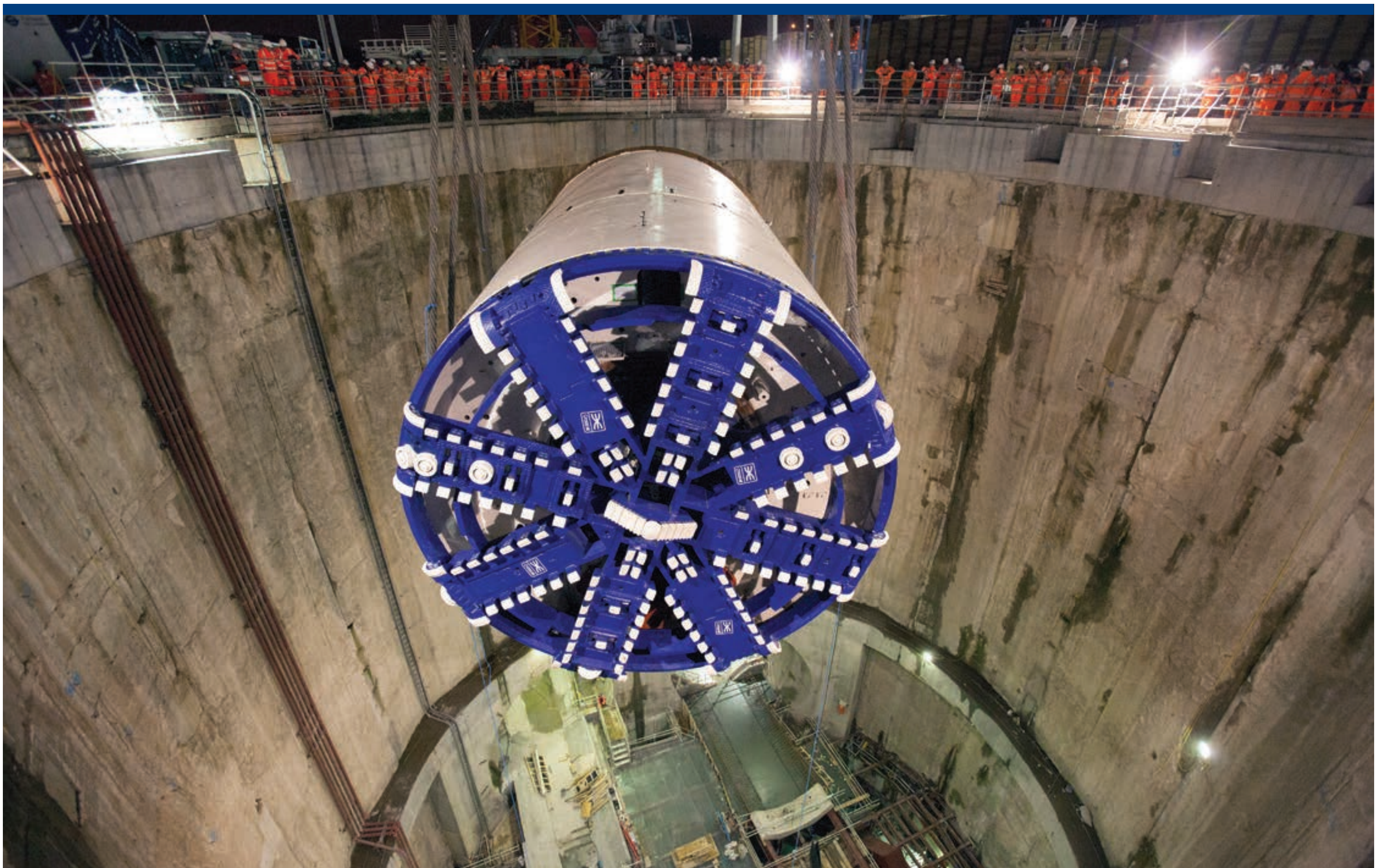
International Transport Forum



Major Transport Infrastructure Projects and Economic Development

Roundtable Report

OECD

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1. Introduction

Socio-economic appraisal of transport investments and transport policies is broadly accepted as a valuable, often indispensable input to decision-making, although opinions differ as to its precise role and there is debate on whether the standard toolkit is up to the task in all cases. An important concern is that applying standard methods of appraisal, which focus on direct benefits for transport users, may produce inaccurate estimates of total benefits. Standard methods are also of little help in gauging the ultimate distribution of project benefits and costs or for estimating impacts on overall output (Gross Value Added) and employment. The issues are particularly pressing for "major projects" – projects with potentially wide-ranging effects outside the narrow transport perspective that lies at the core of standard cost-benefit analysis.

This paper discusses challenges and potential improvements to socio-economic appraisal in the context of two major projects, Crossrail in London and the *Métro du Grand Paris* in the Greater Paris region. It draws from discussions among leading experts at a roundtable meeting on challenges for the appraisal of major projects, held in Paris in December 2011. This discussed strengths and drawbacks of routine appraisal techniques and investigated ways of overcoming limitations. The range of discussions was broad, including issues of methodology, political economy and communication. This paper aims to provide a concise and accessible overview of highlights. Section 1 presents the scope of the London and Paris projects and a brief summary of the results of appraisal. Section 2 discusses the appraisal challenges in more detail.

As a preamble, it is useful to define terms, even though these are necessarily broad, since practice is neither completely uniform nor settled.

- ***Direct Transport Impacts*** are the benefits, revenues and costs for users, operators, infrastructure providers and governments, and the environmental and other impacts on society. Typically, estimates of the costs and benefits will be derived from transport models that incorporate behavioural responses to changes in the transport network, such as rerouting within a mode, modal transfer, redistribution between origins and destinations within the study area, and entirely new trips. The user benefits (travel time, reliability, relief of overcrowding), the revenue effects for operators and infrastructure providers and the environmental impacts (such as noise, NO_X, CO_2) should all be calculated by the model in a consistent manner over the life of the project. This is, of course, a challenging task in itself, but is what conventional transport appraisal aspires to do. Typically, a fixed land-use pattern is assumed with respect to the project; land use may be assumed to vary over time as either the population or the economy is predicted to change, but land use is not assumed to respond to the project.

