which calculated the congestion costs for road transport for Beijing. Based on this figure, an extrapolation was made using the total urban population in China.

8.1.1. Results

The following tables show the results of the broad estimations of average and total social costs for road and rail transport in China. It has to be taken into account that for road transport, the following data do not cover total external road costs but only the external costs of road transport on expressways and national highways, since these are the types of road which compete with rail, air and water transport.

Total external cost of road transport 2006 (only expressways and national highways)					
In billion RMB/a	Car	Light duty vehicle	Heavy duty vehicle	Bus	Road Total
Air pollution cost	5	15	42	8	70
Noise cost	2	3	7	2	14
Climate change cost	4	4	10	3	21
Accident cost	16	16	16	12	60
Total	**27**	**38**	**75**	**25**	**165**

Table 10 Climate change costs are based on the central cost value for 2010 (100 RMB/tonne CO_2).

Total external costs of road transport on expressways and national highways in China account for around 165 billion RMB per year considering environmental and accident costs. Around two thirds of these costs are caused by freight transport (light and heavy duty vehicles) and one third by passenger transport (car, bus). The highest shares of total costs are caused by accidents and air pollution. For all roads (i.e. including urban roads, smaller rural roads, etc.), the total external costs would be much higher. Since mileage on expressways and national highways only account for 6-7% of all roads, total external costs of road transport in China might be around 10-20 times higher: around 2,000-3,000 billion RMB per year).

According to the rough extrapolation of congestion costs, the annual costs of road congestion in China additionally amount to around 500 billion RMB per year (own estimations based on WTPP 2006) for all roads.

Total external costs of rail transport in China (national railways) account for almost 30 billion RMB per year. The data also include external costs of indirect emissions of electricity generation (in the category air pollution). Around 70% of the total rail costs can be attributed to freight transport and only 30% to passenger transport.

One noteworthy feature of the results for rail is that the accident costs are quite high compared to European values, since the average fatality rate per pkm is about 6 times higher in China than the European average (and about 18 times higher than the German value). One reason for the high rail accident rate of China is the fact that Chinese accident data also include casualties from accidents involving trespassers on the tracks or at level crossings; these in fact account for most of the casualties. These costs are however costs caused by the operation of trains in the current situation in China. Therefore, these incidents are included in the unit costs above.

Total external cost of rail transport (national railways) 2006			
In billion RMB/a	Rail passenger	Rail freight	Rail Total
Air pollution cost	1.1	5.5	6.6
Noise cost	0.2	0.9	1.1
Climate change cost	0.2	1.3	1.5
Accident cost	7.4	11.8	19.2
Total	**8.9**	**19.5**	**28.4**

Table 11 Data also include indirect emissions from electricity generation. Climate change costs are based on the central cost value for 2010 (100 RMB/ton CO_2).

According to the following table, the total external cost of domestic aviation in China is around 6 billion RMB/a. This figure does not include noise cost, however. The external costs of inland waterways amount to about 16 billion RMB per year.

Total external cost of domestic aviation and inland waterways 2006		
In billion RMB/a	Domestic aviation	Inland waterways
Air pollution cost	0.25	15.2
Noise cost	n.d.a	-
Climate change cost	5.4	1.0
Accident cost	0.1	-
Total	**5.8**	**16.3**

Table 12 n.d.a. = no data available

Since traffic volume data (e.g. passenger-km and freight tonne-km) for road transport in China is rather weak, the following comparison of average external cost per passenger-km or tonne-km for road and rail transport in China needs to be treated with caution. According to the available data, the average cost per passenger-km in road transport is 0.11 RMB, whereas for rail transport the average cost is around an eighth of this. For air passenger transport, the average costs are ain between those for road and rail but almost twice the figure for rail.For freight transport, the average costs per tonne-km are 0.25 RMB for road, which is more than twenty times higher than for rail transport. For inland waterways, the average costs are much closer to those for rail than for road, but still almost 50% higher than the rail figure. The much greater superiority of rail over other modes than is found in Europe is mainly due to the very high loads carried by typical Chinese trains

External cost in RMB per passenger kilometre or freight tonne kilometre		
	Passenger	Freight
Road	0.11	0.25
Rail	0.013	0.009
Air	0.024	not considered
Water	not considered	0.013

Table 13

8.2 Estimating SRMSC & LRMSC for China's Transport

This section draws upon the cost data discussed above and in annex 1 to carry out some preliminary cost calculations of short run marginal social cost (SRMSC) and long run marginal social cost (LRMSC) for both the road and rail sectors in China. An attempt was also made to calculate the same set of costs for the air and inland waterways sectors but lack of data prevented this in both cases.

The two sets of costs are now presented as a series of tables below. It should be noted that in all cases the costings should only be considered as 'rough & ready' due to the limitations presented by the accuracy of the data supplied. Before presenting the tables it may help to outline what is meant by both SRMSC and LRMSC. The former can be defined as, "…the social cost of an additional trip at the current level of infrastructure provision" (Sansom et al, 2001). Over time however, the level of infrastructure provision changes and so a different measure of cost, namely LRMSC is required which can be defined as, "… the cost of an additional trip allowing for infrastructure provision to be optimally adjusted to the level of demand" (Sansom et al, 2001). Both measures include the same cost categories, with the only differences being that LRMSC also includes the cost of additional infrastructure provision for an additional unit of traffic. We assume that the cost of this extra infrastructure capacity completely offsets the additional congestion costs so that congestion costs are excluded from LRMSC. Short run marginal social cost is therefore relevant when considering adding traffic to the existing infrastructure; long run marginal social cost when considering infrastructure expansion.

We start by identifying the cost categories considered when making the calculations and these are presented in Tables 14 and 15 below. The tables indicate which cost category is included in the calculation of short run marginal social costs (SRMSC) and long run marginal social costs (LRMSC) for rail and road.

Table 14

Rail Calculations

Cost Categories	SRMSC	LRMSC
1. Infrastructure Costs 1.1 Capital Costs 1.2 Maintenance & Renewal Costs	 x ✓	 ✓ ✓
2. Transport Operating Costs	✓	✓
3. Congestion Costs	x	x
4. Environmental Costs 4.1 Air Pollution 4.2 Noise 4.3 Climate Change	 ✓ ✓ ✓	 ✓ ✓ ✓
5. Accident Costs	✓	✓

Table 15

Road Calculations

Cost Categories	SRMSC	LRMSC
1. Infrastructure Costs 1.1 Capital Costs 1.2 Maintenance & Renewal Costs	 x ✓	 ✓ ✓
2. Transport Operating Costs	✓	✓
3. Congestion Costs	✓	x
4. Environmental Costs 4.1 Air Pollution 4.2 Noise 4.3 Climate Change	 ✓ ✓ ✓	 ✓ ✓ ✓
5. Accident Costs	✓	✓

8.2.1 Capital Costs for LRMSC per Vehicle Km

The capital cost estimates were derived as follows

Stage 1:

Estimates of infrastructure capital costs for both rail and road were obtained from our Chinese consultant, Wu Weiping. The figures were given in RMB figures for 2006 and related to the construction of a km of route for both rail & road. The rail figures relate to dedicated new high speed passenger lines, and dedicated freight routes, as these were considered to be the major forms of capacity expansion likely in the foreseeable future. The figures are given in Annex 1 in Table A33 .

Based on the evidence cited in chapter 6, 50% of the maintenance costs were regarded as fixed costs of capacity and treated in the same way as the capital costs, whilst the remainder were treated as variable costs The maintenance costs were provided by our Chinese consultant, Wu Weiping and are given in table A34.

The other 50% of maintenance costs were regarded as variable costs and allocated according to gross tonne kms (for rail) and bus and freight vehicle kms (for road). This is an important assumption as it assumes that the damage caused to roads is carried out by buses and freightvehicles and not cars hence no costs are allocated to cars, but it is broadly justified by the evidence cited above that it is axleweights which determine the amount of damage a vehicle does to the roads.

Stage 2:

The next stage involved unitising capital costs over a 60 year period using a 6% discount rate. This provided the following figures for annual rail and road capital costs as given in table A35.

Stage 3:

This stage involved dividing the unitised capital costs by the respective annual rail and road capacities to derive the LRMSC capital cost per vehicle km figures. The capacity figures for both rail and road had to be calculated. In the case of road we were able to use existing data from the Chinese consultant to do this but in the case of rail we had to make some assumptions. The calculations are outlined in Annex 1, Tables A36 and A37.

Unit Capital Costs per passenger car unit km:

Dividing the unitised capital costs by the annual capacity costs give the following unit capital costs for both rail and road, as given in Table 15.

