3.4 Enhancing current networks

Headlines

- Even after accounting for environmental impacts, well-targeted infrastructure options are able to offer very high welfare and GDP returns per £1 of government expenditure with big gains for businesses, freight and commuters.

Congested and growing urban areas

- A step-change in understanding of the best interventions in urban areas is needed.
- Walking and cycling options have the potential for very high welfare returns relative to their cost but may not be enough alone to tackle the true scale of the further challenges facing the UK.
- Improved bus services are sometimes able to offer a higher-return solution to transport problems than more costly fixed infrastructure options, such as light rail.
- Roads can, in some circumstances, offer a very high-return solution to transport problems in major urban areas; they should not be ignored as an option to consider but environmental impacts must, of course, be accounted for.
- Targeted additional capacity on key commuter corridors into major urban areas can offer very high returns owing to the competing demands for capacity of large volumes of travellers. This offers substantial benefits not just to commuters but also to freight, business and leisure travellers.

Key international gateways

- Private sector investment in additional capacity at ports and airports, where capacity constraints threaten rising costs to the UK economy and environmental effects are accounted for, would make a significant contribution to GDP and welfare.
- Additional capacity on targeted surface access links offers among the highest returns, even after accounting for environmental impacts.

Key inter-urban corridors

- Targeted inter-urban road capacity offers very high GDP and welfare returns, even after accounting for the environmental impacts; looking beyond 2015, in the absence of road pricing and better use measures, there is an economic case for a rate of road build enhancements that exceeds current rates.
- With national road pricing, there would be an economic case for additional strategic road capacity beyond 2015, particularly on the approaches to, and corridors around, major urban areas but it would be significantly lower than the current rate of road build.
- Additional infrastructure intended to transform the economy and relying on untested technologies is unlikely to be a priority given the UK's extensive network and connectivity and the speculative demand benefits. Those step-change measures proposed as a solution to existing and likely future problems are more likely to perform well, but must be assessed alongside other options for a given transport challenge.

INTRODUCTION

4.1 The previous chapter demonstrated that better use options have the potential to contribute significantly to GDP and can have good environmental impacts. Therefore these should always be the first option considered. In some circumstances however, making better use can only go so far, prompting the need to consider the costs and benefits of additional infrastructure.

4.2 The case for additional infrastructure is dependent on the nature and scale of the challenge faced; the economic, demographic and environmental implications of taking action in a particular location; and the costs of alternative solutions. In this chapter, the context of infrastructure options will be set out followed by a description of the range of infrastructure options and their relative returns. Given the available evidence, returns will first be discussed in the absence of road pricing, then each section explores the key issues around the impacts on returns if roads were better priced.

4.3 Instead of taking a modal approach, this chapter adopts a structure based on the strategic priorities identified in Volume 2, namely:

- growing and congested urban areas and their catchments – infrastructure requirements in the UK's often complex urban networks;
- key international gateways – the infrastructure interventions needed to support the UK's internationally competitive position in the increasingly globalised world; and
- key inter-urban corridors – the infrastructure needed to support connections between the UK's major urban areas, and international gateways.

4.4 Before examining these groupings, some overview messages are identified.

INVESTING IN INFRASTRUCTURE: OVERVIEW

4.5 Infrastructure provision can take a range of forms, and may involve a combination of more than a single type. This chapter broadly distinguishes between variable capacity provision, and fixed infrastructure:

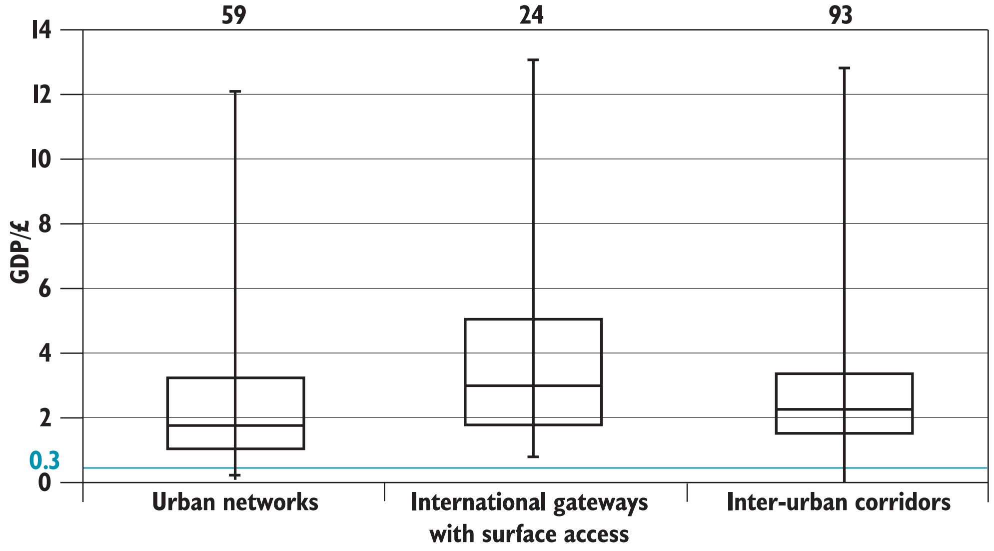
- variable capacity: investment in assets that increase the effective capacity of the existing transport system without the need for significant additional fixed infrastructure. For example, longer trains and platforms, additional buses; and
- fixed infrastructure: investment in long-life transport capital assets that often create a larger 'footprint' in terms of land take, such as new and improved roads, rail lines or ports capacity.

4.6 Most of the evidence available to this study on the GDP and welfare returns is from these two types of infrastructure options. As further described in Chapter 3.5, the evidence reflects real schemes implemented or proposed in the UK, plus modelling of some illustrative interventions. The availability of evidence has meant that the extent to which different interventions or areas are covered is sometimes limited with only a small sample size. For some interventions, there is no robust evidence on which this study has been able to draw, for example on rail freight interventions. In addition, the study relies on evidence which is a function of the existing options generation process. Such interventions have not been generated with growth as the key objective. If they were, different options may have come forward.

4.7 For the purpose of illustration, all sample schemes have been assigned to one of the strategic priorities. This does not necessarily mean that all of these should be a priority, rather it is to allow an understanding, within each grouping, of the types of interventions and their characteristics that are able to contribute to economic welfare. Given the very small sample size of schemes in growing and congested urban areas, other urban interventions have been grouped together along with these to form a group of 'urban networks' interventions.

4.8 Considering GDP returns alone as a sub-set of welfare, as in Figure 4.1, shows that all the priority links have the potential to offer high returns if the interventions are well targeted. There are wide variations within each strategic priority, as shown by the length of the vertical lines that plot the range of return between the very best and lowest-performing schemes of the evidence available. The 'boxes' on each vertical line demonstrate the range of returns from the middle 50 per cent of schemes. For example, for urban networks, 50 per cent of schemes have a GDP per pound in the range £0.70 to £3.20, with a median average £1.65[1].

Figure 4.1: Distribution of GDP per pound by strategic priority



Source: DfT.

4.9 Some schemes show extraordinarily high returns. Around 15 per cent of schemes show GDP returns of greater than £5 for every £1 spent, including a large number of road schemes, partly because of the large number of road schemes that are included in the database.

The urban story is complex

4.10 A more surprising result in Figure 4.1 is the lower relative GDP returns of urban networks with an average (median) return of £1.65 per £1 of government spend. Given the potential agglomeration and labour market impacts as discussed in Volume 1, higher returns would be expected in these areas. The findings from this evidence are due to the higher proportion of public transport schemes that typically offer low business benefits or that have been developed for social objectives, so GDP returns are lower. The size of the database is also not considered representative of the numbers of schemes that could be expected across the different strategic priorities because the majority of evidence is on strategic road capacity enhancements.

[1] For the wider BCR, the threshold above which the intervention is said to have a good return is 1.3. This reflects the fact that benefits to society should at least outweigh the costs of the intervention, plus the efficiency costs of raising the money through taxation to fund it (assumed to be 30 per cent). GDP is a partial measure of welfare. The cost of the intervention – whilst diverting resources from other parts of the economy – does not reduce total GDP. As such, the benefits need only outweigh the efficiency costs of raising taxation. This is reflected in a threshold of 0.3, which is required for an intervention to have a net contribution to GDP.

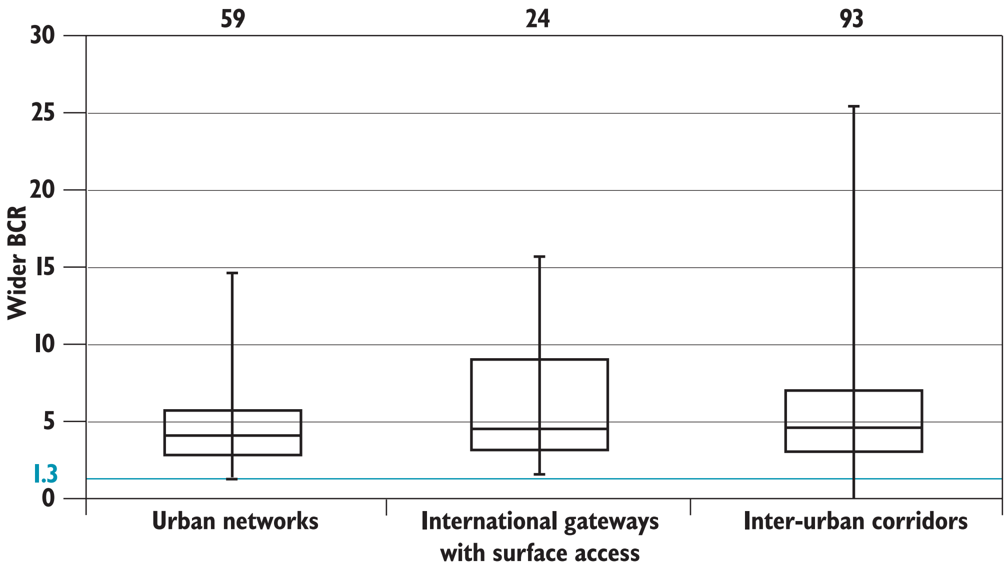
4.11 Even so, it is worth noting that even though the schemes considered are not designed explicitly to target growth, the top 25 per cent of urban schemes offer returns at least as high as the average (median) of the better-performing interventions of around £3 of GDP per £1 of government spend (given the smaller sample size of interventions for which evidence is available).

4.12 Perhaps the most significant element of GDP that is missing from the current approach to appraisal is the agglomeration effect. But the options in major urban areas were not generated with an understanding of these effects. If option generation were to take account of these new effects, higher GDP returns would be achievable.

4.13 When the broader perspective of welfare – the wider BCR – is considered, as demonstrated in Figure 4.2, the disparity in returns between urban networks and the other strategic priorities reduces owing to the fact that direct benefits to commuters and non-work/leisure travellers are now included. They are important beneficiaries of urban interventions.

4.14 As with Figure 4.1, Figure 4.2 has the vertical line plotting the range of returns between the best and lowest-performing interventions of the evidence available for each strategic priority.[2] The wider BCRs are higher than GDP per pound achieved owing to the inclusion of a broader range of benefits. The median average return of urban areas is around 4, and that of inter-urban corridors and international gateways is 4.5.

Figure 4.2: Distribution of economic returns from government expenditure by strategic priority: wider benefit: cost ratio



Source: DfT.

[2] The available evidence has, for the purposes of illustration, been allocated to one of each of the strategic priorities.

Targeted road interventions offer very high welfare returns

4.15 Another feature of the underlying data is that across each of the priority link groupings, the range of returns is significant. The highest welfare returns on roads appear to be where congestion problems are caused by the shared network nature of UK roads. For example, where a road enhancement is able to improve accessibility to a major airport, it is likely that a range of other non-airport travellers will use and benefit from the improved link.[3]

Costs of interventions can constrain relative returns

4.16 On the basis of the evidence available, fixed capacity enhancements other than roads often show relatively low returns. This in part reflects several low-returns public transport schemes such as some light rail options, but also reflects the very high-cost of rail infrastructure projects. Rail schemes can potentially generate significant absolute benefits but the high costs involved mean that the return per pound invested is often constrained, when compared with other interventions.