- ***Induced Land-Use Change:*** particularly for major urban projects, the assumption of fixed land use is inadequate and in some cases misses the point of the project. This is particularly so when the objective of the project is, at least in part, to remove bottlenecks in the transport system and trigger economic change. Models (such as DELTA) have been developed to help estimate the land use response to provision of new transport capacity both in terms of commercial development and housing. However, such models track spatial redistribution of activity rather than net generative effects. Moreover, fully integrating land-use change into benefit calculations for appraisal, though theoretically feasible, has proved to be computationally difficult. This is particularly the case where a transport scheme changes not only zonal accessibility but also zonal attractiveness. Sometimes, it may be necessary to view a transport project with strong expected urban development consequences in a holistic multi-sectoral way rather than as a separable piece of infrastructure.

- ***Wider Economic Impacts***: these are discussed in detail below. They fall into the category of economic effects in the labour and goods/services markets that are additional to the direct transport benefits and not counted in the assessment of direct impacts. The principal mechanisms at work are agglomeration economies and enhanced labour market efficiency through better matching of people to jobs. They include the tax wedge[1] benefits to society of increased employment resulting from improved transport quality.

- ***Macroeconomic Assessment***: conceptually, all three of the above categories of economic effect can be captured within a complete microeconomic account of the impact of a transport project. Assessments vary in the breadth of consideration – the transport market, the effect on land development and the effect on productivity and labour – but microeconomic assessment techniques can be used to estimate each effect if sufficiently detailed data can be included in the modelling. It has been argued at previous Roundtable meetings, however, that the microeconomic approach ignores long-term, dynamic feedback on economic structure and competitiveness (ITF 2011; ITF 2008). While these effects can be ignored for most transport projects, it is implicit in much political discussion that they cannot be ignored for the very largest projects. The link between the microeconomic methods underpinning cost-benefit analysis and macro approaches such as computable general equilibrium or systems dynamic methods needs to be addressed in order to bring a degree of rigour to the analysis of claimed "transformational" effects.

- ***Dynamic, Structuring Effects:*** a particular and important aspect of very large changes to the transport system is that they frequently contain a strong element of structuring the way the regional economy and land use system will develop over the long term. For incremental projects, it is normally quite satisfactory to assume that the population, employment level and pattern is fixed, so the counterfactual against which the scheme is assessed is clear. For mega projects, frequently the question arises – what exactly *is* the counterfactual? If we don't expand the capacity of the city, where will people be living and working, how will predicted population growth be accommodated? The discipline of CBA – and policy analysis generally – depends on there being clear alternative scenarios to compare against each other, and sometimes forecasting what is going to happen in the reference case is just as demanding as forecasting what will happen if we build the project.

2. Greater Paris and Crossrail: characteristics and approaches to appraisal

The *Grand Paris* Project

The *Grand Paris* Project aims to strengthen the economic potential of the Greater Paris region and improve quality of life by removing two obstacles to that potential: (1) substandard transport connections between emerging poles of economic activity, not so much within Paris but in its surroundings, and (2) the shortage of housing. The project proposes the provision of new public transport services – an automated, high-speed metro – and housing in a "structuring" manner, meaning that new centres of activity will be created around metro stations and urban sprawl and car reliance will be contained. The project hence aims to shape land use in the Paris region in the form of clusters, while providing fast public transport between them.

The project is sometimes viewed as the "next upgrade" to equip Paris and its surroundings for a continuing vocation as a world-class metropolis. Earlier large-scale projects include Haussmann's restructuring of the city, establishment of the metro network, creation of the RER network (radial and cross-Paris rail connections between Paris and the suburbs) and the *nouvelles villes* (new cities) connected to Paris by the RER. The Grand Paris metro consists of three lines that form a loop around Paris with a complementary network to the North and East of the city. The loop essentially serves *la petite couronne*, i.e. the three departments[2] surrounding Paris which are characterised by high population density (around 9 000 inhabitants per square kilometre), with a total population of about 6.6 million (Paris itself has about 2.2 million inhabitants and a population density of around 21 000 inhabitants per square kilometre). The full project would add 175 kms of new metro lines and 60 stations, equivalent to a 70% expansion of the current metro network. Transport times for many trips, particularly in the suburbs, should fall by 50% (Prager, 2011). In addition to interconnecting the Paris region, the new network would greatly improve access to the two airports in the region and to high-speed rail stations.

At present, Greater Paris boasts a larger modal share of public transport than many other large cities. In an average week, around 70% of trips between Paris and the surrounding region is by public transport (Viora, 2012), a high share that is supported by the radial structure of current public transport networks. This structure is far less convenient for trips within the region around Paris. These trips now account for around two-thirds of all trips in the Ile-de-France (*ibid.*), and the vast majority of them (80% according to Prager, 2011) are made by car. The Greater Paris project is intended to help meet expected growth of travel demand (+15 to 20% compared to 2010) and to ensure that a larger share of the population uses public transport. More public transport will also mean more use of the current metro network, but the most congested segments will experience a decline in traffic because fewer trips between suburbs will be made by passing through the centre of Paris[3].

Improving the economic vitality of the region is a key objective. It should not in general be taken for granted that more and/or better transport infrastructure can effectively contribute to this aim. In an already well-connected economy the evidence to support the growth-enhancing effects of more transport infrastructure, on average, is weak. This is because there are declining marginal returns to infrastructure provision and because advanced economies rely more on services and knowledge to create welfare, activities that are less reliant on transport than earlier engines of growth. In addition, economic benefits may be reduced by allocating resources to projects with low expected economic returns (see the discussion in ITF *Transport Outlook*, 2013).

Why would this general scepticism not apply to the Greater Paris project? First, scepticism does not rule out that there are beneficial projects. Second, the arguments for the project emphasize precisely the current insufficiency of connectivity between centres of knowledge generation and centres of entrepreneurial activity and that this bottleneck stifles innovation and growth. Whereas industrial activity was well-served by available infrastructure, new activities are in places that are only connected by congested roads.