Table 15 Unit Capital Costs for Chinese Rail and Road (RMB, 2006 prices)

Rail:	Capital Cost per train Km	Road:	Capital Cost per passenger car unit Km
Freight	34.43	Expressways	0.21
Passenger	53.39	National Highways	0.43

For buses and goods vehicles we multiply the road figures by a factor of 2.7 to obtain capital costs per vehicle km of 0.57 RMB (expressways) and 1.16 RMB (National Highways).

It should be noted that expressways only have lower marginal costs than national highways because of the much greater capacity they offer. If that capacity is not required, then national highways will be the cheaper option.

Stage 4:

To obtain the final figures we need to add the 50% fixed maintenance & renewal cost figures to the capital only figures. These result in final capacity costs that are outlined in Table 16.

Table 16

Final Capacity Cost Figures per Vehicle Km (RMB – 2006)

Rail:	Capital Cost per Vehicle Km	Road:	Capital Cost per Vehicle Km
Freight	34.43 + 4.33 = 38.71	Expressways – Car	0.21 + 0.0 = 0.21
Passenger	53.39 + 5.95 = 59.34	National Highways – Car	0.43 + 0.0 = 0.43
		Expressways – HGV and bus	0.57 + 0.03 = 0.60
		National Highways – HGV and bus	1.16 + 0.23 = 1.39

8.2.2 Variable Maintenance & Renewal Costs for SRMSC/LRMSC

Stage 1:

The starting point for these calculations is the annual maintenance and renewal costs given in table A34. We allocate 50% of these costs to capacity costs leaving 50% to be allocated to variable maintenance & renewal costs according to gross tonne kms (for rail) and bus and freight vehicle kms (for road).

In order to allocate these costs between passenger rail and freight rail we have had to use data obtained from our Chinese consultant, Wu Weiping, which indicates that the following gross tonne kms are generated each year by passenger and freight trains resulting in 46% of the maintenance and renewal costs being allocated to passenger trains and 54% to freight trains; which translates into 49,665 RMB and 57,785 RMB for passenger and freight trains respectively.

- Passenger trains – 1,886,920 million gross tonne kms (46%) – 49,665 RMB
- Freight trains – 2,195,441 million gross tonne kms (54%) – 57,785 RMB

Stage 2:

The next stage of this process involves calculating the average number of vehicle kms per route km. Again we were able to obtain data from our Chinese consultant, Wu Weiping that is given in tables A38 & A39.

Stage 3:

The final stage involves dividing the maintenance and renewal costs per route km identified in the first stage by the vehicle kms per route km identified in the second stage. This results in the following figures as given in Table 17.

Table 17 Unit Maintenance & Renewal Costs (RMB – 2006 prices)

Rail:	Maintenance & Renewal Costs per train Km	Road (HGV and bus):	Maintenance & Renewal Costs per Vehicle Km
Passenger	5.946	Expressways	0.0304
Freight	4.332	National Highways	0.2336

8.2.3 Operating Costs for SRMSC/LRMSC

These were taken directly from tables provided by our Chinese consultant, Wu Weiping and are outlined below in tables A40 and A41. Note no distinction is made for road between Expressways and National Highways.

8.2.4 Congestion Costs for SRMSC per Vehicle Km

Congestion costs are not considered for rail and only included for road in the SRMSC calculations. The costs are taken from Table A25. We have assumed central values for both passenger cars and HGV vehicles and have equated expressways with motorways and national highways with trunk roads – resulting in the four values in the table below.

Table 18 Congestion Costs per Vehicle Km

in RMB/ vkm	Passenger cars	Goods vehicles
Motorways	0.09	0.30
Trunk roads	0.04	0.11

8.2.5 Environmental Costs for SRMSC/LRMSC

Environmental costs are applicable for both rail and road and are included in both SRMSC and LRMSC calculations. The costs are taken from a variety of tables as outlined below in Tables 19 to 21.

Air Pollution:

These values are based on the tables A13 and A14.

In terms of the cost calculations these costs have to be added together resulting in the following unit costs.

Table 19 Air Pollution Costs – (RMB – 2006)

Rail:	Air Pollution	Road:	Air Pollution
Freight	4.853	Car	0.0267
Passenger	15.541	Bus	0.3023
		HGV	0.7267

Noise:

The data is taken from Table A17.

In terms of the cost calculations we have used the costs related to daytime and rural areas resulting in the following costs.

Table 20

Noise Costs per Vehicle Km – (RMB – 2006)

Rail:	Noise Costs	Road:	Noise Costs
Freight	0.0433	Car	0.0001
		Bus	0.0006
Passenger	0.0223	HGV	0.0011

Climate Change:

The data is taken from Table A19 and A20.

In terms of the cost calculations we have used the central CO_2 costs related to daytime and rural areas resulting in the following costs.

Table 21

Climate Change Costs per Vehicle Km – (RMB – 2006)

Rail:	Climate Change Costs	Road:	Climate Change Costs
Freight	2.01	Car	0.021
		Bus	0.067
Passenger	0.63	HGV	0.095

8.2.6 Accident Costs for SRMSC/LRMSC

Accident costs are applicable for both rail and road and are included in both SRMSC and LRMSC calculations. For road these costs are taken from table A23, whilst the costs for rail are reported in the subsequent text as being 11.5 RMB per train km.

8.2.7 Overall Estimates of SRMSC and LRMSC

In order to compare the SRMSC and LRMSC calculations between rail and road transport modes it is necessary to convert the calculations outlined above into per passenger km (for passenger trains and cars) and per tonne km (for freight trains and HGVs) figures. For this we use the mean loads given in Table A7.

We now outline a series of tables of results and describe them below.

The first table (table 22) describes the SRMSC in terms of vehicle or train kms with values presented in RMBs for 2006, whilst the second (table 23 presents the SRMSC values in terms of passenger kms and tonne kms. The latter table allows a better and fairer comparison across modes and is the one we focus upon. The first thing to note from the table is that capital costs are not included in SRMSC, as outlined above, nor are any congestion costs with regards to rail. The full list of cost categories of costs includes:

1. Maintenance & Renewal Costs
2. Transport Operating Costs
3. Congestion Costs
4. Environmental Costs
5. Accident Costs

A comparison of costs are presented at various levels, firstly between rail and road, each of which is further disaggregated into different levels. For rail we have a passenger and freight split whilst for road we have a split by road type (Expressway vs National Highway) and then between car, bus and HGV. As SRMSC can vary by time of day and area type we have focused upon the SRMSC associated with rural areas during the day. Turning back to the costs it can be seen that in every costs category rail costs are less than road costs, particularly those associated with transport operating costs and environmental costs. One result to note is the impact of congestion costs, which in urban areas would tend to dominate the overall SRMSC, but clearly this is not the case in rural areas. The overall SRMSC cost for passenger rail comes in at 0.14 RMB which is around 15% of the comparative figure for the car on expressways (0.93 RMB) and about 58% of the figure for bus on expressways (0.24 RMB). In terms of freight, rail's SRMSC is again considerably less than that for HGV at 0.06 RMB compared to 0.43 RMB (HGV - expressway) and 0.50 (HGV – highway). This sends out a clear message with regards the SRMSC advantage of rail over road.

Table 22 SRMSC Presented as Train/Vehicle Km Values (RMB - 2006)

SRMSC - Train/Vehicle Kms	Rail: Rural/Day Category per Train Km (RMB - 2006)		Road: Rural/Day Category per Vehicle Kms (RMB- 2006)					
Cost Categories	Passenger	Freight	Expressway Car	Expressway Bus	Expressway HGV	National Highway Car	National Highway Bus	National Highway HGV
1. Infrastructure Costs								
1.1 Capital Costs	Na	Na	Na	Na	Na	Na	Na	Na
1.2 Maintenance & Renewal Costs	5.95	4.33	0	0.03	0.03	0	0.23	0.23
2. Transport Operating Costs	120	127	1.99	3.53	3.77	1.99	3.53	3.77
3. Congestion Costs	Na	Na	0.09	0.30	0.30	0.04	0.11	0.11
4. Environmental Costs								
4.1 Air Pollution	4.8530	15.5410	0.0267	0.3023	0.7267	0.0267	0.3023	0.7267
4.2 Noise	0.0223	0.0433	0.0001	0.0006	0.0011	0.0001	0.0006	0.0011
4.3 Climate Change	0.6300	2.0100	0.0210	0.0670	0.0950	0.0210	0.0670	0.0950
5. Accident Costs	11.500	11.500	0.022	0.022	0.022	0.320	0.810	0.810
Final SRMSC	131.45	148.93	2.1498	4.25	4.95	2.3978	5.05	5.75

Table 23 SRMSC Presented as Passenger and Tonne Km Values (RMB - 2006)