4.17 It is of course important to remember that the environmental implications of additional infrastructure can, in some cases, be substantial. Figure 4.3 attempts to demonstrate the illustrative estimated impact on the wider BCR of the most significant social and environmental effects for which it is possible to estimate a monetary value. These are: carbon emissions, using Defra guidance; air quality, noise and landscape using published government research.[4] Figure 4.3 plots out the illustrative reduction or increase in the wider BCR that would be brought about by taking the environmental implications into account. Only those schemes for which this has been possible using available evidence are shown; this is around one-third of the schemes in the database.

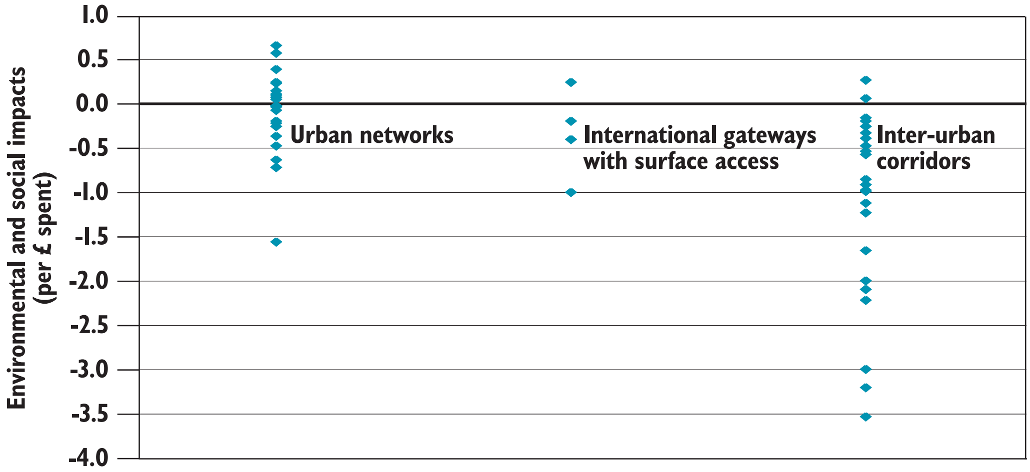
4.18 As Figure 4.3 shows, the variation in impacts is, wide as they are, highly dependent on location. Interventions in urban areas can have beneficial impacts, for example public transport interventions can reduce congestion through providing incentives for modal shift from cars. For fixed infrastructure options, as are captured in surface access and inter-urban links, the adverse impacts on the environment can notably reduce the wider BCR. As Figure 4.3 shows, for some interventions, the BCR can be reduced by more than 3 points, with many reducing by more than 1, i.e. falling from, for example, a wider BCR of 6 to 3.

4.19 Therefore, although the wider BCRs of new inter-urban links are generally stronger, this must be balanced against the environmental effects that are, on average, adverse.

[3] *Transport demand to 2025 and the economic case for road pricing and investment*, DfT, 2006, Chapter 6.

[4] For more detail see, *Transport demand to 2025 and the economic case for road pricing and investment*, DfT, 2006.

Figure 4.3: The impact on the wider BCR of environmental effects by strategic priority[a]



[a]Social effects, such as journey ambience, are also illustratively included where possible.

Source: DfT.

4.20 The next section takes a more focused look at infrastructure options in major urban areas and their catchments.

GROWING AND CONGESTED URBAN AREAS AND THEIR CATCHMENTS

4.21 The majority of congestion and overcrowding is to be found in growing and congested urban areas and their catchments. This stems from the density of economic activity that involves significant transport of goods and people in those areas. In a globalising world, such urban areas are likely to be key to the UK's economic performance as they provide the conditions for a successful and dynamic services sector, especially through their deep and specialised labour markets. If no action is taken to alleviate the pressures, the costs to the economy are likely to be very large and national economic growth will be constrained.

One size does not fit all

4.22 Urban areas have very diverse economic, social, land use, and physical characteristics. Therefore it is not possible to conclude a single list of interventions that are likely to make the most cost effective contribution to GDP because one size does not fit all. The appropriate intervention will be determined by specific local circumstances, making option generation and prioritisation crucial.

4.23 The density of economic activity and transport networks in urban areas also means that interactions between interventions are very important. An intervention implemented in one area is likely to affect the effectiveness and outcomes of others, either positively or negatively. While the evidence provides some limited insights, there remains scope to understand better the types of synergistic effects that may be possible. This was explored as part of the case study work in the South and West Yorkshire area as described later in this chapter.

4.24 The scope for additional infrastructure in major urban areas and their catchment areas covers a wide range of potential options but land space and environmental constraints may mean that some are less likely to be pursued than others. Nonetheless the case for urban infrastructure should be considered because as will be shown in this section, the available evidence suggests high returns are possible from targeted capacity if implemented under the right conditions.

4.25 To reiterate, the evidence discussed here can only reflect what has been available to this study. Very little, if any, evidence is available on some urban interventions and it is possible that considering urban interventions in isolation misses some of the urban network effects that might be expected as schemes and policies interact. In short, the case for urban investment can only be pieced together drawing from both the evidence in Volumes 1 and 2 (a top down approach) and Volume 3 (a bottom up approach).

Small-scale infrastructure options

Walking and cycling schemes can deliver high returns

4.26 Chapter 3.3 on better use showed that the severity of the congestion and overcrowding problems in many urban areas allows measures such as traffic management or urban traffic control to be highly effective. To complement these, relatively small-scale investment in interventions such as walking and cycling capacity can help provide the incentive for mode shift away from the car to reduce the costs of congestion.

4.27 Improving walking and cycling capacity by creating or upgrading routes that make these more attractive modes of travel could provide good welfare and GDP returns, especially if utilising dedicated infrastructure targeted around key services or growing urban areas.

4.28 Evidence on a number of schemes suggests a very wide range of returns is possible and that often they are very high, with wider BCRs ranging from 14.9-32.5.[5] However, GDP per pound returns are often much lower, between £1-2.50, though schemes serving high-economic-growth areas can achieve around £5 per pound invested.

4.29 For most schemes, the majority of benefits, often over 85-90 per cent, accrue from benefits to physical fitness, safety and security effects, which can usefully contribute to government's objectives of promoting a safer and healthier society. Indeed, there are likely to be direct GDP benefits from these health effects but how this feeds through is not yet possible to quantify. Such interventions are also likely to produce a positive impact on the environment, due to the shift to quieter and non-polluting modes, but this may only be small.

On their own, they are unlikely to tackle the true scale of the problems

4.30 Although these schemes are able to offer very good returns if well targeted, they tend to be relatively small in scale so, on their own, are likely to have only a relatively small direct impact on the overall performance of UK's transport network. Especially, as many of these schemes only impact on short-distance journeys and often have a limited scale of achievable benefits. Although this is very beneficial, and such interventions could be valuable complementary measures in many circumstances, to tackle larger challenges, a greater scale of action is needed.

4.31 Where larger scale cycling interventions are implemented, preliminary evidence suggests that the returns may also be relatively high. Given the current use of cycling as a mode of transport in the UK, which is among the lowest of EU countries, this may suggest the potential for larger-scale uptake of cycling under the right conditions. A sharp increase in cycling in London, for example, has recently been seen. The interventions required should of course be assessed on the basis of their relative returns and be well targeted, and would need to be sufficient to achieve a sustained shift in travel behaviour.

4.32 The next section discusses the broader range of infrastructure options in urban areas along with the potential returns.

[5] *Summary Note on the Economic Appraisal of Links to Schools*, Sustrans 2006.

Variable capacity options

Buses can deliver strong returns that tend to be welfare focused

4.33 The transport challenges facing urban areas are very commonly those of road congestion arising from significant volumes of people travelling into or within a dense area at similar times of day. This is a problem for all road users including business travellers, those trying to get to work, non-work/leisure travellers, freight delivery vehicles and buses.

4.34 Not only is there wasted time from delays and unreliable journey times, but there are environmental problems in major urban areas, particularly from emissions and particulates that affect air quality. Options that reduce congestion and reliance on car travel are, therefore, potentially beneficial for the economy and the environment.

4.35 Bus services are a very flexible form of capacity that can be relatively swiftly deployed in response to high travel demands and transport pressures. A minimum level of demand is, however, required to make this a viable form of transport provision.

4.36 Buses are not only competing against other modes for users, they are also competing with cars and freight for road space. This has a number of implications because general road traffic conditions will impact on the service offered by the bus.

4.37 The extent to which mode switch from cars to bus is encouraged and achieved will influence the extent of road congestion in urban areas. Although it would not be efficient or possible to achieve a full shift of all car users to buses, there is a key role for buses to alleviate road congestion.

4.38 Figure 4.4 sets out the types of bus interventions for urban areas that could be considered, though the returns from each will vary according to the specifics of the local area.

Figure 4.4: Types of bus interventions

- **Pricing/Fares:** fares could be used to increase the attractiveness of the bus as an alternative mode to the car. A limitation here is that typically, fares represent only a third of the total (generalised[a]) cost of bus travel. The perception of bus use means that if fares were the only policy tool, it would be likely to take a very large reduction in fares to create the incentive for a large-scale shift in mode from car to bus.
- **Quality/Attractiveness:** improving the attractiveness of bus relative to the car is likely to require interventions to support quality rather than just price. Factors such as improving reliability from introducing bus-only lanes; simplified and common ticketing; real time information; clear routes; and branding and marketing are likely to be more important in making bus services more attractive.
- **Quantity:** broader and more targeted service provision: (i) frequency and (ii) expansion of routes, are also important:
- **(i) Frequency:** at very low levels of frequency there is scope to reduce waiting time by providing extra bus capacity: increasing frequency can deliver greater benefits than changing fares. The opposite is true if services are already frequent (e.g. more than 10 buses per hour). Under these circumstances, it may be more cost-effective either to reduce fares or increase road lanes for bus use.
- **(ii) Network/Route expansion:** Beyond a particular level of frequency, encouraging greater shift from the car is likely to require greater expansion of the bus network including through dedicated bus corridor infrastructure.

[a] This refers to the overall cost of travel, including the perceived value travellers place on time and other aspects such as journey ambience and quality of the service.

As a case study, illustrative interventions in South and West Yorkshire have been explored

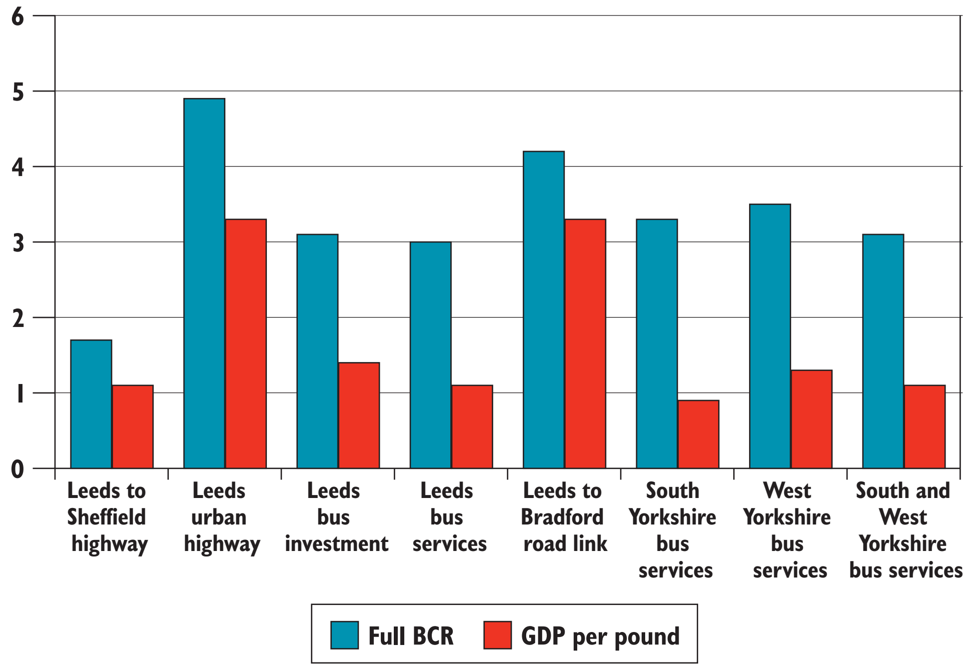
4.39 To try and fill some of the gaps in the evidence base on urban interventions, as a case study, some illustrative interventions were explored in South and West Yorkshire. The purpose was to build an understanding of the possible returns from different policies under different circumstances.