Prager (2011) points to a dearth of interaction between research establishments and entrepreneurial activity in Greater Paris. Both activities are present and improving connections between them should boost the innovative potential of the region. This is not just a matter of providing better transport but also of restructuring universities (including but not limited to their location). The goal is to structure the region around centres of economic activity, with about ten sub-centres around Paris. The expansion of the metropolitan area is not stopped, but controlled. The RER and the *nouvelles villes* that it served have not succeeded in containing car-oriented urban sprawl because rising wealth, car-oriented preferences and car-accommodating policies worked in the opposite direction. The Greater Paris project aims to reduce car-dependence significantly.

The project also aims to raise the quality of life in the Paris region. While incomes in Paris are relatively high on average, inhabitants face degrading transport conditions (high congestion and low reliability for private as well as public transport) and high housing prices (leading to cramped and sometimes low-quality housing and reduced disposable income). Better transport will contribute to better living conditions but a very substantial increase in housing supply is an indispensable part of the project. In order to ensure co-ordination between the metro project and the increased supply of housing in clusters centred around stations, the Greater Paris authority works with local and regional authorities through territorial development contracts (CDT: *contrat de développement territorial*) with a 15-year time horizon. More housing, and more affordable housing, will improve the quality of life. The current shortage is seen as a major drawback for the economic vitality of Greater Paris, particularly because it is increasingly difficult to attract young families.

Appraisal for *Le Grand Paris*

The economic appraisal of the transport component of the Greater Paris project includes the legally required evaluation of the benefits from improved transport services but goes well beyond it, as the methodology is too narrow for a project of this scale and ambition. Standard transport project appraisal is well suited, even if far from perfect, for gauging the benefits of investments that improve the quality of existing infrastructure and services. However, it does not address the full range of the effects of a step-change in transport infrastructure, let alone of a project that explicitly aims to raise the economic potential of a region through a change in land-use patterns (increased polycentrism), a drastic reduction in travel times and a major increase in housing supply[4]. A further difficulty is that impacts will take place in the far future, so standard discounting methods reduce the project's appeal compared to projects with near-term payoffs, perhaps unjustifiably so[5].

Expanding the scope of appraisal is difficult because the broad impacts of infrastructure investment are less well understood than the direct impacts and because views diverge on what is the most appropriate method for addressing them. The approach taken for the Greater Paris project is prudent, recognising lower confidence in the results as broader impacts are studied, using a range of approaches to check the robustness of findings and making conservative assumptions to reduce the risk of overestimating benefits. The core results of the socio-economic appraisal of the project are summarised in Table 0.1.

Table 0.1. **Transport and broader benefits of the Greater Paris Project under three assumptions on employment creation in Greater Paris**
(billion EUR, 2010 prices[6])

	Additional employment compared to situation without the project		
	0	115 000	315 000
Transport benefits	31.3	44.6	41.1
Additional benefits	8.0	29.0	61.9
Total benefits	39.3	73.6	103.0

Source: SGP, Avis du Conseil Scientifique, 2012.

The transport benefits comprise time gains (the largest component by far), benefits from increased frequency and better comfort and reduced environmental impacts. They are calculated with methods prescribed by law, and this likely means they underestimate true benefits for given levels of trip demand. The reasons for this are that the mode choice model is believed to underestimate the share of public transport, benefits from increased reliability are ignored and nation-wide values of time are used instead of the higher values that would be expected to apply to the Paris region.

The additional benefits contain (a) agglomeration benefits, i.e. increased productivity of existing employment resulting from higher economic density; (b) the change in employment as a result of reallocation within Greater Paris; and (c) relocation of employment, which is conservatively taken to be fully accounted for by displacement from outside the region with unchanged national employment, so only the higher productivity of the Greater Paris location is included. The additional benefits represent 20% of the total in the “no extra employment” case, 40% in the middle scenario, and 60% for the high scenario. In other words, whereas the transport benefits are only moderately dependent on the employment assumptions, the additional benefits increase strongly with them. Since the likelihood of the more optimistic assumptions on employment coming true is dependent on the non-transport components of the project, notably the increase in housing supply, it follows that the additional benefits depend crucially on the implementation of the whole project and not just the transport component.

The analysis behind the results of Table 0.1 makes good use of available techniques, showing, *inter alia*, that results are not very sensitive to alternative modelling approaches. Some shortcomings remain, including the absence of evaluation of alternative projects that might deliver similar benefits, or partial realisations of the full transport project and of accompanying transport measures, such as parking and pricing policies.

The Crossrail project in London[7]

The main goal of Crossrail is to strongly increase the capacity of the rail network in London so as to relieve crowding on the current network and to allow the density of employment in Central London to rise and realise productivity gains. Crossrail is a central London rail tunnel that will interconnect the eastern and western main-line suburban networks and link to longer-distance services and in due course to the new High-speed 2 line from London to the Midlands and the North. The Crossrail link adds 6% to existing rail capacity in London, 10% in the central area. It will facilitate travel into central London, reducing platform-to-platform travel times by half in many cases.

When the rail network in the London region was developed in the 19th century, no rail connection was built through London, and the stations were at the fringes of the city. In the 20th century, tram and metro networks were built that connected the main-line stations to workplaces in central London and that established access to places not well served by the main-line stations. With this structure, rail commuters need to switch between non-interoperable networks, which is costly in terms of time and convenience (ITF, 2014). The rising importance of central London as an employment centre has caused crowding and capacity shortage on the city's transport networks and at key interchanges. The need to increase capacity and the opportunity to reduce interchange and relieve bottlenecks are the main inspiration for Crossrail. It is in that sense similar in function to the existing RER system in the Paris region.