SRMSC - Pass./Tonne Kms	Rail Rural/Day Category (RMB - 2006)		Road Rural/Day Category (RMB- 2006)					
Cost Categories	Passenger (passenger km)	Freight (tonne km)	Expressway Car (passenger km)	Bus (passenger km	HGV (tonne km)	National Highway Car (passenger km)	Bus (passenger km)	HGV (tonne km)
1. Infrastructure Costs								
1.1 Capital Costs	Na	Na	Na	Na	Na	Na	Na	Na
1.2 Maintenance & Renewal Costs	0.006	0.002	0.000	0.002	0.003	0.000	0.01	0.02
2. Transport Operating Costs	0.12	0.05	0.87	0.20	0.33	0.87	0.20	0.33
3. Congestion Costs	Na	Na	0.04	0.017	0.03	0.02	0.01	0.01
4. Environmental Costs								
4.1 Air Pollution	0.00485	0.00576	0.01161	0.01679	0.06319	0.01161	0.01679	0.06319
4.2 Noise	0.00002	0.00002	0.00004	0.00003	0.00010	0.00004	0.00003	0.00010
4.3 Climate Change	0.00063	0.00074	0.00913	0.00372	0.00826	0.00913	0.00372	0.00826
5. Accident Costs	0.012	0.004	0.010	0.001	0.002	0.139	0.045	0.070
Final SRMSC	0.14	0.06	0.93	0.24	0.43	1.04	0.28	0.50

If we now consider LRMSC (Tables 24 & 25) which are in essence the same costs categories and figures as presented in the SRMSC calculations but with an additional item, capital costs, and with congestion costs excluded. Capital costs are estimated as the cost per vehicle or train km of capacity of new national highways or expressways and new high speed passenger railways or freight lines. Because the division between internal and external costs is not relevant for government investment planning, total accident costs (internal and external) are included here. These costs help accentuate the difference between rail and road but do not have a substantial impact on the overall result which sees a LRMSC for passenger rail of around 0.20 RMB compared with a LRMSC for car on expressways of around 0.99 RMB (5 times larger) and a LRMSC for bus on expressways of 0.25. In terms of freight the LRMSC of rail is around 0.07 RMB which is considerable less than that of HGV at 0.46 RMB (HGV - Expressway) and 0.61 RMB (HGV – Highway). Again the message to take from these figures is that the LRMSC of rail is considerably less than that of road with the exception of bus where the difference is less acute.

Table 24 LRMSC Presented as Train/Vehicle Km Values (RMB - 2006)

LRMSC - Train/Vehicle Kms	Rail Rural/Day Category per Train Km (RMB - 2006)		Road Rural/Day Category per Vehicle Kms (RMB- 2006)					
Cost Categories	Passenger	Freight	Expressway Car	Bus	HGV	National Highway Car	Bus	HGV
1. Infrastructure Costs								
1.1 Capital Costs	59.34	38.71	0.21	0.60	0.60	0.43	1.39	1.39
1.2 Maintenance & Renewal Costs	5.95	4.33	0.00	0.03	0.03	0.00	0.23	0.23
2. Transport Operating Costs	120	127	1.99	3.53	3.77	1.99	3.53	3.77
3. Congestion Costs	Na	Na	Na	Na	Na	Na	Na	Na
4. Environmental Costs								
4.1 Air Pollution	4.853	15.541	0.027	0.302	0.727	0.027	0.302	0.727
4.2 Noise	0.022	0.043	0.000	0.001	0.001	0.000	0.001	0.001
4.3 Climate Change	0.630	2.010	0.021	0.067	0.095	0.021	0.067	0.095
5. Accident Costs	11.500	11.500	0.022	0.022	0.022	0.32	0.81	0.81
Final LRMSC	190.79	187.63	2.27	4.55	5.24	2.79	6.34	7.03

Table 25 LRMSC Presented as Passenger and Tonne Km Values (RMB - 2006)

LRMSC - Pass./Tonne Kms	**Rail** Rural/Day Category (RMB - 2006)		**Road** Rural/Day Category (RMB- 2006)					
Cost Categories	**Passenger** (passenger km)	**Freight** (tonne km)	Expressway Car (passenger km)	Bus (passenger km)	HGV (tonne km)	National Highway Car (passenger km)	Bus (passenger km)	HGV (tonne km)
1. Infrastructure Costs								
1.1 Capital Costs	0.059	0.014	0.091	0.033	0.052	0.187	0.077	0.121
1.2 Maintenance & Renewal Costs call variable and fixed	0.006	0.002	0.000	0.002	0.003	0.000	0.013	0.020
2. Transport Operating Costs	0.12	0.05	0.87	0.20	0.33	0.87	0.20	0.33
3. Congestion Costs	Na	Na	Na	Na	Na	Na	Na	Na
4. Environmental Costs								
4.1 Air Pollution	0.00485	0.00576	0.01161	0.01679	0.06319	0.01161	0.01679	0.06319
4.2 Noise	0.00002	0.00002	0.00004	0.00003	0.00010	0.00004	0.00003	0.0001
4.3 Climate Change	0.00063	0.00074	0.00913	0.00372	0.00826	0.00913	0.00372	0.00826
5. Accident Costs	0.012	0.004	0.010	0.001	0.002	0.139	0.045	0.070
Final LRMSC	0.20	0.07	0.99	0.25	0.46	1.21	0.35	0.61

8.3 Conclusion

In this chapter we have presented estimates of the total, average and marginal social costs of transport in China. Regarding external cost, our results suggest that the average external cost per passenger-km in inter urban road transport is 0.11 RMB, whereas for rail transport the average cost is around an eighth of this (0.013 RMB/pkm). For air passenger transport, the average costs are about 0.024 RMB/pkm. For freight transport, the average costs per tonne-km are 0.25 RMB for road, which is more than twenty times higher than for rail transport (0.009 RMB/tkm). For inland waterways, the average costs are 0.013 RMB/tkm.

Short run marginal social cost represents the cost of adding additional traffic to the existing infrastructure, and is particularly relevant for pricing. The overall short run marginal social cost for passenger rail, including infrastructure maintenance and renewals and operating cost comes in at 0.14 RMB which is around 15% of the comparative figure for the car (0.93 RMB) and about 58% of the figure for bus (0.24 RMB). In terms of freight, rail's SRMSC is again considerably less than that for HGV at 0.06 RMB compared to 0.43 RMB (HGV - expressway) and 0.50 (HGV – highway). This sends out a clear message with regards the SRMSC advantage of rail over road.

We now consider Long Run Marginal Social Cost (Tables 24 & 25) which is the cost of adding additional traffic including the cost of infrastructure expansion. This comprises in essence the same cost categories and figures as presented in the SRMSC calculations but with an additional item, capital costs, and with congestion costs excluded. Capital costs are estimated as the cost per vehicle or train km of capacity of new national highways or expressways and new high speed passenger railways or freight lines. Because the division between internal and external costs is not relevant for government investment planning, total accident costs (internal and external) are included here. External costs help accentuate the difference between rail and road but do not have a substantial impact on the overall result which sees a LRMSC for passenger rail of around 0.20 RMB compared with a LRMSC for car of around 0.99 RMB (5 times larger) and a LRMSC for bus of 0.25. In terms of freight the LRMSC of rail is around 0.07 RMB which is considerable less than that of HGV at 0.46 RMB (HGV - Expressway) and 0.61 RMB (HGV – Highway). Again the message to take from these figures is that the LRMSC of rail is considerably less than that of road, except for bus transport where the advantage of rail is much less great.

9. Conclusion and Policy Recommendations

Rail typically is much less environmentally polluting than other modes of transport, and this needs to be reflected in regulation, pricing and appraisal. The advantage of rail will vary greatly with the circumstances, being much greater for a heavily loaded electric train using electricity generated from renewable resources than for a lightly loaded rural diesel train. Pricing will automatically give the correct incentives provided it is sophisticated enough to reflect such differences; regulation and appraisal also need to take them into account for rail to play its optimum role in tackling environmental problems.

Estimates for China suggest that rail is the mode of transport with least external cost for both passenger and freight transport. External costs of rail for passenger are around an eighth those of road, for freight, a twentieth; for passenger transport air imposes twice the cost of rail (even excluding noise costs) and inland waterway for freight imposes 50% higher costs than rail.

We were able to make estimates of the full short and long run marginal social cost for road and rail freight and passenger only. For policy and appraisal purposes it is the long run marginal social costs that are most relevant; short run marginal social costs are more relevant to analysis of pricing policy.