4.40 It is important to note that the interventions explored as part of this case study are purely illustrative, using a strategic modelling approach to provide high-level indications of the welfare and GDP impacts of different types of interventions. These results are not to be interpreted as detailed value for money assessments of these particular interventions.

4.41 Figure 4.5 demonstrates the wider BCRs of some of those interventions.[6] Shown in the chart are

- enhancement of the Leeds to Sheffield strategic road link;
- enhanced urban road capacity within Leeds;
- additional bus quality corridors within Leeds;
- changes to fares (down 30 per cent) and frequencies (improved 20 per cent) in Leeds
- enhancement of the strategic road link between Leeds and Bradford;
- changes to fares (down 30 per cent) and frequencies (improved 20 per cent) in South Yorkshire;
- changes to fares (down 30 per cent) and frequencies (improved 20 per cent) in West Yorkshire; and
- changes to fares (down 60 per cent) and frequencies (improved 20 per cent) in South and West Yorkshire as a whole.

Figure 4.5: Returns from some illustrative interventions from South and West Yorkshire modelling



Source: SWYSM.

[6] For more details see the separate paper on the South and West Yorkshire Case Study: *Wider economic impacts of transport interventions*, MVA in association with David Simmonds Consultancy, 2006.

4.42 This demonstrates that returns are similar across the bus interventions considered, with wider BCRs of around 3. These all represent very large-scale bus interventions covering some very large geographical areas in South and West Yorkshire. Conclusions on the extent to which these returns would hold for smaller-scale interventions, or in other areas that demonstrate different transport systems and travel patterns, cannot be made.

4.43 Looking in more detail, despite similar overall welfare returns, there are different wider economic effects. For example, improving bus fares and frequencies in South Yorkshire offers a lower impact on GDP than in West Yorkshire for the same magnitude of intervention. This is due to the different nature of local demographics, economy and travel patterns. It is also important to consider the existing level of bus service in the given area: where bus services already exist and provide a good service meeting all potential demand cost-effectively, the returns from adding more are likely to be lower. In West Yorkshire, accounting for the wider economic effects added around 14 per cent to overall welfare. In South Yorkshire this was just 5 per cent.

4.44 It also appears from this evidence that providing significant additional bus infrastructure that does not take away road space from cars, provides similar welfare and GDP per pound spent, for the given generic cost assumptions, as improving fares and frequencies. The indicative wider BCR is around 3 for both interventions, but adding fixed infrastructure is much more expensive, and would be subject to environmental impacts owing to land take. In practice, many urban areas will not have the landspace available to make this a realistic option.

4.45 It is important to recognise that these wider BCRs are not value for money assessments. It has not been possible to include the environmental implications in these wider BCRs but additional infrastructure in the form of new bus lanes, for example, would have implications for townscape and landscape, depending on the specific location. The impacts are likely to be significant and adverse at some sites.

4.46 Conversely, the environmental impacts of improving bus services should be beneficial, to the extent that there is some mode shift away from cars towards public transport and road congestion is reduced, thus lowering levels of harmful emissions such as carbon and particulates that reduce air quality. This work revealed that when fares and frequencies were improved, carbon emissions were marginally reduced.

4.47 The lower costs of variable bus capacity relative to fixed infrastructure implies a strong case for considering this as one of the policy options for tackling urban congestion challenges before jumping to fixed investment in additional infrastructure.

4.48 However, depending on the nature and magnitude of the problem being faced in major urban areas, there may be a case for considering fixed infrastructure for a long-term solution.

Fixed infrastructure options

4.49 Trams and heavy rail should only be considered as an appropriate policy intervention once an urban area reaches sufficient density: they are not likely to be the most cost-effective solution where transport corridors are more sparsely populated. The density and certainty of future demand on particular corridors is an important factor in the viability of light and heavy rail. Figure 4.6 outlines the capacities of different public transport systems.

Figure 4.6: Capacity offered by different public transport modes

Technology	Maximum system capacity (passengers per hour per direction)
Standard bus	2,500 – 4,000
Busway	4,000 – 6,000
Guided bus	4,000 – 6,000
Tram/Light rail	12,000 – 18,000
Heavy rail	10,000 – 30,000

Source: Commission for Integrated Transport, Mass Transit Guidance September 2005.

4.50 This implies that if demand could only ever reach, say, 6,000 passengers per hour, light or heavy rail options are highly unlikely to prove good value for money.

4.51 The small sample size of available evidence from real tram schemes in the UK demonstrates varying returns with wider BCRs between 2.7 and 5.1 but from a GDP per pound perspective, the returns are considerably lower, ranging between £0.60 and £1.20.

Buses can be a much more cost-effective solution than trams

4.52 The high costs of fixed and dedicated infrastructure investment constrain the relative returns achievable. For the schemes explored, costs are between £350-650 million. To tackle the same capacity constraint, bus options could deliver a slightly lower level of absolute benefits but at a much reduced cost, around £15-170 million, hence higher relative returns.

4.53 Quality factors are an important consideration in the extent to which trams may be preferred to bus services and prove viable. Higher quality bus schemes with segregated infrastructure can bring the attractiveness and benefits of buses closer to that of trams.[7] Figure 4.7 sets out the factors that influence mode choice.

Figure 4.7: Factors influencing appropriate mode choice in urban areas

The appropriate mode choice – road, bus, light rail, heavy rail – is determined by specific local circumstances. Scheme specific cost-benefit analyses are needed, but some indicative pointers are:

- **density/size of the urban area or agglomeration:** the more densely populated the city (which also implies a greater degree of agglomeration economies), the more justifiable is the consideration of heavy mass transit as one of the options to be assessed to deliver a cost-effective way of transporting large numbers of travellers;
- **density of specific transport corridor:** mass transit systems are likely to be more cost-effective on high-density transport corridors; where trip-making patterns are more dispersed, private car use and/or bus networks are likely to be most appropriate;
- **geography and land space:** parts of the UK are densely populated and land space in urban areas is limited. Some public transport schemes would need to share existing road space, and could take away from road capacity, which tends to explain why sometimes these schemes can fare poorly from a congestion perspective. There are also broader environmental and landscape issues to consider as free space is scarce; and
- **costs:** the environmental and geographic characteristics of urban areas mean that the costs of transport interventions can be extremely high, and could influence mode choice. Whole life costs tend to be higher for rail than for bus assuming basic road infrastructure exists, but at appropriate densities, cost per passenger can be lower.

[7] *Atkins Study of high quality bus in Leeds*, 2005.

4.54 Heavy rail is most likely to be a worthwhile option where significant volumes of people are being moved such as on radial links into major urban areas and demand management measures are not, on their own, sufficient to tackle the scale of the problem. This can be a particular problem where longer-distance, inter-urban travellers need to use the same available infrastructure as commuters, and sometimes freight, on radial links creating high levels of overcrowding. This is particularly true for London.

4.55 Evidence is available from TfL on the welfare returns of additional variable rail capacity on overcrowded radial commuter corridors into London.[8] These interventions are in the form of longer trains, new rolling stock with seating reconfigurations and longer platforms on existing rail lines.

4.56 This evidence suggests that the costs of implementing these measures can differ significantly depending on the routes being examined with capital costs ranging between £50 million and £3.5 billion. Returns also vary with BCRs typically between 1 and 3. Importantly, this analysis does not include the benefits in terms of agglomeration and wider labour market effects, which for some interventions could significantly add to the benefits.

4.57 The environmental implications of these interventions are not known and will largely depend on the degree of additional fixed infrastructure required.

4.58 This range of return demonstrates the high importance of being able to target interventions. Higher returns are most likely where the enhancement is able to provide benefits over a large part of the day to many travellers, and not just for the limited time during the morning commuter peak, and where additional fixed infrastructure requirements are minimal.

4.59 Rail plays a unique role in the central London economy given its density of employment and volumes of commuters. In general, GDP returns from variable rail capacity are more likely to be cost effective where:

- demand levels far exceed available capacity in the morning peaks creating severe overcrowding and the need for passengers to stand for relatively long distances;
- there is scope to shorten the journey time for significant volumes of travellers on a particular corridor;
- minimal supporting infrastructure is required to deliver the variable capacity such as platform lengthening, so as to keep costs down;
- the link serves an area with industries that are able to exploit the benefits of deeper labour markets such as financial services. This would support agglomeration; and
- rail has a high mode share for accessing the employment centre, otherwise other interventions might be a higher priority.

New rail infrastructure may be cost-effective but only in the right circumstances

4.60 There may be a case for additional new fixed rail infrastructure in some limited circumstances where demands are very high and pressures on existing links are severe. However, the costs of delivering this are also likely to be very high, which may act to constrain the relative returns from such fixed infrastructure.

[8] TfL modelling analysis, which assumes Crossrail is in the base case.

4.61 That said, it could be that even with additional variable capacity on existing lines, this may not be sufficient in the longer term in the face of high projected demand growth. In such circumstances, options for additional capacity will need to be considered.

4.62 Recent evidence from large urban rail schemes in London aimed at alleviating extreme capacity pressures in the urban centres suggests wider BCRs between 2 and 3, and GDP returns per pound also in the same range, but with costs running into several billions of pounds. The magnitude of such interventions implies that in absolute terms, the level of GDP and welfare could be substantial.

4.63 But it is not just passenger movement that should be the focus. Many rail links are heavily used by both passenger and freight services. The sharing of those links can in some cases create significant pressures, for example, around London. Upgrading these links could therefore potentially be beneficial for welfare and GDP, subject to the costs. There is little available evidence on returns from these types of intervention but they must of course be assessed on their own merits having considered an appropriate set of options.

Supporting infrastructure may also be needed

4.64 Overcrowding is already a common problem at many key rail and tube stations. Evidence suggests that additional capacity at stations that are subject to overcrowding could contribute to welfare by relieving station congestion, speeding up journey times and improving reliability of interchange facilities. Station congestion relief projects at two proposed London Underground stations suggest BCRs (not including the impacts on the wider economy) between 4.5 and 8.0.[9] Such complementary capacity enhancements play a key role in ensuring the full potential benefits of increased effective capacity on rail and Tube lines can be realised from the whole journey perspective.

4.65 This highlights the importance of recognising the requirements of the whole journey. For example, if heavy rail is used to reach the urban centre but then an onward journey is required to reach the final destination, such as the place of work, enhancing capacity on one leg of the journey may increase pressures on another leg. This should be accounted for in assessing options to enhance corridors into major urban areas.

4.66 Therefore, the complexity of urban transport systems means the need to improve transport connections into and within urban areas is likely to imply considering a mix of measures and interventions, some of which may need to be implemented as a package. Additional capacity may be needed where better use options are either not sufficient, or are not cost-effective.

4.67 Public transport options have been shown to offer good welfare returns under certain conditions, in others, urban road capacity should be considered.

Urban road capacity as a policy option

4.68 Road congestion is a huge problem in urban areas and conurbations. A key benefit of the car is the flexibility it offers in terms of route choice and time of travel, that cannot always be matched by public transport. In addition, the nature of urban areas with the mismatch between employment and household location implies significantly dispersed journey patterns, both for passengers and drivers, and freight vehicles to get goods to outlets.

[9] TfL analysis. These BCRs include the value travellers place on a pleasant station ambience.