The Abercrombie Plan (1944-46) proposed a co-ordinated land-use and transport plan for Greater London. Some elements of the plan were (partly) implemented, including the Greenbelt around London, the development of satellite towns and moving manufacturing out of London. A main-line railway through London was also part of the plan but was not built. By the end of the 1980s, growing pressure on the central London transport network inspired renewed interest in capacity expansion. The Central London Rail Study (CLRS, 1988-89) favoured the option of regional rail over metro expansion but funding problems and the onset of a recession, with declining commuting traffic, temporarily reduced interest in the project. The exploration of Crossrail routing and funding options revived with the 2002 Crossrail Review and the Cross London Rail Links (CRLR) business case in 2003. This business case rested on conventional appraisal, i.e. the focus was on transport users' direct benefits. Assumptions were made on increases in employment, on the grounds that lack of capacity would constrain employment growth, but they were not valued. The business case was revised in 2005, with a downward correction of the cost-benefit ratio for direct transport benefits (from 2 to 1.8) but also with increased attention to wider economic impacts. Overall, this revised and extended analysis strengthened the case for Crossrail.

Appraisal for Crossrail

The socio-economic evaluation of Crossrail in 2005 was carried out in a context of growing interest in the productivity and growth effects of transport investments, and not just their direct impacts on transport users. The desire to quantify wider economic impacts was not limited to Crossrail but was particularly strong here, given the explicit objective of strengthening the economic potential and performance of central London. The possibility of designing funding arrangements in line with expected economic benefits provided a further impetus. Hence, although the Department for Transport's (DfT) guidelines on the appraisal of wider economic impacts were still under development at the time of the Crossrail appraisal, the valuation of these benefits became a central part of the exercise. Table 0.2 summarises the results.

Table 0.2. **Transport and broader benefits of the Crossrail Project, Department for Transport and Transport for London versions**
(billion £ sterling, 2002 prices[8])

	Department for Transport	Transport for London
Transport benefits	11.0	**15.5**
Additional benefits	6.4	**7.0 – 18.0**
Total benefits	17.4	**22.5 – 33.5**

Source: Worsley, 2011b.

The additional benefits are large, amounting to between 31% and 54% of the total benefits, depending on the scenario. These orders of magnitude are similar to those found in the Greater Paris appraisal. They include the following effects: external benefits from agglomeration, reallocation to more productive jobs, increased labour force participation, and a correction of the valuation of business travel time to account for imperfect competition[9]. The analysis for Greater Paris considers a similar set of effects, except that the correction for imperfect competition, a smaller benefit, is not included. In the DfT, agglomeration and reallocation are the largest effects by far, representing 80% of the entire additional benefits.

Earlier cost-benefit analyses for Crossrail had worked with exogenous assumptions on employment growth and productivity effects, an approach not deemed satisfactory given the central interest in the project's contribution to growth and employment. The DfT appraisal used an elasticity of 0.059 of productivity with respect to effective density to estimate agglomeration benefits of £3.1 billion. Transport for London applied a higher elasticity (0.075) to obtain benefits of £4.5 billion. To estimate the increase in labour supply, DfT translated changes in commuting costs into changes in labour supply through an elasticity of labour supply. TfL took a different approach by (a) estimating how removing the commuting capacity constraint would allow employment to grow along past trends (taken to be unconstrained by transport capacity) and (b) assessing the extent to which employment growth would be below the unconstrained case in the situation without and with Crossrail. All employment growth in central London is taken to come from people moving to more productive London jobs, with the productivity premium at 30% or higher values in some TfL scenarios. The DfT analysis has been qualified as conservative on wider benefits, for example, because convergence of the central London employment density to levels observed in parts of New York, Paris and Tokyo would produce considerably higher wider benefits.

Grand Paris and Crossrail compared

The Paris and London projects both are "very large" in the sense that they are expensive, pose major engineering challenges and constitute a radical change in the set of transport options available once built. However, apart from the general notion that the projects foster economic growth, their intended impact on the regional economy is different. Crossrail aims to improve the accessibility of central London to workers in order to boost the productivity of employment in an already thriving area. The main idea is to lift a constraint on growth. This, perhaps, is in line with the central view of the 2006 Eddington Transport Study, commissioned by the Government, that the main contribution of transport infrastructure to growth in an already well-connected economy is to remove bottlenecks in places where growth potential exists, and not to create new growth clusters.

The Greater Paris project is advanced as a “structuring project”. The goal is to shape the spatial distribution of economic activity in the Paris region, thereby raising its productive potential. Urban expansion is not stopped but is controlled, the idea being that creating secondary centres of productive activity around Paris is better for growth and for quality of life than poorly controlled and car-oriented urban expansion (the current situation), but also better than trying to raise the intensity of usage of central Paris even more (an alternative project). As emphasized in Section 2, the transport and housing components of the project are complementary, and it is certain that the full benefits will not materialise if either component is lacking (as is illustrated by comparing total benefits under various assumptions on employment creation). What is less clear, and has not been appraised, is what benefits could be delivered by partial realisation of the transport component.

Although they aim to achieve their objective in different ways, both projects’ ambition is to stimulate growth in a metropolitan area. In both cases, the socio-economic appraisal seeks to quantify the productivity effects as well as the direct transport user benefits, and the approach is roughly similar. Detailed transport models are used to calculate transport benefits according to national guidelines for appraisal (even if that has drawbacks for the case at hand). For the additional or wider economic benefits, no similarly standardised tools are available (although they are under development in the UK), requiring more innovative approaches and acceptance of reduced confidence levels.

At the core of the wider benefit appraisal is the evaluation of agglomeration economies and the reallocation and relocation of workers and the productivity effects this entails. For Greater Paris as well as for Crossrail, accounting for the wider economic benefits increases total project benefits appreciably, more than doubling them in some scenarios. The wider benefits for middle scenarios are between one-third to one-half of total expected benefits.

The more a transport intervention is expected to have structural and macroeconomic consequences the stronger the case for trying to examine the effect on Gross Value Added (GVA) as an alternative appraisal metric. In such cases the relevant appraisal comparison for the Ministry of Finance may be with other interventions outside the transport sector as much as with other transport projects. GVA provides an alternative (or complement) to CBA for prioritising projects for funding under a budget constraint. Modelling of GVA allows for land-use change and estimates local productivity increases from decisions of firms and workers to relocate as a result of changes in accessibility. Worsley (2011a) discusses the development of the technique for regional governments in the UK by KPMG and LSE (LSE, 2009). The results are obviously of great interest for local decision-making but do not usually distinguish between relocation of jobs and net creation of employment. They do not therefore provide information on the overall value of the project to the economy in the way that net present value indicates overall value under cost-benefit assessment. KPMG recently extended its model to examine the potential national impacts of the proposed high speed rail link from London to the north of England (KPMG, 2013), identifying which regions would gain and which lose. The results were widely challenged, partly because of problems of identifying causality and of separating out improvements in accessibility from all the other changes likely to take place, both of which require large amounts of detailed data to produce convincing results. This is discussed further below.