Both in terms of short run and long run marginal social cost, rail is very much cheaper than car or heavy goods vehicle for both passenger and freight transport, suggesting that both in terms of pricing and investment policy a cost minimising approach to dealing with traffic growth will favour rail over these modes whenever this is a feasible alternative. Bus is more competitive in terms of long run marginal social cost, and the scope for making more use of bus, for instance by giving it more priority, should also be considered. It must be said, however, that the comparative costs are dominated by infrastructure and operating costs; the lower incomes in China mean generally that external costs are a less significant part of the overall costs than in Europe, although they may be expected to grow proportionately as incomes rise.

We draw the following policy conclusions:

1. There is a need to develop more detailed social costs estimates for China. It appears that the costs of road accidents and air pollution from lorries, as well as road congestion, are particularly important issues. What is needed is both better physical data, for instance on the volumes of traffic and speeds on individual stretches of road, and China specific estimates of monetary valuations of items such as the value placed on time savings and and on increased safety. Valuation of noise nuisance, including aircraft noise, should be another priority.

2. The analysis needs to be extended to urban areas, where many external costs are likely to be much greater than for inter urban traffic. However, obtaining reliable results for urban areas really needs detailed information on

factors such as traffic flows and numbers of houses affected by different levels of noise and air pollution.

3. External costs should be taken into account both in overall investment strategy and in detailed appraisal of individual projects, using values derived from state of the art techniques. This could be done simply from by transferring values from international experience as used in this report, but again more accurate results require the estimation of monetary values for China from specific new studies.

4. China should move towards more efficient pricing. A fuel tax to reflect global warming costs, and more roughly other externalities (whose impacts are less well correlated with fuel consumption), would be a good start, although it is likely that reflecting the high levels of social costs in cities would require some form of additional charge, such as a cordon toll. Obviously the implications of these developments for current levels of tolls on interurban roads would need to be considered.

5. Rail should be seriously considered wherever there is a choice between car or heavy goods vehicle and rail for medium/long distance passenger or freight traffic. Bus is competitive with rail for passenger traffic in terms of costs, and better use of bus transport, for instance by building in more bus priorities, should also be considered. Even if road traffic forecasts suggest a need for additional inter urban road capacity, the very much lower marginal costs for rail and bus compared with car and heavy goods vehicle indicate that an assessment should be made of the extent to which rail and bus investment, possibly accompanied by changes to quality of service and pricing on the different modes, could reduce the need for new road capacity.

ANNEX 1 Social cost estimates for China (additional information)

Input data

The following tables show some of the most important input data for the estimation of social cost factors for China. The tables cover energy consumption and emission data, transport volume, load factors, accident statistics and economic data.

Emission data:

Fuel / electricity consumption							
	Road					Rail	
	Motorcycle	Car	Bus*	Light truck	Heavy truck	Passenger train	Freight train
Gasoline (litre/100 veh-km)	n.d.a.	10.0	29.3	27.0	-	-	-
Diesel (litre/100 veh-km)**	n.d.a.	n.d.a.	27.7	24.2	39.5	290**	930**
Electricity consumption (kWh/train-km)	-	-	-	-	-	10.87	37.48

Table A1 n.d.a. = no data available. veh-km = vehicle-kilometer * Bus data are average of minibuses and (conventional) buses. ** Data for rail: litre/100 train-km.

Emission factors					
kg pollutant/ ton fuel	Motor-cycle (gasoline)	Car (gasoline)	Light duty vehicle diesel	Heavy duty vehicle diesel = train diesel	Bus diesel*
CO_2	2,852.0	2,852.0	2,898.0	2,898.0	2,898.0
NO_x	4.9	24.5	91.4	110.0	50.3
SO_2	1.6	1.6	4.0	4.0	4.0
PM	0.0	0.0	1.4	2.1	1.4
CO	800.0	892.4	75.7	91.2	43.0
HC	323.2	88.2	18.2	21.9	11.8

Table A2 * Bus data are average of minibuses and buses. Variations of the emissions between the different vehicles of a given fuel type reflect different motor technology, age and composition of vehicle fleet.

Transport volume:

Mileage, road (2006)				
in million vehicle-km	Car	Bus*	Light truck	Heavy truck
Expressways	98,138	9,785	8,154	48,927
National Highways	92,463	41,095	71,916	51,368
Total (Expressways and Nat. Highways)	190,601	50,880	80,070	100,295

Table A3 * Data include minibuses and buses

Mileage, rail (2006)			
in 1,000 train-km	Rail passenger	Rail freight	Rail total
Electric trains	258,070	414,130	672,200
Diesel trains	385'900	614,410	1,000,310
Rail total*	643,970	1,028,540	1,672,510

Table A4 * National railways

Volume: passenger- and freight-kilometre (2006)		
	Passenger transport in 1,000 pkm	Freight transport in million tkm
Road total	1,013,085	975,425
Road: Expressways and Nat. Highways	466,019	448,695
Rail total*	662,212	2,195,441

Table A5 * National railways

Share of mileage in different spatial areas				
Share of mileage in different spatial areas (in %)	Road		Rail	
	Expressways	National Highways	Passenger	Freight
Urban metropolitan	0%	2%	3%	2%
Other urban/suburban	10%	12%	11%	10%
Rural	90%	86%	86%	88%

Table A6 Own assumptions based on advice from Chinese partners

Load factors:

Load factors						
	Road				Rail	
	Car p/veh	Bus p/veh	Light truck t/veh	Heavy truck t/veh	Passenger train p/train	Freight train t/train
Average load factor	2.3	Minibus: 8 Big bus: 30 Mean: 18	Small: 1 Medium: 3 Mean: 2	Heavy: 8 Trailer: 15 Mean: 11.5	1,000	2'700

Table A7 Own assumptions based on advice from Chinese partners

Accident statistics:

Transport accidents in China (2006)						
	Road		Rail*			
	Total	Exp.ways, Highways (40%)	Staff	Passengers	Trespassers on the tracks	Total
Number of accidents	378,781	151,512	10	1	9,208	9,219
Killed persons	89,455	35,782	2	0	5,749	5,751
Injured persons	431,139	172,456	8	13	3,242	3,263

Table A8 * National railways

As the table above shows, in most rail accidents involve trespassers on the tracks. Only very few incidents involve passengers or train staff. However, also incidents with trespassers need to be attributed to rail transport.
The average accident rate (accidents per pkm) for road transport in China is slightly higher (+25%) than in European countries on average.

Economic data:

GDP per capita based on purchasing-power-parity (PPP)							
in current international dollars	2000	2001	2002	2003	2004	2005	2006
China	2,372	2,612	2,881	3,217	3,614	4,079	4,650
Europe: Euro area	25,372	26,358	26,925	27,536	28,652	29,833	31,446
Germany	26,267	27,170	27,616	28,129	29,285	30,505	32,432
Poland	10,280	10,711	11,061	11,741	12,700	13,571	14,884
Czech Republic	15,008	15,817	16,406	17,344	18,744	20,290	22,184

Table A9

Inflation: GDP deflator							
Index	2000	2001	2002	2003	2004	2005	2006
China	198.44	202.51	203.69	209.01	223.46	232.78	240.30
Europe: Euro area	100.00	102.44	105.07	107.37	109.41	111.50	113.67
Germany	100.00	101.20	102.63	103.90	105.06	105.84	106.43
Poland	100.00	103.47	105.81	106.21	110.57	113.49	115.17
Czech Republic	100.00	104.87	107.83	108.84	113.77	113.53	115.45

Table A10

Exchange rate Euro -> Chinese Yuan Renminbi							
	2000	2001	2002	2003	2004	2005	2006
EUR > RMB	7.658	7.413	7.827	9.363	10.297	10.196	10.010

Table A11

Results of social cost estimations for China

The following tables give an overview of the social cost estimations for transport in China. On the one hand, there are cost factors for input values (such as cost per causality, per tonne of pollutant, etc.). On the other hand, cost factors per vehicle-kilometre are given for all cost categories. Cost factors per passenger-kilometre (for passenger transport) and per tonne-kilometre (for freight transport) have been calculated, too.

Air pollution costs

a) Input values: costs per unit of air pollutant

Unit costs per tonne of air pollutant (China, 2006)	
Pollutant	*Unit costs, in RMB / tonne of pollutant*
NOx	9,100
NMVOC	1,300
SO2	11,000
PM2.5 (exhaust): urban metropolitan	355,200
PM2.5 (exhaust): urban	114,300
PM2.5 (exhaust): rural	88,900
PM10 (non-exhaust): urban metropolitan	142,000
PM10 (non-exhaust): urban	45,800
PM10 (non-exhaust): rural	35,600

Table A12

b) Costs per mileage (vehicle-km, train-km)

Unit costs air pollution, road (China, 2006)						
In 0.01 RMB/ vkm (= Fen/vkm)	Motor-cycle	Car	Light duty vehicle	Heavy duty vehicle	Bus diesel	
NO_x	n.d.a.	1.66	14.96	32.74	10.50	
NMVOC (HC)	n.d.a.	0.88	0.44	0.96	0.36	
SO_2	n.d.a.	0.13	0.79	1.45	1.01	
PM2.5 (exh): urban metropol.	n.d.a.	0.00	9.16	23.87	11.68	
PM2.5 (exh): urban	n.d.a.	0.00	2.95	7.68	3.76	
PM2.5 (exh): rural	n.d.a.	0.00	2.29	5.97	2.92	

Table A13 n.d.a. = no data available. Bus data include minibuses and buses (average value for both types).