4.69 Although often not considered or explored, in some cases, additional road capacity is likely to be the most cost-effective option in congested and growing urban areas, especially where origins and destinations of journeys are very diffuse. Urban roads are identified as those found within or in very close proximity to dense urban areas where speed limits are generally less than 50 miles per hour.

In some circumstances additional urban road capacity will be the high value for money solution

4.70 As shown in Figure 4.5, illustrative urban road capacity options explored in South and West Yorkshire suggested relatively strong returns with wider BCRs over 4 with GDP per pound of over £3. These results are for the given illustrative cost assumptions but are suggestive of the potential for a higher return to be delivered than for public transport options in some cases.

4.71 The local environmental implications of urban road capacity will be highly location specific and may in some circumstances be prohibitive. If the road enhancement is able to reduce congestion and allow more economically important journeys to take place, this is likely to come with an environmental cost. If traffic increases, then noise and emissions of carbon and particulates will increase. Mitigation measures could however be implemented to lessen these effects. Perhaps of more significance is the impact on landscape and townscape in densely populated urban areas. As with additional public transport infrastructure, this should be assessed on an individual basis as the range of potential implications is large, so some may only offer low returns.

4.72 Where high returns are possible, they are likely to be driven by congestion relief in those areas that are particularly capacity-constrained for a wide range of users for prolonged periods of the day. The gains from alleviating pressures and reducing the costs of accessing the urban centre are likely to be higher where the urban centre is productive and has high traffic flows. The density of retail activity in major urban areas also means that there are important benefits to freight from reducing urban congestion, both in terms of the direct benefits of reduced delays and unreliability, but also through the effect on freight logistics.

4.73 Real urban road capacity enhancement in other areas also appears to have delivered strong returns but the range is wide. For example, urban roads on which evidence is available to this study suggests wider BCRs in excess of 3, with one with a BCR even in excess of 11. The environmental implications would of course need to be accounted for to determine a view of overall returns.

4.74 From the evidence available, some key strategic roads around major urban areas and agglomerations, where congestion problems are very high and a wide mix of users travel on the road, are able to offer wider BCRs of between 4 and 11 with GDP per pound returns very high, at between £3 and £7. The cost of these interventions ranges between some £60 million and £300 million. Indeed, these interventions offer some of the very highest returns of the data available.

4.75 This evidence suggests that although there may be land-space constraints in some very dense urban areas, there are circumstances where enhanced urban road capacity may be the most cost-effective option and delivers relatively high returns. Where there are land space constraints to road build, public transport options may be the only feasible policy solution.

The link with housing

4.76 Over coming years this anticipated growth of the bigger urban areas is likely to be fed by increasing population and migration. Where additional housing is needed to support the continued success of a growing urban area, particularly to maintain and expand its labour market catchment, it is intuitive that in some circumstances, new or improved transport connections will be needed to deliver potential agglomeration benefits. That is not to say that housing policy should simply drive transport needs: the importance of cost-effective policy making applies here as in any other area. The location of new housing, its transport and other infrastructure requirements all need to be planned together in order to maximise the available benefits. Again this is an area which needs a much improved evidence base in order to support robust decision making.

The impact of road pricing on the case for additional urban infrastructure

4.77 Road pricing, if targeted on congestion and environmental problems, is likely to have a significant impact on congestion in urban areas.

4.78 Road pricing is able to have a significant impact on congestion in most urban areas. Analysis carried out in the context of strategic roads implies that with road pricing the case for additional road capacity in these areas is likely to fall but still remain. High prices signal that congestion is a problem and hence additional capacity may be worth exploring. This is further discussed later in this chapter in the context of inter-urban strategic road investment.

Road pricing and appropriate public transport can work well together

4.79 Preliminary evidence on the returns from public transport interventions when implemented in combination with road pricing as described in the South and West Yorkshire modelling case study suggests that greater welfare returns from the package are possible than if considering them separately. This is largely driven by the beneficial impacts on commuters from improving public transport when road pricing raises the cost of road travel. However, this would benefit from further analysis to understand better the nature of the interaction and the investments likely to offer greater returns.

4.80 The impacts that road pricing might have for the case for additional public transport capacity is determined by a number of locally specific factors. These include:

- the availability of other travel options and whether they are able to absorb additional demand;
- the price of public transport use relative to roads: this will depend on subsidies and the prices set by operators; and
- the type of road pricing being introduced and behavioural responses: mode shift is more likely when journeys are time critical and where public transport services allow the journey to be made at a given time; where road users have more time flexibility, they may travel by car at a different time rather than shift mode.

4.81 In terms of its implications for public transport demand, road pricing is likely to improve the relative attractiveness of public transport in areas where road prices are high. TfL estimates that the London congestion charge reduced car travel by 15 per cent within the congestion charging zone, and that some 50-60 per cent of that traffic was displaced to public transport. Conversely, in areas with little or no congestion, such as some rural areas, the prices could be lower than at present, potentially generating a mode shift away from public transport onto road.

4.82 Some users who place a lower value than others on making a particular trip by road, such as some commuters and non-work/leisure travellers, are likely to switch from car use to public transport for journeys in areas where road prices are high; many business travellers, will be willing to pay higher prices to use faster and more reliable roads, generating a small amount of mode shift towards road use for business users.

4.83 The car remains the dominant mode of travel in urban areas outside Central London, so even a small modal shift away from the car as a result of pricing could represent a substantial increase in demand for public transport owing to the small initial base.

4.84 The introduction of road pricing could also affect the case for subsidising public transport. On the one hand, the environmental and congestion case for subsiding other modes will be reduced or removed if road users are paying the full external cost of their journeys and, in urban areas, as the increase in demand may increase the viability of public transport. On the other, where there are external economic benefits from enabling people to make economically important journeys, there may be a case for subsidy to reflect these external benefits.

Road prices are affected by the level of public transport provision

4.85 Evidence from the modelling case study in South and West Yorkshire suggests that when improvements to bus services in the form of lower fares and improved frequencies are implemented in the presence of a distance-based, congestion-targeted road pricing scheme, not only are the benefits of the package higher than the sum of the separate interventions, but road prices can on average be set lower. The maximum charge paid when bus services are improved is some 10 per cent lower. In addition, the adverse impacts on agglomeration of road pricing would be slightly reduced with improved bus services owing to the reduction in adverse impacts on commuters.

4.86 In summary, the implications of road pricing for the economic case for additional public transport capacity will depend on a number of locally specific factors, and detailed appraisal work would be needed for specific areas.

4.87 Taken together, the evidence suggests that some guiding principles on where there may be a case for additional urban infrastructure capacity, for road and public transport are as follows:

- The prices themselves: if targeted on the true costs of road use, high prices reflect demand pressures and hence a greater case for considering more capacity.
- Where there remains a capacity constraint: congestion maps show that even with pricing, travel demand remains high in large conurbations suggesting evidence of capacity constraints; and
- Where there are external costs from altering particular trips that are not reflected in an individual's decision making; for example, in the absence of viable alternatives to car use, some commuters may be priced off the roads and may be forced out of the labour market or into less well paid jobs that are cheaper or easier to access.

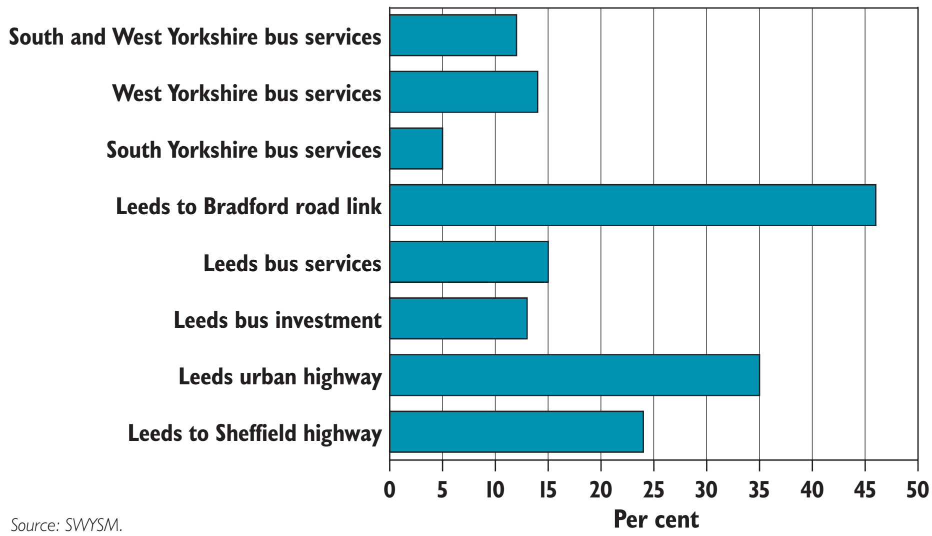
4.88 The case study of South and West Yorkshire has been referred to in several places throughout this volume, so the next section provides a little more detail of the impacts of illustrative interventions in this case study area.

Case study findings: modelling of illustrative interventions in South and West Yorkshire[10]

4.89 In order to try and fill some of the evidence gaps, a case study area of South and West Yorkshire was chosen to explore a range of interventions and their relative contributions to welfare and GDP. It is important to note that the interventions are purely illustrative and the assessments in this chapter are from strategic modelling to build an understanding of relative returns. It was not, therefore, possible to carry out a detailed value for money assessment of these interventions, but the results are indicative of the relative returns of different policy options. No attempt was made to draw conclusions or recommendations about specific schemes in the area as this was not the objective.

4.90 The illustrative interventions explored suggest that the extent to which wider economic effects are currently missing from appraisals varies significantly according to type and location of intervention. Figure 4.8 demonstrates the percentage added to conventionally assessed welfare benefits when the currently missing GDP elements – such as agglomeration and labour market effects – are accounted for.

Figure 4.8: The addition to welfare of missing GDP effects for illustrative interventions from South and West Yorkshire modelling



Source: SWYSM.

4.91 As Figure 4.8 shows, up to around 45 per cent can be added to welfare by considering the wider economic benefits, as was the case with improvements to the Leeds to Bradford link. This is the top end of the range so the average is of course lower. The highest additions appear to be for those interventions that improve accessibility between or within a productive major city. This should of course be balanced against the likely higher costs of additional infrastructure in those areas. Taken with the evidence in Figure 4.5, this case study allows some overall messages to be drawn out.

[10] For more detail see separate paper on the South and West Yorkshire Case Study *Wider economic impacts of transport interventions*, MVA in association with David Simmonds Consultancy.

4.92 Some more general conclusions from the work in South and West Yorkshire are as follows.

- The nature and composition of the local economy and existing transport system have a significant effect on the potential for GDP gains. For example, the same bus improvements in South Yorkshire (with low GDP per head) contributed far less to GDP than the same magnitude of intervention in the more agglomerated and productive economy of West Yorkshire. This does of course need to be considered in the context of overall welfare returns for prioritisation purposes.

- High GDP returns are likely from those interventions that increase accessibility within productive areas, or improve links between productive areas. This result will of course be sensitive to the cost assumptions made.

- Agglomeration is generally the most substantial impact of transport interventions currently missing from appraisals. In assessing this effect, a wide geographical area must be considered because a shift in activity may have disagglomeration effects that should be netted off.

- Transport interventions that increase the labour market catchments of productive urban areas (eg Leeds) are likely to provide good GDP benefits, though of course overall returns are subject to costs.

- Both economic GDP and environmental objectives can be met with some interventions. For example, improvements to bus services in West Yorkshire and in Leeds provide good GDP returns for the estimated cost and are also able to provide environmental and social benefits.

4.93 This section has shown the following for urban areas:

- Walking and cycling can deliver very high welfare returns, mainly through health and safety benefits rather than GDP effects.

- Bus interventions can in some cases provide a higher value for money solution than costly light rail options but where demand pressures are particularly high, there may be a case for fixed infrastructure options.

- Urban roads can, in the right conditions, be a very high value for money solution to urban congestion problems.