3. Difficulties with appraisal of major projects and emerging solutions

Evaluating long-term, structuring and multi-component projects

Even though the Greater Paris project is inspired by a diagnosis of an existing problem (lagging economic performance of the region at least partly due to insufficient quality of transport), the proposed solution starts from a vision of the future structure of the region, instead of proposing an incremental response to the existing transport problem. This prompts some questions and concerns:

- The success of the project requires co-ordinated completion of its components. Given that commitment to the public components is not necessarily strong over time and the commitment to private-sector components is even less secure, the project is characterised by high uncertainty, a feature exacerbated by its very long-run nature. Mechanisms for co-ordination and for improving time consistency should ideally be part of the project design. A judgment on the appropriate allocation of risk between private and public agents will have to be made.

- There is no explicit statement of why the proposed project has been selected rather than potential alternatives. Alternative approaches are possible, for example improving use of current road capacity in and around Paris, or improving capacity and reliability on existing rail networks in the region, or lifting constraints on the density of development in Paris. These alternatives may or may not perform better, or may or may not be feasible for political reasons, but such scenarios have not been assessed, whereas large transport projects are usually judged in comparison with potential alternatives (ITF, 2004).

- It would also make sense to explicitly analyse partial realisation of the plan, i.e. investigate the modularity of the project.

- The project does not address some of the potential causes of the region's relatively weak performance outside the transport sector. The current public transport system in Paris arguably compares favourably to that of many of its peers. The region's competitiveness may be weaker for reasons unrelated to transport. This may mean that cheaper ways of increasing productivity exist outside the transport sector, and/or that the project itself will turn out less effective than hoped for if other hurdles are not overcome.

- Risks relating to co-ordination between sectors are perhaps the largest source of uncertainty in assessment of the project. The strong need for co-ordination can be seen as the key difference between a non-marginal project (like Crossrail) and a transformational project (such as the Greater Paris project).

These broad concerns aside, there is still the challenge of evaluating the likely benefits of the proposed project. One difficulty is that benefits will emerge in the far future which, under standard discounting practice, means that the project will compare unfavourably with alternatives that yield nearer-term benefits. The Greater Paris project proposes a structure and capacity for places where densities are currently low. It contrasts with the philosophy of the Eddington Study which favours projects that remove bottlenecks in places where congestion and densities are high now. The focus is on near-term benefits, not on long-run and "structuring" projects. Such "near-termism" arguably gains appeal in a macroeconomic crisis.

Development of the Grand Paris project coincided with a review of the way long-term benefits and risks are addressed in project appraisal, through two reports commissioned by the French Government (Gollier, 2011 and Quinet, 2012). These reports recommend an extension of project evaluation horizons beyond the current 50 years for transport infrastructure. Risks are separated into three main categories. First, pure uncertainty is set aside as it is not susceptible to quantification by statistical techniques. Second, are risks related to construction and demand when the project comes on stream. These include optimism bias, construction co-ordination and management risk, geological risk etc. The recommendation is to adjust for optimism bias in demand forecasts, by the use of reference forecasts, and (for the purpose of examining long-term effects) ignore the other factors, as these risks are resolved when the project enters service. Third, are systematic risks linked to macro-economic performance. For this category of risk the discount rate used for evaluation is split into two parts: a risk-free rate and a project-specific risk premium which varies according to how closely project benefits are correlated with economic growth. The project-specific premium is, in turn, the product of two parts: a risk premium common to all (transport) projects and a coefficient that reflects the link between project benefits and economic activity. The reports recommend using coefficients between 1.0 and 1.5 depending on mode of transport (Quinet, 2013). It would clearly be useful to distinguish between structuring and non-structuring projects if a workable boundary could be established.

Evaluating agglomeration economies and productivity impacts

Agglomeration economies belong to the class of wider economic impacts, those not captured in cost-benefit analysis, which focusses on direct user benefits only. It is increasingly recognised that measuring direct user benefits alone may result in under- or over-estimates of total benefits, particularly for larger projects such as the ones discussed in this paper (see ITF, 2007). One remedy is to evaluate benefits additional to the direct benefits, an approach which has the advantage of modularity but may entail a risk of double-counting: an alternative, examined briefly in the next subsection, is to measure economic impacts through regional or national macroeconomic models.

Inspired by UK research, four sources of wider economic benefits are commonly distinguished:

1. Agglomeration impacts;
2. Changes in output in imperfectly competitive markets;
3. Changes in labour supply; and
4. Switching to more productive jobs (WebTAG section 3.5.14).

The separability – and therefore additionality – of these effects is sometimes challenged (e.g. Kidokoro, 2012) and different empirical identification strategies can lead to differing interpretations of ostensibly identical concepts. Debate at the roundtable focused on potential problems with measuring agglomeration economies.

The productivity of firms and workers depends, among other things, on the density of firm location, or more generally on the accessibility to economic mass that comes with that location. There are gains from proximity. The sources of these gains include increased opportunities for labour market pooling, scope for industry specialisation, greater efficiency in knowledge or technology sharing and improved opportunities for input-output matching. Changes in accessibility due to improved transport quality are, effectively, increases in proximity.

If a transport project leads to changes in accessibility,, it is of interest to quantify the consequential changes in productivity, as has been done in the appraisal of Crossrail and the Grand Paris project. However, the quantification of agglomeration benefits is laden with difficulties and uncertainties. This does not mean these benefits should be ignored but that careful use needs to be made of the evidence. As research on agglomeration economies has progressed, it has tended to attach increasingly modest (although still significant) values to the effect; smaller values than a simple correlation of productivity and some measures of accessibility would suggest.