Unit costs air pollution, rail (diesel trains) (China, 2006)		
In 0.01 RMB/ train-km (= Fen/train-km)	Passenger train	Freight train
Direct emissions		
NO_x	216	692
NMVOC (HC)	6.3	20.3
SO_2	9.5	30.5
PM2.5 (exh): urban metropolitan	157	505
PM2.5 (exh): urban	50.6	162
PM2.5 (exh): rural	39.4	126
Indirect emissions *(air pollution, climate change)*		
Electricity generation (electric trains)	6.5	18.3

Table A14

Unit costs air pollution, domestic aviation and inland waterways (China, 2006)			
	Domestic aviation		Inland waterways freight *(in RMB/1,000 tkm)*
	Passenger aviation *(in RMB/1,000 pkm)*	Freight aviation *(in RMB/1,000 tkm)*	
Total air pollution costs	0.84	5.4	11.8

Table A15

Noise costs

a) Input values: Unit costs per person exposed per year

The noise indicator Lden (day-evening-night noise level) reflects an average noise exposure over the whole day, with a different weight of daytime (d), evening (e) and night (n). Noise during nighttime is weighted more strongly than during daytime. So, data in the following table represent cost per person exposed to an average yearly noise level indicated.

Unit values: annual costs per person exposed (China, 2006)			
Noise level (average yearly level), in Lden (db(A))	*in RMB/(exposed person*year)*		
	Road	Rail	Aviation
≤ 51	9	0	13
≤ 55	42	0	66
≤ 60	85	42	131
≤ 65	127	85	197
≤ 70	169	127	262
≤ 75	280	239	397
≤ 80	352	309	490

Table A16 Lden: day-evening-night noise indicator

b) Costs per mileage (vehicle-km, train-km)

Unit costs noise, (China, 2006)				
In 0.01 RMB/ vkm (= Fen/vkm)		Urban	Suburban	Rural
Road				
Car	Day	0.66	0.10	0.01
	Night	1.21	0.19	0.03
Motorcycle	Day	1.33	0.21	0.03
	Night	2.41	0.38	0.04
LDV	Day	3.30	0.51	0.06
	Night	6.03	0.95	0.11
HDV	Day	6.08	0.95	0.11
	Night	11.08	1.73	0.20
Bus	Day	3.30	0.51	0.06
	Night	6.03	0.95	0.11
Rail				
Train, passenger	Day	20.5	17.9	2.23
	Night	67.6	29.8	3.72
Train, freight	Day	36.4	34.7	4.33
	Night	148.3	58.7	7.33

Table A17

Climate change costs

a) Input values: costs per unit of CO_2 emissions

Unit values: annual costs per person exposed (China, 2006)			
Year of application	Lower value	Central value	Upper value
In EUR/tonne CO_2			
2010	2	10	18
2020	12	30	60
2030	22	55	100
2040	22	70	135
2050	20	85	180
In RMB/tonne CO_2			
2010	20	100	180
2020	120	300	600
2030	220	550	1,000
2040	220	700	1,350
2050	200	850	1,800

Table A18 The short-term values (2010) are based on short-term climate damage cost for China (see methodology chapter above), the long-term values are based on global damage values (based on IMPACT 2008).

b) Costs per mileage (vehicle-km, train-km)

The following unit costs are based on short-term cost values for 2010 (see table above).

Unit costs climate change, road (China, 2006)						
In 0.01 RMB/ vkm (= Fen/vkm)	Motor-cycle	Car	Light duty vehicle	Heavy duty vehicle	Bus diesel	Bus gasoline
CO_2 lower value	n.d.a.	0.4	1.0	1.9	1.3	1.3
CO_2 central value	n.d.a.	2.1	5.2	9.5	6.7	6.3
CO_2 upper value	n.d.a.	3.8	9.4	17.1	12.0	11.4

Table A19 n.d.a. = no data available

Unit costs climate change, rail (diesel trains) (China, 2006)		
In 0.01 RMB/ train-km (= Fen/train-km)	Passenger train	Freight train
CO_2 lower value	13	40
CO_2 central value	63	201
CO_2 upper value	113	362

Table A20

Unit costs climate change, domestic aviation and inland waterways (China, 2006)			
	Domestic aviation		Inland waterways freight *(in RMB/1,000 tkm)*
	Passenger aviation *(in RMB/ 1,000 pkm)*	Freight aviation *(in RMB/1,000 tkm)*	
CO_2 lower value	3.3	33	0.16
CO_2 central value	16	164	0.80
CO_2 upper value	30	295	1.43

Table A21

Accident costs

a) Input values: Unit costs per casualty (fatality, injury)

Unit values for casualties due to transport accidents (China, 2006)			
In RMB/ casualty	Fatality	Severe injury	Slight injury
Cost per casualty avoided	1,074,000	147,000	11,200

Table A22

b) Costs per mileage (vehicle-km, train-km)

Unit costs accidents, road (China, 2006)			
In RMB/ vkm	Urban roads	Motorways	Other roads
Motorcycles	2.33	0.015	0.41
Cars	0.32	0.022	0.12
HDV	0.81	0.022	0.20

Table A23

RMB1,000*Congestion costs*

a) Time costs per hour (value of travel time savings, VTTS)

<table>
<tr><th colspan="5">Recommended values of time per hour, China (2006)</th></tr>
<tr><td rowspan="2">Values of time for different transport modes</td><td colspan="3">Passenger transport (RMB per passenger per hour)</td><td rowspan="2">Freight (RMB per ton per hour)</td></tr>
<tr><td>Work (business)</td><td>Commuting, short distance</td><td>Commuting, long distance</td></tr>
<tr><td>Car / HDV</td><td rowspan="2">23.5</td><td rowspan="2">8.4</td><td rowspan="2">10.8</td><td>2.9</td></tr>
<tr><td>Rail</td><td>1.2</td></tr>
<tr><td>Bus/coach</td><td>18.9</td><td>6.0</td><td>7.7</td><td>-</td></tr>
<tr><td>Air</td><td>32.4</td><td>-</td><td>16.1</td><td>n.a.</td></tr>
</table>

Table A24 HDV = heavy duty vehicles

b) Costs per mileage (vehicle-km, train-km): Optimal external costs

These values cannot be used directly for CBA. They represent optimal costs for pricing. The values are based on cost factors of the European study HEATCO 2006 and IMPACT 2008.

Unit costs congestion, road (China, 2006)						
In RMB/ vkm	Passenger cars			Goods vehicles		
	Min.	Central value	Max.	Min.	Central value	Max.
Large urban areas (>2 million inhabitants)						
Urban motorways	0.26	0.43	0.78	0.91	1.52	2.73
Urban collectors	0.17	0.43	1.04	0.43	1.08	2.60
Local streets centre	1.30	1.73	2.60	2.60	3.47	5.20
Local streets cordon	0.43	0.65	0.87	0.87	1.30	1.73
Small and medium urban areas (<2 mio.)						
Urban motorways	0.09	0.22	0.35	0.30	0.76	1.21
Urban collectors	0.04	0.26	0.43	0.11	0.65	1.08
Local streets cordon	0.09	0.26	0.43	0.17	0.52	0.87
Rural areas (<2 mio.)						
Motorways	0.00	0.09	0.17	0.00	0.30	0.61
Trunk roads	0.00	0.04	0.13	0.00	0.11	0.33

Table A25

For rail transport and domestic aviation, there is no data currently available to calculate scarcity costs.

The differences between the values can be explained by the different likelihood of congestion (influenced mainly by the number of vehicles) in different areas: in large urban area, likelihood of (heavy) congestion is much higher than in small urban areas or rural areas. Therefore, average costs per vehicle-km are higher. Additionally, the likelihood of congestion differs also between different road types: in dense urban areas, local streets in the centre are more prone to congestion than motorways (not in total congestion hours, but in congestion time per vehicle-km driven on a type of road).