- Road pricing is likely to affect the demand for public transport and therefore the economic case for additional capacity.

- Additional public transport capacity on key commuter corridors is likely to be effective where large volumes are moving into the very densest urban areas.

INTERNATIONAL GATEWAYS

4.94 The growing significance of globalisation means that the international connectivity of the UK has become more important, and is likely to be increasingly so over the next two to three decades.

4.95 Trade in goods and services is set both to increase and to change in nature, leading to rising and changing demands on international gateways. Strong growth is projected for the volume of goods imported through UK ports, particularly from Asia. Given the UK deep-sea ports capacity, this implies capacity constraints are likely to bite with consequent increases in the cost of moving those goods. In addition, as the service economy grows, the need for people to travel internationally implies increasing strain on UK airports with consequently higher costs of travel, unreliable journeys and a potential reduction in trading opportunities.

Additional ports capacity at deep-sea, feeder and ro-ro ports

Government has a keen interest in port development owing to the implications for the UK economy

4.96 UK ports are for the most part privately owned and operated as private businesses.[11] Without adequate capacity there are implications for the wider economy. They are the key gateways for UK trade in goods, so if UK competitiveness is to be maintained and face the challenges of increasing globalisation, ports must be among the priorities for transport policy.

4.97 Although the public sector is therefore not generally responsible for bringing forward additional port capacity in the UK, there is a role to play for government in ensuring there are no unnecessary barriers to development, for example through the planning system.

4.98 By looking at where the demand for ports traffic is likely to exceed available capacity, research commissioned by DfT for the Ports Policy Review[12] was able to assess when capacity constraints may bite over the next two to three decades by considering a range of scenarios. This work suggests constraints will be at:

- deep-sea container terminals in the South East: this is despite the assumed construction of two recently approved major new container terminal developments, plus one development that currently has 'minded approval' status, all in the greater South East.[13] Capacity and efficiency improvements at existing ports and changes in shipping-line behaviour could also affect when and where capacity constraints will actually bite;
- feeder berth capacity around the country for container services via hub ports elsewhere; and
- roll-on – roll-off (ro-ro) terminal capacity, particularly in the South East.

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[11] Notable exceptions being Dover and the Port of London (trust ports) and Portsmouth and Sullom Voe (municipal ports)

[12] *Ports policy – Your views invited,* May 2006.
http://www.dft.gov.uk/stellent/groups/dft_shipping/documents/page/dft_shipping_611693.pdf.

[13] The Secretary of State for Transport gave final consent for development at Felixstowe South in February 2006, for Bathside Bay in March 2006 and reconfirmed minded approval for London Gateway in August 2006.

4.99 If UK container ports are unable to handle forecast demand growth, this could be for two reasons: they are unable to accommodate the absolute increases in volume; and/or with loads being consolidated in ever larger container vessels, they are unable to berth the largest ships. In this case, the UK will still import and export the additional goods, but they would be transhipped at a Continental port onto a smaller feeder vessel headed for the UK. Transhipment increases supply-chain costs by introducing two additional lifts and an additional sea leg though inland distribution costs may be reduced. The DfT's research found that a scenario that assumes full construction of Felixstowe South, Bathside Bay and London Gateway, which will remove the need for a good deal of transhipment, delivery costs could be reduced by around £260 million a year or up to 10 per cent by 2025 when compared to a scenario where these three new terminals are not built.

4.100 Even if new container terminals are developed in the South East of England, there will still be growth in demand for container feeder berth capacity in the South East and across the country. For example, by 2020, container feeder volumes are expected to triple at North East ports and grow five-fold in volume at ports in the North West of England. Under this scenario, at least 1,800 quay metres of additional feeder berth capacity would be projected to meet demands at ports in Great Britain by 2015.

4.101 With the three new terminals, UK container ports should on central forecasts be capable of accommodating rising demand to at least 2020. However, growth is forecast to continue up to 2030 and probably beyond, so capacity constraints will again begin to bite. In this scenario, the constraints imply delivery costs per TEU[14] will rise again by some 5 per cent between 2020 and 2030 amounting to some £140 million[15] more each year by 2030, or on average about £9 per TEU.[16] This includes some, but not all, elements of generalised cost,[17] and the operating and capital costs of providing feeder quayside capacity, existing or new.[18] These figures do not account for wider effects such as impacts on trade, globally mobile investment and reliability.

4.102 Given current market trends, private sector investment proposals for additional deep-sea container port capacity in the South East could be expected within the next two to three decades and would create net economic benefits for the UK. However the same is unlikely to be true for new deep-sea container capacity outside the greater South East. In a scenario where there is no remaining deep-sea capacity in the South East, deep-sea container vessels are much more likely to tranship additional traffic at a Continental port, provided that capacity is available there.

4.103 Demand growth and increasing vessel size at ro-ro ports is also likely to exceed current ro-ro port capacity over this period especially at the most heavily used ports such as Dover. Greater use of spare capacity at other ports or on Channel Tunnel freight services may delay the point at which the capacity constraint is reached by a few years but capacity constraints are likely to bite by around 2015 at the latest. Therefore, ro-ro capacity is likely to be under greater strain over this study's timeframe than deep-sea container capacity.

[14] Twenty-foot Equivalent Unit – a measure of port capacity.

[15] This is the undiscounted nine pounds on 16 million TEU in the one-year, 2030.

[16] *UK Container Transhipment Study,* MDST for DfT, 2006.

[17] Includes a fixed rate per distance for road and rail surface transport costs (therefore takes into account the shorter haul of the increasing volume of goods arriving at northern ports closer to their destination) but does not take account of changes in road or rail congestion or reliability, differences in delivery time (on average rail boxes leave ports before road boxes), potential impact of road pricing, or inland warehousing or labour costs (transhipment traffic might be able to take advantage of lower input costs outside the South East).

[18] If the cost of providing additional feeder quayside capacity increases significantly, perhaps because more berths are built on greenfield sites, then this may be an underestimate – but an estimate of this risk is unavailable.

Environmental effects must be accounted for

4.104 If additional ports infrastructure is added, there are, however, likely to be adverse environmental impacts. Ports are mainly located in estuaries where they compete for sheltered locations with birds and coastal habitat such as mudflat and saltmarsh. The three key impacts on nature conservation of additional capacity are:

- direct and indirect nature conservation losses, direct loss of land, longer term changes to inter-tidal and sub-tidal habitats resulting from hydrological change, disturbance from recreational activities, pollution from anti-foulants and spillages, erosion from shipwash;
- knock-on effects from port developments in terms of upgrades to road and rail links that have their own impacts; and
- impacts on air and water quality through emissions, including those from ships (SO_2) and accidents.

4.105 Even if additional infrastructure is not needed, surface access and increased levels of traffic between ports and inland destinations will also have an adverse effect on the environment. This is more likely to be significant if road is relied on as the main means of inland movement of goods owing to the associated emissions and noise. This is likely to be the case for transhipped short-sea traffic where rail may be less viable owing to the smaller consolidated loads and shorter distances involved. The location of additional port capacity to cope with the forecast rise in demand for imports has implications for the environment because impacts will be worse where the distance to final destination is longer and road conditions are more congested.

4.106 The environmental impacts of additional port capacity need to be mitigated against, where possible, as part of the planning consent process, and balanced against the benefits to welfare and the UK economy of providing additional ports capacity. The recent port capacity planning approvals demonstrate that in some cases the case stacks up even after accounting for the environmental effects.

Additional airports capacity

4.107 As with ports, high levels of current and projected demands are likely to put strain on UK airport capacity. Where capacity is insufficient to meet the demand, there will be adverse implications for the economy: higher costs, both time and money, of international travel; reduced reliability of both air services and services within the airport; and potentially reduced trading opportunities.

4.108 Air services are relied on for international business activity, as well as tourism and non-work/leisure trips. Business and consumers place a high value on the range and frequency of air links offered from different airports.

4.109 This study has not sought to repeat the analysis of the Air Transport White Paper[19] (ATWP) which suggests there are significant economic benefits from increasing runway capacity at Heathrow and other airports in the South East. Above a baseline of maximum use of existing runways, direct economic benefits of additional capacity at Stansted (2012) and Heathrow (2020) are estimated at some £24 billion. It is estimated that of this figure, some £6 billion[20] accrue direct to business travellers, and these benefits would be higher still if reliability were accounted for. Other benefits not captured within this figure include the trade benefits of international connectivity and the benefits from increasing the attractiveness of the UK for foreign investors. Plus, there can be economies of scope from hub airports, through enabling a greater variety and frequency of onward connections, and from greater efficiencies in the provision of support services and fixed costs.

4.110 However, the gross benefits must be adjusted to reflect the impacts on the environment from additional runway capacity. The main environmental impacts of aviation that can be estimated quantitatively are noise from aircraft and the effects of aircraft emissions. Air Transport White Paper analysis estimated that the cost of increased carbon emissions over and above a baseline of making maximum use of existing runways could be in the region of some £3-5 billion.[21] In addition, there are likely to be impacts of increased noise and health impacts from reduced air quality but these are likely to be an order of magnitude lower than these climate change impacts, leaving very substantial net benefits.

4.111 The ATWP also assessed the benefits of additional fixed runway infrastructure at other airports and suggested that an additional runway at two other UK airports could each provide overall benefits that are much lower than for expanding major airport in the South East, with the highest benefits at some £1.6 billion over the period to 2060. The benefits of capacity enhancement at other regional airports are therefore likely to be of a much smaller magnitude than for other major airports, given the lesser magnitude of pressures faced.

4.112 This study identifies international gateways as a key strategic priority for the future, and the vital role of aviation in supporting the international competitiveness of the UK's high-tech manufacturing and financial services sectors. This is in line with the analysis from the ATWP set out above, which demonstrated that the potential economic benefits from further expansion of aviation capacity are significant, running to tens of billions of pounds. However, any growth in aviation needs to be sustainable, and must take full account of its environmental costs. One of the most effective mechanisms for achieving this is by ensuring that air travellers pay the full environmental costs of their journey, including climate change impacts. The principle of ensuring users pay their full external costs was supported by the Government in the Air Transport White Paper and was strongly supported by the Stern Review of the economics of climate change.

4.113 The ATWP passenger demand forecasts assumed the introduction of some form of pricing mechanism to ensure air travellers faced the full external costs of their climate change impacts. This was based on the Defra central cost of carbon estimate of £70 per tonne of carbon (in 2000 prices). With this pricing mechanism in place, the analysis demonstrated that demand would continue to grow, and that there would be significant economic benefits from some additional runway expansion. It is important to understand the impact of a range of carbon pricing scenarios on the case for aviation expansion, and the forthcoming ATWP Progress Report will test a wider range of carbon price scenarios.

[19] *Air Transport White Paper*, DfT, 2003.

[20] Present value benefit over the period to 2060.

[21] Present value over the period to 2060.

4.114 Provided economic analysis shows that there is a net benefit from increasing airport capacity, even after users pay the full environmental costs of their journeys, there will remain a strong economic case for additional runway capacity.

4.115 As with ports capacity, government has a role to play in forming policy to support the private sector development of airport capacity where there are likely to be significant gains for national welfare after taking account of the environmental implications.

The importance of surface access links

4.116 The realisation of these benefits resulting from the provision of additional fixed infrastructure at ports and airports also depends on the extent to which there is adequate capacity on surface access links.

4.117 Surface access links are often used not only by those accessing the port or airport, they are also shared by travellers for a range of purposes, particularly around large urban areas. For example, links to major airports such as Heathrow or Birmingham are used by travellers undertaking inter-urban journeys for business, non-work/leisure, commuting and freight not linked with the ports or airports. The shared nature of these links means that many are subject to high levels of congestion.

4.118 Available evidence suggests that investment in additional fixed infrastructure in these places can deliver strong returns for the economy and benefit a wide range of users. The available evidence is mainly for road links, but sometimes, additional capacity on rail links will be the most cost-effective solution to the problem. For example, in some situations one option to consider may be enhancements to the gauge of rail links on some surface access links to ports where larger containers are likely to be moved.