While agglomeration is associated with higher productivity, it is less obvious under what conditions reductions in transport costs – following, for example, the construction of additional infrastructure – contribute to higher productivity. Some (partially overlapping) reasons are as follows:

- Causality: If more productive workers tend to locate at denser places, a phenomenon for which there is evidence, then productivity is higher at these denser places. But which is the direction of causation – from high productivity to improved city infrastructure or the reverse? We need to separate out the effect of increased accessibility on productivity but this is econometrically challenging.

- Scalability: the variation in access to economic mass that is used in the econometric estimates of agglomeration effects typically is much larger than the change in accessibility brought about by even large transport investments, and it is not straightforward that similar results apply at these different scales.

- Threshold effects: there is evidence that agglomeration effects are flat over large ranges of density and that changes need to exceed a threshold before effects can be measured; this can be seen as a strong form of lack of scalability.

- Data: cross-section analysis uses density as a proxy for agglomeration, but this is subject to problems; in time series, variation in density is limited; within cities, treatment and control groups overlap; as a consequence, the mechanisms underlying agglomeration are poorly identified even if they are conceptually clear, and the resulting estimates are not transparent.

- Microeconomic assumptions: for example, sectors such as government, which tend to be important in large cities, are assumed to operate in the same way as the market sector.

As a consequence, while great steps have been taken in research investigation over the last decade towards estimation of agglomeration elasticities taking account of the above phenomena (for example, Graham, 2007), there is not yet a settled body of evidence on the value added by transport investments through the exploitation of agglomeration economies.

In particular, Graham underlines:

- Agglomeration economies do matter and they can be substantial, particularly for services;

- Concerning transport provision, the important point is that productivity may be strongly associated with economic density;

- It seems likely that an increase in effective densities induced through transport investment will have associated productivity benefits via agglomeration;

- These benefits will accrue to firms as a result of being closer to larger labour markets, having improved access to input and product markets, and from an increase in the scale and spatial concentration of other firms, which encourages the sharing and matching of resources and knowledge.

For the practice of project appraisal, it is important to consider early in the process what linking mechanisms between transport and the economy will be important for the project. For example, an urban regeneration project which is expected to open up new land for development will require a different modelling and appraisal approach from a large inter-urban project whose land-use effects are extremely diffuse. There is also an issue of proportionality in appraisal, in terms of the size of the public funds at risk from incorrect decisions, but it is not size alone that matters.

As long as transport infrastructure budgets are limited and are not themselves strongly dependent on expectations of total project benefits, the main point of interest is whether agglomeration effects affect the ranking of projects. Rankings can be affected by agglomeration effects when:

(a) comparing projects in different places, e.g. cities *vs*. rural areas or large *vs*. small cities, even if their direct benefits and costs are similar; and

(b) comparing different major projects in the same regions (e.g. the plan for Greater Paris as compared to a mobility plan that focused on the core of Paris).

Whereas in case (a) the current understanding of agglomeration effects provides some indication of how rankings of projects are likely to change when agglomeration is accounted for, this is much less the case in case (b), so that case-specific investigation is of great potential value here.

One insight from both theory and empirical work on agglomeration is that there is a trade-off between congestion and agglomeration. Strengthening agglomeration by alleviating congestion is likely to be more effective than policies that aim to strengthen it directly, e.g. through subsidies as these tend to cause displacement. It is worth noting that agglomeration and high productivity are not synonymous with density. To the contrary, all else equal, denser places are less productive. Lower transport costs allow cities to spread out and substitute land for labour, with productivity increases a result. Projects like Crossrail are likely to work in both directions at different points on the system, strengthening agglomeration at the centre and facilitating substitution of land for labour at the periphery. Agglomeration is strengthened by reducing the cost of productive interactions between economic agents – increasing accessibility of economic mass. Lower transport costs contribute to agglomeration in general, and agglomeration leads to higher land prices, which in turn tends to increase density.

The aim of the Grand Paris project is to create new centres of economic activity in the vicinity of Paris, through a controlled expansion of the urban region. Employment densities in the surrounding areas would rise, as would the level of employment. To calculate the productivity impacts, estimates are needed of the rise in employment densities and of the productivity effect this has (i.e. the agglomeration effect), and of the origin and characteristics of the incoming workers. Combes and Lafourcade (2012) provide orders of magnitude for the effects involved. By way of illustration, if employment in the zones surrounding Paris were to increase by 500 000[10], density in these zones would rise by 9.6%, and the productivity of workers would rise by 0.18% (elasticity of 0.02 according to evidence for France, after controlling for composition of the workforce and for endogeneity).

Endogeneity means that this increase would attract workers, and allowing for this means using an elasticity of 0.024.

If the 500 000 incoming workers are of average French productivity, then their productivity in the Paris region would be higher by 6.6%. This, however, is an upper bound, as (a) the incoming workers plausibly come from higher-than-average-productivity places, (b) the productivity increase in the areas around Paris is lower than if the workers were relocated to central Paris, and (c) some workers may come from central Paris and this would entail a productivity decline. Furthermore, the increase is calculated on the assumption that incoming workers retain their initial characteristics. Following the British approach, the effect of increased agglomeration on the productivity of the existing Paris region workforce should also be included. This is a smaller effect but spread over a much larger number of people.

What this example illustrates is that it is possible to assign lower and upper bounds to productivity increases that are associated with any given relocation of workers. Land-use and transport interaction models are capable of producing systematic relocation scenarios for a given transport project, although household and – in particular – firm location choices are not very well understood. In sum, systematic estimates of upper and lower bounds of productivity effects are within reach, but with current knowledge it is not possible to assign evidence-based probabilities to the different scenarios.