Results of social cost estimations:
Unit values per passenger-km and per tonne-km

Air pollution costs

Unit costs per passenger-km and per tonne-km:

Unit costs air pollution, road (China, 2006)						
	Motor-cycle	Car	Light duty vehicle	Heavy duty vehicle	Bus diesel	Bus gasoline
	RMB/ 1,000 pkm	*RMB/ 1,000 pkm*	*RMB/ 1,000 tkm*	*RMB/ 1,000 tkm*	*RMB/ 1,000 pkm*	*RMB/ 1,000 pkm*
NO_x	n.d.a.	7.2	74.8	28.5	5.8	5.2
NMVOC (HC)	n.d.a.	3.8	2.2	0.8	0.2	1.0
SO_2	n.d.a.	0.6	4.0	1.3	0.6	0.2
PM2.5 (exh): urban metropol.	n.d.a.	0.0	45.8	20.8	6.5	0.0
PM2.5 (exh): urban	n.d.a.	0.0	14.7	6.7	2.1	0.0
PM2.5 (exh): rural	n.d.a.	0.0	11.5	5.2	1.6	0.0

Table A26 n.d.a. = no data available. pkm = passenger-kilometre, tkm = tonne-kilometre

Unit costs air pollution, rail (diesel trains) (China, 2006)		
	Passenger train *in RMB/1,000 pkm*	Freight train *in RMB/1,000 tkm*
Direct emissions		
NO_x	2.16	2.56
NMVOC (HC)	0.06	0.08
SO_2	0.10	0.11
PM2.5 (exh): urban metropolitan	1.57	1.87
PM2.5 (exh): urban	0.51	0.60
PM2.5 (exh): rural	0.39	0.47
Indirect emissions *(air pollution, climate change)*		
Electricity generation (electric trains)	0.07	0.07

Table A27 pkm = passenger-kilometre, tkm = tonne-kilometre

Noise costs

Unit costs per passenger-km and per tonne-km:

Unit costs noise, (China, 2006)				
		Urban	Suburban	Rural
Road				
Car *in RMB/1,000 pkm*	Day	2.9	0.5	0.0
	Night	5.2	0.8	0.1
Motorcycle *in RMB/1,000 pkm*	Day	13.3	2.1	0.3
	Night	24.1	3.8	0.4
LDV *in RMB/1,000 tkm*	Day	16.5	2.6	0.3
	Night	30.1	4.8	0.6
HDV *in RMB/1,000 tkm*	Day	5.3	0.8	0.1
	Night	9.6	1.5	0.2
Bus *in RMB/1,000 pkm*	Day	1.8	0.3	0.0
	Night	3.3	0.5	0.1
Rail				
Train, passenger *in RMB/1,000 pkm*	Day	0.21	0.18	0.02
	Night	0.68	0.30	0.04
Train, freight *in RMB/1,000 tkm*	Day	0.13	0.13	0.02
	Night	0.55	0.22	0.03

Table A28 pkm = passenger-kilometre, tkm = tonne-kilometre

Climate change costs

Unit costs per passenger-km and per tonne-km:

Unit costs climate change, road (China, 2006)						
	Motor-cycle	Car	Light duty vehicle	Heavy duty vehicle	Bus diesel	Bus gasoline
	RMB/ 1,000 pkm	*RMB/ 1,000 pkm*	*RMB/ 1,000 tkm*	*RMB/ 1,000 tkm*	*RMB/ 1,000 pkm*	*RMB/ 1,000 pkm*
CO_2 lower value	n.d.a.	1.8	5.2	1.7	0.7	0.7
CO_2 central value	n.d.a.	9.2	26.1	8.3	3.7	3.5
CO_2 upper value	n.d.a.	16.6	47.1	14.9	6.7	6.3

Table A29 n.d.a. = no data available. pkm = passenger-kilometre, tkm = tonne-kilometre

Unit costs climate change, rail (diesel trains) (China, 2006)		
	Passenger train *in RMB/1,000 pkm*	Freight train *in RMB/1,000 tkm*
CO_2 lower value	0.13	0.15
CO_2 central value	0.6	0.7
CO_2 upper value	1.1	1.3

Table A30 pkm = passenger-kilometre, tkm = tonne-kilometre

Accident costs

Unit costs per passenger-km and per tonne-km:

Unit costs accidents, road (China, 2006)			
	Urban roads	Motorways	Other roads
Motorcycles *in RMB/1,000 pkm*	2'328	15	414
Cars *in RMB/1,000 pkm*	138	10	52
HDV *in RMB/1,000 tkm*	70	2	18

Table A31 pkm = passenger-kilometre, tkm = tonne-kilometre

For **rail**, the average accident costs are **11.5 RMB per 1,000 passenger-km**.

Congestion costs

Unit costs per passenger-km and per tonne-km:

Unit costs congestion, road (China, 2006)						
	Passenger cars *in RMB/1,000 pkm*			Goods vehicles *in RMB/1,000 tkm*		
	Min.	Central value	Max.	Min.	Central value	Max.
Large urban areas (>2 million inhabitants)						
Urban motorways	113	188	339	126	211	379
Urban collectors	75	188	452	60	151	361
Local streets centre	565	754	1'131	361	482	722
Local streets cordon	188	283	377	120	181	241
Small and medium urban areas (<2 mio.)						
Urban motorways	38	94	151	42	105	169
Urban collectors	19	113	188	15	90	151
Local streets cordon	38	113	188	24	72	120
Rural areas (<2 mio.)						
Motorways	0	38	75	0	42	84
Trunk roads	0	19	57	0	15	45

Table A32 pkm = passenger-kilometre, tkm = tonne-kilometre

Additional data for calculation of marginal costs

Capital Costs for Chinese Rail and Road (RMB, 2006 prices)

Rail:	*Cost per Route Km*	*Road:*	*Cost per Route Km*
Freight	40,000,000	Expressways	60,920,000
Passenger	62,130,000	National Highways	31,260,000

Table A33

Maintenance Costs for Chinese Rail and Road (RMB, 2006 prices)

Rail:	*Cost per Route Km*	*Road:*	*Cost per Route Km*
Freight	115,570	Expressways	59,500
Passenger	99,330	National Highways	141,200

TableA34

Annuitised Capital Costs for Chinese Rail and Road (RMB, 2006 prices)

Rail:	Cost per Route Km	Road:	Cost per Route Km
Freight	2,478,604	Expressways	3,771,310
Passenger	3,847,412	National Highways	1,938,603

Table A35

Rail Capacity:

The calculation of annual rail capacity involved a number of assumptions whether are outlined below.

- Assumption 1 - Trains per hour = 12
- Assumption 2 - Hours run per day = 20
- Assumption 3 - Days train run = 300

Based on these assumptions we can calculate that there are 240 trains per day on any given route km (12*20) and that the annual capacity on any given route km is equal to 72,000 trains. (12*20*300)

Road Capacity:

The calculation of annual road capacity involved less assumptions and was based upon tables provided to us by our Chinese consultant, Wu Weiping, which are given in Tables 19 and 20 below.

Table A36

Expressway Designed Capacity (cars/day)

Travelling speed	4 lanes	6 lanes	8 lanes
120 km/hr	40,000 – 55,000	60,000 – 80,000	75,000 – 100,000
100 km/hr	35,000 – 50,000	55,000 – 70,000	70,000 – 90,000
80 km/hr	30,000 – 45,000	50,000 – 65,000	65,000 – 85,000
60 km/hr	25,000 – 40,000	45,000 – 60,000	60,000 – 80,000

To calculate the annual expressways capacity we had to make some assumptions as outlined below:

- Assumption 1 - 6 lane design
- Assumption 2 - 80 km/hr and a midpoint capacity of 60,000 cars per day.
- Assumption 3 – Days roads used = 300

Based on these assumptions we calculated an annual road capacity of 18,000,000 passenger car units (60,000 * 300) for expressways.

Table A37

National Highways Designed Capacity (cars/day)

Travelling speed	2 lanes	6 lanes
120 km/hr	3,000 – 7,500	15,000 – 30,000

To calculate the annual national highway capacity we had to make some assumptions as outlined below:

- Assumption 1 - 6 lane design
- Assumption 2 - 120 km/hr and a low capacity of 15,000 cars per day.
- Assumption 3 – Days roads used = 300

Based on these assumptions we calculated an annual road capacity of 4,500,000 passenger car units (15,000 * 300).

Existing rail and road traffic per route km.

Table A38

Rail – Route and Train Kms

Rail:	Route Kms	Train Kms	Train Kms per Route Km
Freight	77,100	1,028,540,000	13,340
Passenger	77,100	643,970,000	8,352

Table A39

Road – Route and HGV Kms

Rail:	Route Kms	HGV Kms	HGV Kms per Route Km
Expressway	50,000	48,927,000,000	978,540
Passenger	170,000	51,368,000,000	302,165

Operating costs

Table A40 Rail Operating Costs per Vehicle Km (RMB – 2006 prices)

Passengers	Freight
120	127

Table A41 Road Operating Costs per Vehicle Km (RMB – 2006 prices)

Car	Bus	LGV	HGV
1.99	3.53	2.83	3.77

ANNEX 2 Marginal cost estimates for Europe

Road Wear and Tear Marginal Costs

The table below summarise the average and marginal cost for the road case studies.