4.119 The case for additional surface access infrastructure should take into account the full range of possible options and impacts. Use of rail lines for freight surface access, for example, would need to be balanced against the competing need for use of the line by passenger trains and of course the costs of enhancement. These uncertainties point to the need for a study of surface access needs in the UK.

Surface access improvements can offer the best welfare and GDP returns of all options

4.120 The potential returns from road surface access to ports can be strong with wider BCRs often in excess of 3 and some even around 15, in some circumstances, and GDP returns per £1 again often over £3 and up to around £11 in some circumstances. The cost of these interventions is relatively low, ranging from around £10 million up to £170 million.

4.121 The available evidence also demonstrates enhancing capacity on selected surface access links to airports is able to deliver strong GDP returns. The evidence suggests wider BCRs of additional fixed strategic road infrastructure in the range 2-15 with GDP returns per £1 of £1-9. The corresponding range of costs is from less than £10 million to just over £88 million indicating that some very strong returns are possible from relatively low-cost interventions targeted at particular pinch points.

4.122 The environmental implications of additional strategic road capacity are likely to be significant, particularly for carbon emissions, air quality, landscape and possibly biodiversity. Incorporating these effects, in many cases, reduces the wider BCRs presented above, possibly by up to one point off the wider BCR, as shown in Figure 4.3. These effects must of course be accounted for in the assessment of each intervention, as some are likely to be highly location specific. It could be possible to mitigate some of these effects on many links. On balance, even after accounting for these effects, in many instances the case for this additional surface access capacity would still be strong, as is also shown later in this chapter in the discussion of strategic road capacity investment.

Impact of road pricing on the case for surface access

4.123 In a world with road pricing, the case for additional fixed road infrastructure is generally likely to weaken. However even with road pricing, on very congested surface access links where prices are consequently higher, the economic case for additional capacity is still likely to be good. The wider BCRs on some of these links are so high that a strong case is likely to remain in a world of road pricing. This would of course need to be assessed in the light of the particular road pricing regime in place that would determine the impact on behaviour of all travellers. On rail surface access, it is unlikely that the case for additional infrastructure would be significantly affected by road pricing, though a slightly stronger case for passenger rail due to induced mode shift might be expected.

4.124 Where the impacts of road pricing might also be significant is around the long-term implications for logistics. It may be that in response to road pricing and the changing balance of costs for different aspects of goods movement, operators may locate warehouses and distribution centres in more cost-effective locations, or they may change port for example.

Conclusions on international gateways

4.125 A number of conclusions emerge from the evidence on the returns from investing in international gateways infrastructure. Policy should support additional ports capacity where, given the changing scale and nature of international trade, capacity constraints are likely to bite. Environmental considerations should of course be accounted for in the overall assessment.

- Provided economic analysis shows that there is a net benefit from increasing airport capacity, after users pay the full environmental costs of their journeys, there will remain a strong economic case for additional runway capacity.
- The realisation of the benefits of additional port and airport capacity is dependent on the capacity and travel conditions on surface access links.
- Targeted additional capacity on surface access strategic roads can offer some of the highest returns.

INTER-URBAN CORRIDORS

4.126 Certain inter-urban corridors play a key role in the economy where they link major urban areas, and where they allow large volumes of people and goods to move across the country to support economic activity, or support the economy directly or indirectly through reducing costs, distributing goods and facilitating domestic trade.

4.127 Sections of the UK's inter-urban corridors suffer from very high levels of congestion, overcrowding and unreliable journey times. The value of time wasted owing to travel delays amounts to a multi-million pound cost to the UK economy every year and this is set to rise significantly.

4.128 Particular problems on the inter-urban network exist where a mix of users wish to use the transport system at a similar time of day.

4.129 The next sections discuss the options for enhancing inter-urban capacity and describe where the evidence points in order to deliver strong welfare returns.

Strategic road infrastructure

4.130 As the car is the dominant mode of travel in the UK, the most significant problem for inter-urban travel is road congestion.

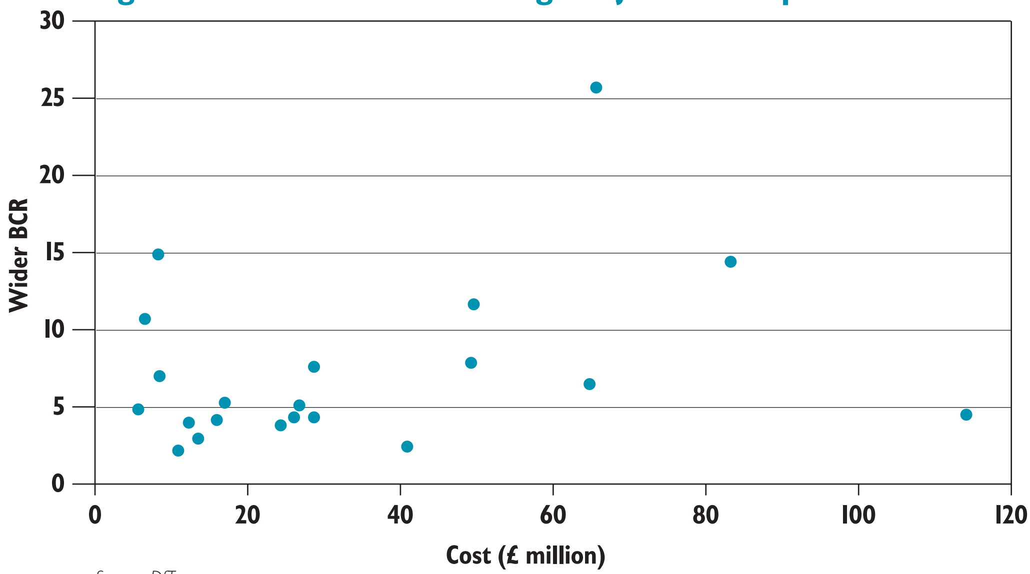
Infrastructure to relieve bottlenecks offers high returns

4.131 On some links, small improvements can deliver very strong returns for road users, including freight. Where roads are capacity constrained, relieving pressures through junction improvements, for a relatively low cost, offers some very significant returns with many wider BCRs in excess of 5.

4.132 Figure 4.9 below plots out the wider BCRs of a range of junction improvements along with their costs, on which evidence is available to this study.

4.133 In some cases, additional junction capacity enhancement may be sufficient alone to tackle particular bottlenecks and therefore deliver high returns. In other cases it may be able to complement larger-scale investment in fixed infrastructure.

Figure 4.9: Returns from a range of junction improvements



Source: DfT.

4.134 In the absence of national road pricing, evidence of real schemes from the Highways Agency and strategic analysis using the National Transport Model (NTM)[22] both indicate a very strong case for targeted additional road infrastructure in the UK.

Some strategic road investments offer very high welfare returns

4.135 Targeted strategic road infrastructure has been appraised for inclusion in the Highways Agency's Targeted Programme of Improvements (TPI) that looks out to 2015. Much of this investment delivers very strong returns with wider BCRs, often above 3 and up to 13. The highest returns are for additional capacity on those links around major urban areas and large agglomerations where there is a high demand for movement from a range of users including business, commuters and freight; and where there are significant capacity constraints.

[22] For more detail, see separate paper *Transport demand to 2025 and the economic case for road pricing and investment*, DfT, 2006.

4.136 There are substantial environmental implications from adding road space. Not only does the footprint of existing roads increase with consequent landscape effects, but the likely higher volumes of road traffic generate higher levels of carbon emissions, lower air quality and increased noise levels. Analysis of the available evidence of such effects, where they have been possible to estimate, suggests that BCRs can in some cases be significantly reduced, potentially reducing BCRs by over 3 points for some strategic road enhancements, as shown in Figure 4.3. These must clearly be balanced against the benefits of additional road capacity.

4.137 Even after accounting for environmental effects, there appears to be a good case for adding strategic road infrastructure over and above the schemes in the TPI. Strategic analysis that uses best available evidence to estimate the benefits and costs suggests an economic case[23] for additional capacity of between 2,900 and 3,350 additional lane kilometres on the strategic road network between 2015 and 2025.[24] This analysis includes impacts on the economy, environment (such as the impacts on landscape, carbon emissions, noise and air quality) and construction costs. This would imply a rate of investment over 50 per cent higher than that assumed under the baseline scenario over that period, and would cost some £29-33 billion.

4.138 That is not to say that government would want to prioritise all of this capacity because there are diminishing returns as more investment is added. Therefore, the first chunks of investment will offer far higher welfare and GDP returns than latter chunks. Where the latter are concerned, there are likely to be other transport options that offer higher relative returns.

4.139 For example, beginning with the assumed strategic road network in 2015, the wider BCR of an additional tranche of some 1,450 lane kilometres is estimated to be around 9; as a further 800 lane kilometres are added, the wider BCR of this additional chunk of investment falls to around 3. The wider BCRs of subsequent additional investment then fall rapidly as more capacity is added. The fact that returns fall as more and more additional capacity is added has implications for the extent to which additional capacity enhancements are prioritised, given constrained resources.

4.140 Of course, financial constraints, public acceptability and non-monetised environmental impacts will mean that investment on this scale is not desirable: the key point is that this evidence highlights the strength of the returns of targeted strategic road enhancement.

4.141 The values placed on environmental damage have been estimated using the best available sources including Defra and DfT research on the external costs of transport.[25] Impacts that have been estimated as part of this analysis are landscape, noise, carbon emissions and air quality. Past experience from the DfT methodology for assessing the value for money of transport interventions has been used to estimate the illustrative magnitude of these possible environmental effects. Even after accounting for these, the net benefits are substantial. Figure 4.2 set out their impacts on each of the strategic priorities.

High returns even after accounting for environmental effects

4.142 The strong economic case for additional targeted strategic road capacity after accounting for the environmental effects is driven by the fact that the majority of the investment involves widening existing roads, rather than building new. The impacts of the additional capacity are therefore lower than they would otherwise be in terms of landscape. Carbon emissions, air quality impacts and noise are likely to be worse as these are driven by the volume and speed of traffic, but these are generally outweighed by the benefits to transport users in terms of reduced overall costs of travel and improved reliability.

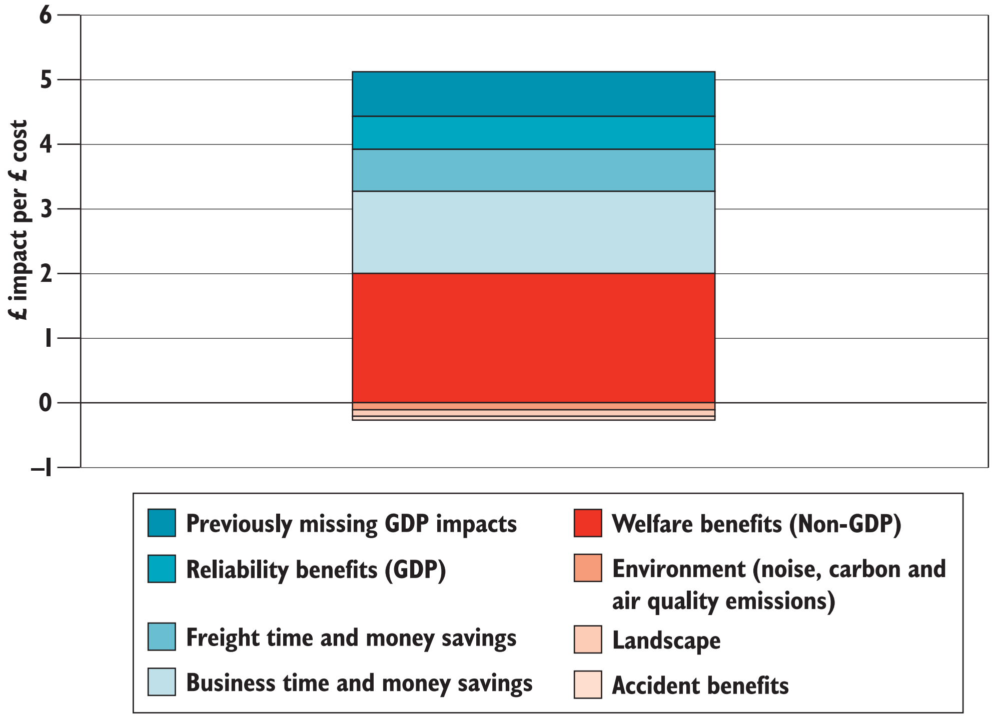
[23] Defined to be where the benefits exceed the total costs, including the inefficiency costs of raising public funds.