Welfare, productivity and growth

Insight into a potential investment's likely net economic benefits within the welfare economics paradigm remains fundamental, and indeed can be seen as a practical attempt to use a broad measure of economic well-being (Stiglitz, Sen and Fitoussi, 2009). But policymakers and stakeholders often are at least as strongly interested in the distribution of positive and negative impacts, employment effects in the short and long run, and impacts on productivity and the economy measured by changes in Gross Value Added (GVA). This difference in what cost-benefit analysis provides and what decisionmakers are interested in is not new but is amplified in the post-crisis and low growth context of many OECD economies. If there is reluctance within the appraisal community to meet this demand, it is not the consequence of disagreement about the validity of the request (although there is insistence that "welfarist" evaluation is also important or more important) but more a lack of operational tools (let alone standardised tools) to do the analysis.

There is also the practical difficulty of explaining to decision-makers why the different metrics are capable of giving such different answers. The explanation can be summarised as follows:

- CBA and GVA do not measure the same thing.
- CBA is generally based on the assumption of full employment in the economy so that the marginal benefit of increased employment is either zero or the labour market tax wedge. GVA methods tend to include the gross value of additional output/employment, tacitly assuming that the social marginal cost of producing such output is zero.
- CBA is almost always intended to take a national perspective; indeed the difficulty of identifying regional distribution of benefits is an acknowledged weakness. By contrast, GVA methods are sometimes used at the regional level, in which case redistribution of employment from outside the region is counted as a net benefit with no consideration of lost employment elsewhere. This gap arises not from differences in methodological assumptions, but differences in the practical application of compatible methodologies.

- CBA relies primarily on values of time and other direct transport benefits as the main driver of the calculations, with agglomeration and labour market effects treated as additions. GVA methods rely on the relationship between infrastructure and employment density/capacity and then between density and productivity to generate the results. A lot of weight is placed on the validity of a few econometric relationships, issues which are discussed above.

DfT (2005) discusses the overlap and differences between GVA and welfare measures of the returns on transport projects. Welfare includes benefits from leisure and commuting time savings, costs or benefits from environmental impacts and safety; GVA excludes these effects. The elements included in welfare but not in GVA are not minor, amounting to 50% or more of total benefits (Laird and Mackie, 2010), and for this reason welfare is the preferred measure from a pure appraisal point of view.

GVA includes some labour market effects pertaining to increases in labour supply, the benefits of which are captured in time savings in the welfare approach. If a project has large employment effects, the difference in the way these benefits are accounted for can produce substantial differences in results. Cost-benefit analysis usually assumes full resource use, so that at the margin potential workers are indifferent between working and not working. If there is involuntary unemployment, there is a gap between the wage and the opportunity cost of time spent working but, as long as this opportunity cost is not zero, counting the full wage as a benefit would be an overestimate.

DfT (2005) argues that it is possible in principle to calculate GVA impacts but that it requires information, e.g. on the impact of the project on the location of employment, that is not produced in routine appraisal. For major projects, however, scenario analysis on the location and productivity of employment is part of the appraisal, so that inputs for a GVA evaluation along the lines proposed by DfT (2005; 50-54) are available. Laird and Mackie (2010) review value-added and output-based assessment methods and find they are "in their infancy and need work to ensure they pass internal consistency and robustness tests."

Transport and the macro economy

The methods discussed above are variants of the partial equilibrium approach. They vary in the account they take of the relationship between transport and land use and between transport and productivity and employment. But outside the analysis of interest, the rest of the economy is assumed to stay constant – *ceteris paribus* is assumed. There are at least two sets of reasons why for very large structuring projects this might be unsatisfactory.

First, for something as potentially transformative as *Le Grand Paris*, it is possible that the project would affect the competitive dynamics of the entire French economy, or at least significant sectors of it. That would certainly be a part of the political rationale. Thus, it would be desirable to model sectors such as higher education, financial services and other sectors expected to be changed by the project. This is very demanding but it seems a logical consequence of the aspirations for such projects that their structuring effects need to be represented in the economic modelling.

Secondly, it is essential that very major projects are assessed within a clear and coherent macroeconomic framework within which constraints such as capital and labour availability, exchange rates and other macro variables are explicitly represented. Modelling for the assessment should be capable of representing the interactions between transport and the rest of the economy and it should close the fiscal loop, not just assume the cost of capital is 3% (or whatever standard rate of return is used in microeconomic appraisal). Whereas the join between micro and macro can be disregarded for a by-pass project, it cannot be ignored for projects which take up a significant share of scarce public capital and/or are expected to be agents of economic change.

The desirable properties of the economic model are matters for debate but one potentially useful framework is the Spatial Computable General Equilibrium (SCGE) approach which has seen various applications to transport [Venables and Gasiorek (1999); Elhorst and Oosterhaven (2008); Brocker and Mercenier (2011)]. CGE models have been developed to analyse impacts such as changes to trade barriers which tend to be uniform between countries. Extending the analogy to transport implies linking sectoral production and consumption to a transport network and modelling changes, including feedback loops such as congestion effects, so as to predict impacts at regional or city level. There are some strong assumptions, such as all-round increasing returns and imperfect competition, that may not always be appropriate. Obtaining suitable data at both spatial and sectoral level is also a problem in many countries. Nevertheless, embedding appraisal of very major projects within an SCGE framework does seem, conceptually, a way forward.

4. Conclusions

Cost-benefit analysis of transport projects has seen many years of development as a transport sector specific tool of decision support, relying on the proposition that the transport benefits are a reasonable proxy for the total economic system benefits. For the generality of incremental projects, it remains the case that good quality modelling and appraisal of the direct impacts is sufficient for project assessment and ranking. However, for non-marginal and transformational projects, the linkages between transport, accessibility, land development and economic performance are too strong and central to the purpose of the project to be ignored.

The conclusion drawn at the Roundtable was that cost-benefit analysis remains a useful framework for assessment of such projects provided that additional analysis using robust methods is used for assessing effects on the wider economy and induced land-use change. It was also noted that it is important to assess the total impact of the project in cost-benefit analysis. For example, the direct impact of a high speed rail line might be modest – although much work remains to be done on the effects of intercity connectivity on economic performance – but the indirect effect through release of capacity on conventional lines to enable increased commuting could be substantial. For wider economic effects, the work of Graham, Lafourcade and others is extremely useful for determining agglomeration economies.