	Average Cost	Marginal Cost	Output variable
	€/Xkm	€/Xkm	X
Renewal			
Germany R	1.590	1.390	HGV
Poland R	0.210	0.120	All veh
Sweden R paved	0.036	0.032	HGV
Sweden R gravel	0.415	0.236	HGV
Sweden duration model	-	0.0013	HGV
Renewal and Maintenance			
Sweden R+M	0.059	0.040	HGV
Poland R+M	0.270	0.130	All veh
Maintenance/Operation			
Poland M	Na	Na	All veh
Sweden O	0.024	(0.002)	All veh
Sweden O winter	0.015	(0.001)	All veh
Sweden O paved	0.003	(0.001)	All veh
Sweden O gravel	0.066	(0.010)	All veh

Table A1 Average and marginal cost in the road sector, Source: GRACE 2006b

Rail wear and tear Marginal Costs

Average and marginal costs are presented in the table below.

	Average Cost	**Marginal Cost**	**Output variable**
	€/Xkm	€/Xkm	X
Renewal			
Sweden – duration model		0.00028	Gross Tonne (Passenger)
		0.00012	Grosse Tonne (Freight)
Maintenance and Renewal			
Sweden	0.00285	0.00070	Grosse Tonnes
Switzerland (A+B)	0.00364	0.00097	Grosse Tonnes
Maintenance			
Sweden	0.00209	0.00031	Gross Tonne
Switzerland (A)	0.0022	0.00045	Gross Tonne
UK (model V)	0.00828	0.001978	Gross Tonne
Switzerland (part of A)	0.00133	0.00038	Gross Tonne
Operation			
Sweden	0.153	0.054	Trains

Table A2 Average and marginal cost in the rail sector Source: GRACE 2006b

The following table shows results of other studies.

Study (maintenance costs only) / Model estimated	**Country**	**Marginal Cost Estimates (Average), in EUR per 1,000 Gross Tonne-km**	**Elasticity of cost with respect to tonne-km**
Johansson and Nilsson (2004)	Sweden	0.127	0.169 (average)
Johansson and Nilsson (2004)	Finland	0.239	0.167 (average)
Tervonen and Idstrom (2004)	Finland	0.18	0.133-0.175
Munduch et al (2002)	Austria	0.55	0.27
Gaudry and Quinet (2003)	France	Not reported	0.37 (average)
Andersson (2005)	Sweden	0.293 (pooled OLS model) 0.272 (random effects model)	0.1944 (average pooled OLS model) 0.1837 (average Random effects model)
Booz Allen & Hamilton (2005)	UK	1.196	Proportion of maintenance cost variable with traffic: 0.18; 0.24 for track maintenance

Table A3 Results from other studies compared against the estimated models
Source UK CS

Airport infrastructure costs

(Selected airports)	*Passengers*	*Scale*	*MC ATM €*	*MC WLU €*
LIEGE	*206 986*	*1.17420559*	*194.01*	*4.25*
GRAZ	*898 504*	*1.1097998*	*526.20*	*11.29*
SALZBURG	*1 493 553*	*1.1249021*	*742.97*	*14.94*
NUREMBERG	*3 296 267*	*1.11846462*	*298.80*	*10.91*
PERTH	*6 654 967*	*1.12742364*	*1266.37*	*0.06*
VIENNA INTL	*15 926 354*	*1.13344413*	*671.26*	*10.12*
MUNICH	*26 835 231*	*1.11200586*	*555.55*	*14.80*
TORONTO PEARSON	*29 914 750*	*1.09727589*	*597.02*	*9.74*
HONG KONG INTL	*38 297 485*	*1.12730555*	*2373.61*	*3.41*
BEIJING CAPITAL	*41 004 008*	*1.09166634*	*1357.88*	*13.87*
DALLAS-FT.WORTH	*60 412 434*	*1.17238187*	*264.17*	*1.20*
HARTSFIELD	*83 265 471*	*1.19511836*	*158.74*	*0.23*

Table A4. Scale elasticities and long run marginal costs for airports. Individual estimates GRACE Deliverable 4
Note: ATM – average traffic movement
WLU = work load unit

(Selected airports)	*MC ATM €*	*MC WLU €*
LIEGE	262.48	2.55
GRAZ	343.25	4.87
SALZBURG	737.66	6.27
NUREMBERG	202.16	6.84
PERTH	396.95	0.50
VIENNA INTL	145.82	8.94
MUNICH	11.07	11.98
TORONTO PEARSON	44.23	6.46
HONG KONG INTL	463.21	2.46
BEIJING CAPITAL	159.72	7.56
DALLAS-FT.WORTH	-16.85	2.11
HARTSFIELD	-9.09	0.56

Table A5. Short run marginal costs for airports. Individual estimates (GRACE deliverable 4)

Supplier Operating Cost

Urban public transport, Lisbon

This case study was dedicated to the estimation of the supplier operating marginal costs of a recent commuter service crossing Tagus river, in Lisbon. The operator, Fertagus, started the production of the service in 1999, framed in the new legal structure for the rail sector, which established the division between rail infrastructure and rail operation. The company runs the service across the Tagus to and from Lisbon and benefits from a 30-year concession period. Service is provided from 5:35 AM to 1:55 AM, linking the two line extremes in 27 minutes. During peak periods, the service headway is 7.5 minutes.

Swedish rail case study

This case study provides an analysis of the price-relevant marginal cost of an interurban rail passenger transport service, in Sweden, with emphasis on the supplier's marginal cost. More precisely, the analysis was focused in the long-distance route between Stockholm and Sundsvall that has a total distance of 816 km. This route integrates the following segments: Stockolm/Gävle; Gävle/Söderhamn and Söderhamn/Sundsvall. The service is operated with a flexible-formation train as are many other railway services in Sweden. However, since the fixed formation train has taken a substantial share of the total rail market, the case study also considers this type of operation.

Synthesis of the Results

The next table shows marginal costs values and MC/AC ratios derived from research carried out as part of the Lisbon and Swedish case studies.

	Average cost per train km peak (EUR 1998)	**Average cost per train km off peak (EUR 1998)**	**Marginal cost per passenger km in peak (EUR 1998)**	**Marginal cost per passenger km in off peak (EUR 1998)**
Urban public transport case study, Lisbon*	17.640	1.864	0.0216	0.0086
	Marginal cost per passenger km (EUR 1998)	Marginal cost per passenger km in peak ** (EUR1998)	Marginal cost per passenger km, off peak *** (EUR 1998)	
Swedish rail case study	0.036	0.072	0.022	

Table A6: Supplier operating costs. Source UNITE

Notes: considering an occupancy rate of 0.5, 80 seats per carriage and a voyage speed of 90 kmh
* Average cost as a proxy for marginal cost
** Marginal cost per passenger round trip in peak/line distance = 59/816 = 0.072 Euro
** Marginal cost per passenger round trip in off peak/line distance = 18/816 = 0.022 Euro

Externalities road transport

The following table presents the unit values for road transport, recommended in the European research project IMPACT. The values reflect marginal cost figures based on a series of European studies. Note that values for the different cost components are not fully consistent as they are based on different base years. If values differ for EU countries, exemplary values have been taken for Germany as a large, central European country.