[24] In addition to investment assumed under the baseline scenario up to 2015.

[25] The methodology and detailed analysis are set out in the separate paper *Transport demand to 2025 and the economic case for road pricing and investment*, DfT, 2006.

4.143 The fact that the benefits to wider society from an intervention exceed the costs in terms of environmental effects like higher carbon emissions, implies that, if desired, those benefits could be used by society to invest in actions to reduce climate change in a cost-effective way. Figure 4.10 demonstrates the relative magnitude of impacts of the strategic road investment discussed above. Clearly, public debate is necessary to consider the implications of these choices.

Figure 4.10: Composition of overall welfare benefits for strategic road build, 2025



Source: DfT.

4.144 Figure 4.10 demonstrates the magnitude of benefits to society from investing in those strategic roads for which there is an economic case in 2025. The benefits vastly outweigh the estimated value of adverse impacts on the environment, such as landscape and carbon emissions. This is of course strategic analysis, so local effects cannot be accounted for but this analysis does make clear the balance of the effects.

4.145 Welfare benefits are estimated to be over £3 billion per year from this scale of investment in infrastructure, after accounting for construction and environmental costs. These benefits are driven by the fact that inter-urban strategic roads are heavily used by a wide mix of road users who are subject to significant levels of congestion and unreliability. Users such as business travellers and freight often place a high value on their time and, therefore, lower congestion. A key point to note about this strategic analysis is that it covers inter-urban links, as well as strategic road surface access links to ports and airports. The multiple role of the UK inter-urban strategic road network bolsters its importance in supporting economic activity.

4.146 The gains are largely driven by the reduction in congestion. Inter-urban roads would be expected to benefit from 12 per cent lower congestion with an average reduction over all roads of some 5 per cent. These gains are net of the impacts on urban areas that may see congestion rise a little, by less than 0.5 per cent.

4.147 Road pricing would of course strongly impact on the case for additional strategic road capacity.

The impacts of road pricing on the case for additional strategic road capacity

Even with road pricing, there is still an economic case for additional inter-urban infrastructure

4.148 If widespread road pricing were introduced, the nature and location of challenges on the roads would be altered.

4.149 Analysis undertaken to understand what this means for the case for additional infrastructure in the UK in the longer-term suggests that road pricing would significantly reduce, but not completely eliminate, the amount of additional road build for which there would be an economic case.

4.150 By looking at the returns from additional fixed infrastructure, it is estimated that instead of 2,900 to 3,350 lane kilometres, if national road pricing were introduced, this would fall substantially to just an additional 500 to 850 lane kilometres on the strategic road network between 2015 and 2025. This is a reduction of some 80 per cent.

4.151 Such a package might cost around £5-8 billion and would generate annual welfare benefits in 2025 of some £30 billion. The vast majority of the benefits of this package of road build and pricing derive from the pricing element with only around £600 million of benefits generated by the road build.

4.152 An important variable here is the form of road pricing that is implemented. This analysis assumes that national, distance-based marginal social cost pricing is in place. This is likely to be at the upper end of the possible benefits achievable, and in reality only a much simpler road pricing scheme could be introduced. The extent to which the need for additional capacity would change is likely to be lower under alternative road pricing regimes.

Potentially big environmental benefits from combining investment with road pricing

4.153 Another benefit of a combination of road pricing with additional infrastructure investment is that there are likely to be environmental benefits relative to the case where only infrastructure was used to tackle the congestion bottlenecks. This is for two reasons. Firstly, road pricing itself has the objective of making better use of the road space, so the lower congestion reduces the time vehicles spend idling in traffic queues emitting harmful gases and particulates. Secondly, the ability of pricing to significantly reduce the case for additional capacity means less damaging implications for landscape and biodiversity etc.

Some strategic road build would be worthwhile with or without road pricing

4.154 The vast majority of this 'with pricing' road-build package would offer an economic case for investment in a world with or without road pricing. For those links where this is true, these should be the priority for investment to support the economy and welfare and are to be found generally around and on the key corridors approaching the growing and congested urban areas, and other key links where congestion problems are most severe.

4.155 This section has highlighted that, owing to the interaction of road pricing with the case for additional road build, robust long-term decisions on strategic road capacity can be better made if the case for capacity enhancement has been tested in an environment where pricing – localised or widespread – is approaching. Given the long lead times of such transport interventions, this will be particularly important when considering interventions to tackle challenges beyond 2015.

Providing additional infrastructure when road pricing is uncertain

4.156 The nature of the congestion problem in urban areas and on the strategic road network, and the consequent need for high road prices, indicates that there is likely to be a case for additional road capacity, even if road pricing is introduced.

4.157 Given the uncertainty around road pricing in the long term, there would be merit in testing the case for long-term investments in an environment where pricing is approaching. Priority should be given to those investments for which the case stands up to this test.

4.158 Even with a firm timeframe for the introduction of road pricing, it is likely to take several years. In the meantime there are costs to the economy from road congestion and other pressures. This may therefore point to considering the case for implementing variable capacity options that are cheaper and faster to deliver than fixed infrastructure, reducing the risk of unnecessary investment.

4.159 A framework for identifying and evaluating the case for complementary investment and pricing on other modes and how it will change through time is therefore needed.

Inter-urban public transport capacity

4.160 Inter-urban rail services are likely to experience significant growth over the next two decades with consequent increases in crowding on some services at peak times. These problems are likely to be concentrated on rail links into major urban areas including London. The major cause of pressure is due to the competing demands for rail services on the same lines from both longer distance inter-urban travellers and shorter distance commuters.[26]

4.161 To the extent that these high levels of overcrowding are perceived to increase the costs of commuting into the major urban areas, there are likely to be adverse labour market effects from the impacts on employment choices and therefore costs on the economy.

4.162 When compared with the sample size of returns from inter-urban strategic road investment, there is much less evidence on the returns from public transport interventions on key inter-urban corridors. The evidence available suggests that where volumes of travellers are high enough to cause capacity constraints, and the density of employment and activity at the destination are also very high, there can be good returns from additional variable capacity on existing rail lines. In the UK this suggests that the case will be stronger on corridors into major urban areas.

4.163 Improved signalling has played an important role in delivering significant benefits on the London Underground. For example, signalling and new rolling stock plus other enhancements such as track and civil works and improved power, communications and depot facilities delivered strong returns on the Central Line. The reappraisal of the scheme in 1999 suggested the scheme was financially positive, such that the benefits to travellers plus increased revenues from higher patronage were greater than the cost of the scheme.[27]

4.164 To increase the effective capacity of existing heavy rail lines, rail signalling could be adopted, such as 'moving block'. This technology allows trains to travel at faster speeds and closer together, potentially improving the effective capacity of existing rail lines by some 10-20 per cent depending on the type of traffic and mix of services. These technologies are already being used successfully on a number of light rail schemes, for example the Docklands Light Railway.

[26] For more detail see *Interurban rail forecasts*, Atkins, commissioned for the DfT and Eddington Study, 2006.

[27] *The Central Line: A Step Change*, Report for the DETR September 2000.

4.165 Therefore, if and only if the costs, risks and challenges associated with this technology were such that this could feasibly be considered on a larger scale for national rail, it could potentially deliver consequent benefits to the economy. It could also be considered as a complement to new additional variable capacity on existing rail links where capacity constraints bite.

4.166 Upgrading rolling stock and lengthening trains on congested rail links, combined with changes to timetables to increase frequency can significantly increase the effective capacity of existing rail lines. Evidence of illustrative interventions to increase variable capacity on inter-urban links into London by investing in new rolling stock, for example, suggests strong returns are possible from well-targeted interventions, with wider BCRs ranging between 1 and 13 and costs between £50 and £500 million but more typically between 1 and 3.[28] The higher returns are largely driven by the ability to add variable capacity with minimal infrastructure requirements.

4.167 Both variable capacity on rail and inter-urban strategic road capacity are therefore likely to deliver high returns cost-effectively if targeted on the key pressures on the transport system.

DO STEP-CHANGE MEASURES DELIVER FOR GDP?

4.168 It has been argued that investment in new fixed infrastructure can, in some circumstances, create a step-change in economic performance. For example, measures that provide a step-change in the speed or cost of connection may generate wider economic benefits through increasing the catchment areas for labour markets or through enabling return business journeys in a day. Volume 1 showed that such effects are quite limited in mature economies with well-developed infrastructure.

4.169 To explore this further, a review of appraisal and evaluation evidence of step-change investments in the UK and abroad[29] revealed that schemes that tackle existing congestion problems and bottlenecks are likely to offer larger economic benefits per £1 of cost than those that are primarily focused on opportunities or enhancements.

4.170 The literature and evidence used in this volume also suggested that the bulk of the economic benefits of transport schemes will come from the value of time saved and reliability benefits captured by conventional appraisal, with a limited uplift from including wider economic benefits.

4.171 High-speed rail is often considered as an example of a step-change measure. But, it is first important to note a distinction between possible high-speed rail options:

- those that offer the ability to run trains at high-speed using existing and tested technologies, as is the case on some inter-city lines for example; and
- those that allow trains to run at even higher speeds, relying on new, developing and often untested technologies.

4.172 For the latter option, the approach taken to the development of some very high-speed rail line options has been the opposite of the approach advocated in this study. That is, the challenge to be tackled has not been fully understood before a solution has been generated. Alternative options do not, therefore, appear to have been fully explored so it is not clear what the highest return solution to a problem would be; nor indeed is the challenge clear.

[28] For more detail see *Interurban rail forecasts*, Atkins, commissioned for the DfT and Eddington Study, 2006.
[29] *Step-change Transport Improvements*, Mann, 2006. See Volume 1.

4.173 Interventions to significantly increase rail journey times are sometimes claimed to provide a step-change in economic performance. The literature suggests that in most cases, the returns are likely to be modest relative to other smaller-scale options. For example, the evidence on the costs and benefits of new North-South high speed rail lines available to this study suggests returns at the lower end of the distribution compared to the returns available from other policy options. These relatively modest returns are likely to be driven by several factors including the following:

- the UK's compact economic geography means that most major urban areas are already close together when compared to many European and international competitors;
- for those economically important connections that are more distant, such as London to Edinburgh and Glasgow, air services already provide fast, frequent connections serving business needs and other markets at relatively low cost. The new rail link, therefore, would not be a step change as the link is already there and there is very little evidence that high-speed rail links help regional performance;
- the benefits accruing to intercity business and non-work/leisure travellers in the UK from this new link are likely to be subject to significant uncertainty and speculation because the demand for the link has not been tested and proven;
- history has shown that for large-scale infrastructure projects that rely on emerging technological solutions, costs tend to increase by an order of magnitude against original estimates; and
- in addition, where new rail lines are added and speeds greatly increase, there are likely to be very significant environmental implications from the need for land take, plus emissions and noise.

4.174 Given the distinction made above about the types of high-speed rail interventions, it is important to recognise that not all high-speed rail line options would be subject to the same issues. For those that do not involve relying on untested technologies and are targeted at solving proven congestion and overcrowding problems, higher and more certain returns are likely than for high-risk options on new links where demands are speculative. There are several areas of the network where congestion and overcrowding have already been identified and are projected to worsen over coming decades without appropriate policies or responses, for example on commuter links into London and perhaps other cities. New infrastructure options are one potential solution, but they should be assessed alongside other options designed to meet the same objective.

4.175 When considering significant improvements to inter-urban links between agglomerations, on any mode, it is useful to recognise that commuters are generally prepared to do a 40-50 minute commute, and measures to improve the speed of connection between neighbouring agglomerations bring more people within this threshold, therefore widening the labour market. Agglomeration benefits are likely to drop off over longer distances.

4.176 Step-change measures to deliver a transformation of the transport system are therefore generally unlikely to be a priority, given fixed funding resources. The scale of wider transformational benefits is uncertain and is extremely unlikely to be enough on its own to justify very large amounts of public spending involved. Those that are able to tackle a particular and already demonstrated problem on the other hand, are generally more likely to be cost-effective, but should of course be assessed on their own merits relative to other options such as pricing, variable infrastructure options and line upgrades.

4.177 The case for investing in step-change projects must always be considered against other options for solving the same problem, and against the returns offered by other transport schemes and policies.

4.178 In addition to their potential economic benefits, it has been argued that high-speed rail could deliver reduced carbon emissions from the transport sector by offering a more energy-efficient and lower-carbon alternative to air travel for long distance inter-urban journeys. As the Government has an objective to reduce carbon emissions, it is also important to consider the strategic environmental case for high-speed rail links in the UK.

4.179 Our guiding principle in considering the most effective policy options in contributing to growth has been that government should prioritise limited public resources on those policy options that offer the greatest returns to public spending, and which make the most effective contribution to meeting government objectives. This argument applies equally to money spent on achieving environmental objectives, and government should prioritise those policies which achieve the greatest reduction in carbon emissions per pound spent, taking into account other costs and benefits.

4.180 It is outside the scope of this study to assess the detailed costs and benefits of specific high-speed rail options. Rather, our approach has been to make a strategic assessment of the factors influencing the likely effectiveness of high-speed rail as a policy option for reducing carbon emissions and achieving other environmental objectives.

4.181 At average load factors, rail has an environmental advantage over air travel as it consumes less energy, and therefore produces lower carbon emissions per passenger per kilometre. In theory this suggests that a modal shift from air to rail would offer reductions in carbon emissions. Figure 4.11 analyses the carbon benefits that could be achieved if all air travellers between London and Scotland transferred to rail over a 60-year period, assuming average load factors and energy consumption for rail. The cost of these carbon savings would be high relative to other carbon reduction policies identified in the Government's Climate Change Programme Review.

Figure 4.11 Potential carbon savings from a modal shift from air to high-speed rail

A high speed line from London to Scotland could attract modal shift from passengers who currently make this journey by air. To get a sense of the potential for high speed rail to generate carbon saving from modal shift from air, it is useful to estimate the carbon benefits of an extreme scenario in which all of the current air travellers between London to Scotland were attracted onto high speed rail.

In 2005 around 8 million passengers flew between Scotland and London one way. The carbon emissions per person from making this journey by air or train are roughly 25kg and 10kg of carbon respectively, assuming average load factors for both modes. There would be further climate change benefits on top of these carbon savings due to a reduction in other emissions from aviation. If it were possible to power a high speed rail service with entirely carbon-free electricity, the climate change benefit would be even greater. Factoring in all of these potential benefits, a generous estimate of the net benefit for every person who travels by high speed rail rather than air would be about 40kg carbon.

If a zero carbon high speed rail line were able to attract all of the existing air travellers between London and Scotland to rail, the approximate net annual benefit would be 0.33 million tonnes of carbon equivalent (MtCe), including an assumption for the non-carbon impacts of aviation. To get a sense of the size of this reduction, the carbon emissions from the UK domestic transport sector were 35 MtC in 2004, and 152 MtC from the UK in total. 0.33 MtCe would represent a saving of 0.2 per cent of the UK's annual carbon emissions. Taking account of the predicted growth in aviation demand over the period to 2060, the total carbon savings if all aviation passengers on this route were to switch to high speed rail over a 60 year appraisal period would be 31.4 MtCe, or 0.5 MtCe per year on average. In practice, the carbon savings that would be achievable are likely to be much smaller than this, for a number of reasons set out in paragraph 4.182 below. Even under such favourable and optimistic assumptions, this would not represent a major carbon saving measure compared to, for example, the EU ETS (saving 8 MtC per year from 2010).

The cost of saving carbon in this way is also likely to be relatively high. A standard cost-effectiveness approach working out the cost of saving each tonne of carbon gives a high number (showing poor cost-effectiveness), but this is potentially misleading in that contrary to most climate change policies, the main benefit of the policy is not carbon saving but the time-savings benefits to the users which are not captured in the cost-effectiveness number. A fairer approach might be to compare the benefit of the carbon saved with the total costs and benefits of the scheme. The value of the carbon saved would be around £3.2 billion (31.4Mtc over 60 years) on the government's central cost of carbon of £70/tC (and £2.1 billion to £5.4 billion using the sensitivity range of £35/tC to £140/tC, all 2000 prices). The *High Speed Line Study* by Atkins for the Strategic Rail Authority estimated the construction cost of a London to Scotland high speed line at £33 billion (excluding maintenance and operating costs). On a project with costs of this size, carbon saving benefits of £2.1-5.4 billion (undiscounted), under the most optimistic assumptions, are never likely to play a major role in the business case.

4.182 This analysis represents the maximum carbon savings that could be achieved through modal shift from air to high-speed rail on this route. In practice, there are a number of reasons to be more cautious about the likely cost-effectiveness of a North-South high-speed rail line as a policy for reducing carbon emissions:

- it is highly unlikely that high-speed rail would achieve this level of modal shift from aviation, even with carbon pricing;
- and relatedly, rail's carbon benefit over aviation will depend upon the load factors achieved, and there is a significant risk that demand for high-speed rail would be low on some parts of the route, and at some times;
- rail's energy consumption and therefore carbon emissions per kilometre increases with speed meaning that, all other factors being the same, high-speed rail has higher carbon emissions per passenger kilometre than conventional rail, and a smaller carbon advantage over air travel;
- there could be carbon costs from passengers switching from conventional to high-speed rail, both because of the energy consumption of the respective modes and because load factors could be reduced on existing rail services; and
- there would be significant carbon and other environmental costs in the construction of the line.

4.183 These issues are discussed in more detail below.

Potential for modal shift from air to rail

4.184 The impact of high speed rail on the air market depends upon how competitive it is compared to flying, in terms of both cost and travel time. The Atkins High Speed Line study anticipated a 9 per cent reduction in air demand for the London to Edinburgh journey in 2016, rising to 24 per cent in 2031.[30]

4.185 Some commentators acknowledge the uncertainties around the demand forecasts, but argue that if air travellers were made to pay the full external environmental costs of their journey, this would increase the comparative price advantage of rail travel, leading to a modal shift from air to rail, increasing the commercial viability and environmental performance of high-speed rail.

4.186 This study fully supports the principle of ensuring transport users face their full external costs, including environmental and congestion costs. This volume earlier explained that the introduction of some form of carbon pricing for aviation would result in increased air fares for passengers. Such a pricing mechanism might increase the cost of a one-way air fare from London to Scotland by around £6, including an assumption for climate change costs of other non-carbon emissions from aviation.[31] A price increase of this magnitude would not be expected to have a significant impact on the competitive position of rail versus air on this route. Furthermore, it is expected that this increase in costs would be offset by cost savings through increased efficiency and competition in the aviation sector over the medium term, meaning prices would not be expected to rise in real terms.

Importance of achieving high load factors

4.187 Rail's environmental benefit compared to other modes will depend heavily on its load factors. A well-utilised rail service has relatively low carbon emissions per passenger per kilometre. But if services are running at low occupancies, the energy consumption and carbon emissions per person could be high, potentially higher than those of alternative modes for the same journey.

[30] *High Speed Line Study: summary report*, Atkins for the Strategic Rail Authority, 2004, www.dft.gov.uk.
[31] DfT analysis.

4.188 If a rail service was well utilised throughout the day and on all parts of the route, it would most likely offer environmental benefits over other modes for making the same journey. But as discussed previously, demand for high-speed rail in the UK would be expected to be relatively low on those sections of the route where new capacity would be provided in the hope of stimulating demand rather than relieving existing capacity constraints. The risk of low demand on some sections of the route would therefore have implications for the environmental benefits of the scheme as well as its commercial feasibility.

Carbon implications of higher speeds

4.189 Rail's comparable energy efficiency and carbon advantage over air travel decreases as the speed of the train increases. This is because air resistance, or aerodynamic drag, increases exponentially with speed, meaning more energy, and therefore carbon emissions, are required to overcome air resistance at higher speeds. In simple terms, all other factors being equal, a high-speed train would have higher carbon emissions per passenger than a conventional speed train covering the same distance.

4.190 The availability of low-carbon sources of energy would have implications for the balance of carbon emissions across modes, and it is likely that low-carbon rail will become feasible before low-carbon aviation. If a high-speed rail line could be constructed and powered by entirely carbon-free energy sources, this would increase the potential carbon saving (in the worked example above it would increase the potential carbon savings by around 40 per cent). But the increased carbon savings would need to be viewed against the increased costs, if any, of sourcing low-carbon sources of energy.

Carbon performance of high-speed rail compared to conventional rail

4.191 While there may be carbon benefits from passengers moving from air to rail, it is likely that there would be carbon costs from passengers moving from conventional rail to high-speed rail, both because of higher energy consumption and carbon emissions per passenger km from high-speed rail, and because of possibility of load factors being reduced on conventional rail services.

Wider carbon and environmental costs

4.192 The calculation in Figure 4.11 does not take account of the carbon costs of building a new line, which could be considerable. Furthermore, wider environmental implications of a new high-speed rail line may not all be positive. There would be significant landscape costs from building new track, including implications for biodiversity, national parks and national heritage. The route of a high-speed train could potentially pass through the Chilterns and/or the Peak District National Park. A feasibility study by Atkins for the Strategic Rail Authority noted that high-speed rail does not perform particularly strongly on wider environmental implications 'since a scheme requiring such substantial new infrastructure would inevitably have significant negative landscape, biodiversity and heritage impacts, with relatively small benefits to air quality and noise levels'.[32]

Conclusions of the strategic environmental case for a North South high-speed rail line

4.193 High level analysis of the potential carbon benefits from modal shift from air to high-speed rail suggests that these benefits would be small relative to the very high cost of constructing and operating such a scheme, and that under current assumptions a high speed line connecting London to Scotland is unlikely to be a cost-effective policy for achieving reductions in carbon emissions compared to other policy measures.

4.194 High-speed rail is likely to make the most effective contribution to environmental objectives where the scheme is developed to address existing or projected capacity constraints, increasing the probability of high demand and high load factors, and improving the economic and environmental returns.

[32] *High Speed Line Study – Summary Report*, Atkins for the Strategic Rail Authority, 2004. www.dft.gov.uk.

4.195 The energy consumption, and therefore carbon emissions, of very high speed rail is likely to be higher than that of conventional rail, all other factors being the same. Any consideration of the potential for high speed rail to deliver carbon benefits needs to be based on detailed analysis of the costs and benefits, rather than on broad generalisations about the environmental benefits of different modes.

4.196 As argued previously in this chapter, decisions on specific schemes or policies would need to be informed by detailed appraisals of specific high-speed rail proposals, and of appraisals of other policy options for achieving the same objectives.

Conclusions

4.197 This section has therefore shown the following:

- there is an economic case for a significant amount of targeted additional inter-urban road capacity, even after environmental effects have been accounted for;
- the introduction of better road pricing would reduce the amount required. Even with road pricing, however, there is an economic case for additional inter-urban road infrastructure, albeit at a much lower order of magnitude and in fewer places;
- the case for targeted additional capacity on key commuter corridors into major urban areas is strong; and
- step-change measures intended to provide a transformation to the transport system and rely on untested technologies are not, in a world of constrained resources, likely to be a priority. Those step-change measures proposed as a solution to existing and likely future problems are more likely to perform well, but must be assessed alongside other options for a given transport challenge.