Cost component		**Passenger car**	**Heavy duty vehicle (HDV)**
€ct/vkm		Unit costs (bandwidths)	Unit costs (bandwidths)
Noise	Urban, day	0.76 (0.76 - 1.85)	7.01 (7.01 - 17.01)
	Urban, night	1.39 (1.39 - 3.37)	12.8 (12.8 - 31)
	Interurban, day	0.12 (0.04 - 0.12)	1.1 (0.39 - 1.1)
	Interurban, night	0.22 (0.08 - 0.22)	2 (0.72 - 2)
Congestion	Urban, peak	30 (5 - 50)	75 (13 - 125)
	Urban, off-peak	0 (-)	0 (-)
	Interurban, peak	10 (0 - 20)	35 (0 - 70)
	Interurban, off-peak	0 (-)	0 (-)
Accidents	Urban	4.12 (0 - 6.47)	10.5 (0 - 13.9)
	Interurban	1.57 (0 - 2.55)	2.7 (0 - 3.5)
Air pollution	Urban, petrol	0.17 (0.17 - 0.24)	(-)
	Urban, diesel	1.53 (1.53 - 2.65)	10.6 (10.6 - 23.4)
	Interurban, petrol	0.09 (0.09 - 0.15)	(-)
	Interurban, diesel	0.89 (0.89 - 1.8)	8.5 (8.5 - 21.4)
Climate change	Urban, petrol	0.67 (0.19 - 1.2)	(-)
	Urban, diesel	0.52 (0.14 - 0.93)	2.6 (0.7 - 4.7)
	Interurban, petrol	0.44 (0.12 - 0.79)	(-)
	Interurban, diesel	0.38 (0.11 - 0.68)	2.2 (0.6 - 4)
Up- and downstream processes	Urban, petrol	0.97 (0.97 - 1.32)	(-)
	Urban, diesel	0.61 (0.61 - 1.05)	3.1 (3.1 - 6.9)
	Interurban, petrol	0.65 (0.65 - 1.12)	(-)
	Interurban, diesel	0.45 (0.45 - 0.92)	2.7 (2.7 - 6.7)
Nature & landscape	Urban	-	0 (0 - 0)
	Interurban	0.4 (0 - 0.4)	1.15 (0 - 1.15)
Soil & water pollution	Urban/Interurban	0.06 (0.06 - 0.06)	1.05 (1.05 - 1.05)
Total			
Urban	**Day, peak**	38.4 (8.4 - 63.9)	107.3 (33.7 - 187.4)
	Day, off-peak	7.9 (3.5 - 13.3)	34.8 (22.5 - 67)
	Night, off-peak	8.6 (4.1 - 14.8)	40.6 (28.2 - 80.9)
Interurban	**Day, peak**	14.1 (1.7 - 26.7)	54.4 (13.3 - 109)
	Day, off-peak	4.1 (1.7 - 6.7)	19.4 (13.3 - 39)
	Night, off-peak	4.2 (1.8 - 6.8)	20.3 (13.6 - 39.9)

Table A7 Road transport: exemplary unit values per cost component in €ct/vehicle-km for Germany (€2000). Source: IMPACT 2008

Externalities Rail transport

The following table presents the unit values for rail transport, recommended in the European research projects IMPACT. The values reflect marginal cost figures based on a series of European studies. Note that the values for the different cost components are not fully consistent as they are based on different base years. If values differ for EU countries, exemplary values have been taken for Germany as a large, central European country.

Cost component		**Rail passenger**	**Rail freight**
		Unit costs (bandwidths)	Unit costs (bandwidths)
Noise costs	Urban, day	23.7 (23.7 - 46.7)	41.9 (41.9 - 101.2)
	Urban, night	78 (78 - 78)	171.1 (171.1 - 171.1)
	Interurban, day	20.6 (10.4 - 20.6)	40.1 (20.7 - 40.1)
	Interurban, night	34.4 (34.4 - 34.4)	67.7 (67.7 - 67.7)
Scarcity costs	Peak	20 (0 - 20)	20 (0 - 20)
Accident costs	Urban/Interurban	8 (8 - 30)	8 (8 - 30)
Air pollution	Urban, electric	0 (0 - 0)	0 (0 - 0)
	Urban, diesel	144.8 (144.8 - 297.2)	366.8 (366.8 - 752.6)
	Interurban, electric	0 (0 - 0)	0 (0 - 0)
	Interurban, diesel	90.7 (90.7 - 203.6)	305.8 (305.8 - 686.4)
Climate change	Urban, electric	0 (0 - 0)	0 (0 - 0)
	Urban, diesel	11.4 (3.2 - 20.6)	28.9 (8.1 - 52.1)
	Interurban, electric	0 (0 - 0)	0 (0 - 0)
	Interurban, diesel	8.6 (2.4 - 15.5)	28.9 (8.1 - 52.1)
Up- and downstream processes	Urban, electric	24.8 (16.4 - 52.1)	44.4 (22.3 - 93)
	Urban, diesel	13.8 (12.2 - 27.7)	34.8 (30.8 - 70.1)
	Interurban, electric	15.9 (8 - 33.4)	44.4 (22.3 - 93)
	Interurban, diesel	10.3 (9.1 - 22.5)	34.8 (30.8 - 75.7)
Nature & landscape	Interurban	23.2 (0 - 23.2)	7.5 (0 - 7.5)
Soil & water pollution	Urban/Interurban	0.3 (0.3 - 0.3)	1 (1 - 1)
Total external costs			
Urban	**Day, electric, peak**	76.8 (48.3 - 149)	115 (73 - 245)
	Day, electric, off-peak	56.8 (48.3 - 129)	95 (73 - 225)
	Day, diesel, peak	222 (192.1 - 442)	502 (457 - 1027)
	Day, diesel, off-peak	202 (192.1 - 422)	482 (457 - 1007)
	Night, electric, off-peak	111.1 (102.6 - 160)	225 (202 - 295)
	Night, diesel, off-peak	256.3 (246.5 - 454)	611 (586 - 1077)
Interurban	**Day, electric, peak**	88 (26.7 - 127)	121 (52 - 192)
	Day, electric, off-peak	68 (26.7 - 107)	101 (52 - 172)
	Day, diesel, peak	181.7 (121 - 336)	446.2 (374 - 913)
	Day, diesel, off-peak	161.7 (121 - 316)	426 (374 - 893)
	Night, electric, off-peak	81.8 (50.7 - 121)	129 (99 - 199)
	Night, diesel, off-peak	175.5 (144.9 - 329)	454 (421 - 920)

Table A8 Rail transport: exemplary unit values per cost component in €ct/train-km for Germany (€2000).

Source: IMPACT 2008 Handbook

Externalities air (eurocents 2000 per passenger km)

	Air Pollution	Climate Change	
Flight Distance (km)	Direct Emissions	Direct Emissions	Indirect Emissions
<500 km	0.21	0.62	0.71
500 – 1000	0.12	0.46	0.53
1000 – 1500	0.08	0.35	0.40
1500 – 2000	0.06	0.33	0.38
>2000	0.03	0.35	0.40

Table A9 Air transport costs of air pollution and global warming

Noise costs per landing or take off (Schiphol)

	40 seater	100 seater	200 seater	400 seater
Fleet average	180	300	600	1200
State of Art	90	150	300	600

Table A10 Air transport noise costs (example)
Source: IMPACT 2008 Handbook

Externalities water (euro per ship km)

			Global Warming	
		Air Pollution	Direct Emissions	Indirect Emissions
Dry cargo	<250 tonne	0.89	0.08	0.08
	250 – 400	0.89	0.08	0.08
	400 – 640	1.22	0.11	0.11
	650 – 1000	1.86	0.17	0.16
	1000 – 1500	2.54	0.23	0.22
	1500 – 3000	4.63	0.42	0.40
	>3000	4.63	0.42	0.40
Tanker	<250 tonne	0.89	0.08	0.08
	250 – 400	0.90	0.08	0.08
	400 – 640	1.22	0.11	0.11
	650 – 1000	1.28	0.17	0.16
	1000 – 1500	2.54	0.23	0.22
	1500 – 3000	7.28	0.65	0.62
	>3000	7.28	0.65	0.62

Table A11 Water transport air pollution and global warming
Source IMPACT 2008 Handbook

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Annex 4 Glossary of technical terms

Avoidance cost approach
An approach to valuing external cost which estimates the cost of reducing the level of the externality concerned in the most efficient way possible.

Damage cost approach
An approach to valuing external costs which values the actual damage done by the physical impact of the externality.

External costs or benefits (also called externalities)
Costs or benefits not borne directly by the person taking the transport decision

Impact Pathway Approach
An approach to valuing external costs of pollution based on three major steps. First, air pollution exposure of the population is calculated on the basis of emission, transmission and exposition data. Secondly, the physical impact of this air pollution exposure on humans (health effects such as myocardial diseases), ecosystems and materials (e.g. buildings) is calculated on the basis of dose-response functions known from scientific studies. The third step involves the valuation of these adverse effects in monetary terms, which finally leads to the external costs of air pollution

Internal costs or benefits
Costs or benefits borne directly by the person taking the transport decision

Long run marginal social cost (LRMSC)
The social cost of carrying more traffic on the mode in question when infrastructure is expanded in line with demand.

Passenger Car Unit (PCU)
A unit of measurement of road capacity which adds different types of vehicle with weights according to the relative amount of capacity they take up. Cars are given a weight of 1.

Purchasing power parity (PPP)
A PPP exchange rate describes the relative purchasing power of the two currencies

Short run marginal social cost (SRMSC)
The social cost of carrying more traffic on the existing infrastructure

Social costs
The sum of internal and external costs

Willingness to pay approach
An approach to valuing externalities which uses either actual decisions or hypothetical surveys to estimate what people would be willing to pay for the externality to be removed.