The contrast between the project of the SGP and Crossrail illustrates the relevance of land use change. The latter is a non-marginal project where supplementing assessment of the direct transport benefits with an assessment of the wider economic impacts seems appropriate and manageable. The SGP project is really a multi-sectoral land use development project intended to transform the regional economy of the Ile-de-France. As such it requires a high-level development plan which includes multi-sectoral appraisal, investment incentives for commercial development and housing, public investment in education and political/commercial partnerships for infrastructure funding and development at the growth poles. Transport analysis is essential but must sit within a broader appraisal framework.

In the case of such ambitious development plans, the structural effects on the regional economy are central. It must be accepted that these are less certain and estimates of them less precise than direct transport impacts, but that is not an argument for ignoring them. As with all policy analysis, the crux is to develop a credible reference case against which to assess the impact of the investment plan.

Credibility will be critical for very broad economic assessments, requiring tests of results for "common sense" so that thorough analysis can be distinguished from unsubstantiated claims. The more we can learn from *ex-post* studies of past projects, the better placed we will be to deliver credible assessments and provide the information that politicians and taxpayers require.

Notes

1. The "wedge" arises because, whilst workers make decisions to change employment on the basis of differences in net wages, the value of marginal output to society is the change in gross wages (Mackie, 2010).

2. Hauts-de-Seine, Seine-Saint-Denis and Val-de-Marne.

3. By one estimate, traffic on the busiest part of the RER A would increase by 18% without the project, and decline by 11% with the project (Viora, 2012).

4. In more technical terms, standard appraisal is well-suited for marginal improvements. But, as a transport project, the Greater Paris project is not a marginal improvement to the transport system, and the full project is not just a transport project.

5. The standard analogy here is that of (successful) metro projects, of which the *ex-post* benefits are thought to exceed the *ex-ante* estimates, although no systematic evidence on the issue is available.

6. Present value of benefits over fifty years from completion of the scheme.

7. Paragraphs in Section 2 on the Crossrail project are based on Worsley, 2011a.

8. Present value of benefits over a 60-year life including the construction period.

9. Imperfect competition means that output is restricted below efficient levels and that the benefit of the marginal unit of production is higher than its resource cost. If lower transport costs lead to more output, this gap needs to be accounted for in the valuation, which in the direct benefit logic of cost-benefit analysis means a mark-up to business time savings (UK guidance prescribes an uplift of 10%).

10. A higher number than the ones listed in Table 0.1.

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Chapter 1

The Evolution of London's Crossrail Scheme and the Development of the Department for Transport's Economic Appraisal Methods

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Abstract

Cost-benefit analysis has been used in the United Kingdom for the appraisal of road schemes over the past fifty years. It was less widely used for rail, where most investment was concerned with renewing the existing network. The Central London Rail Study (1988) used cost-benefit analysis to address the problem of overcrowding on London's rail network. The Crossrail scheme proposed in the Study was discontinued because of a recession and because of the priority given the developing links to London's Docklands. Progress on Crossrail was resumed in 2002 at the same time as the Department's appraisal methods were being revised to incorporate wider economic benefits. The quantification of these additional benefits, the resolution of a source of funding and the role of the Mayor all influenced the Government's decision that the scheme should be built. Identification of some of the wider benefits poses problems for transport models that are only partially resolved through the use of land-use transport interaction models. Although the use of a Gross Value Added metric provides an alternative way of estimating the economic impacts of a scheme, it does not replace cost-benefit analysis as a decision aid for government ministers.

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1. Introduction

The role of cost-benefit analysis in providing decision-makers with the information that helps them make good choices has always been unclear. In today's environment, with economic growth as a priority, many decision-makers seek evidence of how a scheme affects the real economy, a sentiment which is echoed by land-use planners and others who want to know how it will affect economic activity in their city or region. Research commissioned by the Department for Transport has provided evidence of the wider impacts of transport in terms mainly of agglomeration benefits and effects on the labour supply. These go some way towards bridging the divide between the welfare-based approach and a measure aligned to Gross Value Added, and hence GDP.

It is argued that the use of this additional evidence has been influential in the case of London's Crossrail scheme. It provided new evidence which demonstrated that the scheme would deliver high value for money and helped to make the case for the City's contribution to the scheme. The use of more traditional methods had failed to achieve this when the scheme was first appraised in the 1980s. Alternatives to the welfare-based approach, such as estimating a present value of the cost savings that are measured in terms of GDP or estimating the Gross Value Added by a scheme, have been developed as a means of providing decision-makers with information about the economic impacts of a scheme but both of these measures are of less general application. However, despite the theoretical advantages of the economic welfare method of estimating wider economic impacts, the limited evidence from studies set up to provide an *ex-post* evaluation of these impacts has been unable to identify their existence.

2. The Development of London's rail passenger network, 1835-1960

When the main-line railways which linked London with the rest of Great Britain were built in the middle of the eighteenth century, they did not penetrate or cross Central London. Each railway company built its terminus on the fringe of the city. High land prices and engineering constraints made cross-city links unaffordable. Parliament, whose agreement was needed for each project in order to facilitate the purchase of land, remained opposed to any proposal for a railway to enter the city centre. Passengers had to continue their journeys into the central area by foot or by horse-drawn buses. Journeys were slow and the streets congested.

As Central London's employment increased and became more specialised, developing an expertise in financial and business services, the urban area expanded, a process encouraged by increasing household incomes and a demand for more housing space. The population of London increased from 2 to 4 million between 1841 and 1871. By 1911, the population had reached 7 million, with most of the growth by then taking place in the outer urban area. The main-line railways provided commuter services to meet this demand. At the beginning of the twentieth century both electric tramways and the deep-level underground tube network were being built to provide a means of carrying commuters from the main-line stations to their central London workplaces as well as to provide commuter services in competition with, or in places not well served by, the main-line railway companies. The deep-level underground network was built with tunnels that were narrower than used by main-line trains. This lack of capacity and of interoperability with main-line train services has long imposed costs on London's rail users in terms of interchange and crowding.

The inter-war years showed little expansion of central London's transport network other than the growth of bus transport. Much of the limited investment in new capacity was aimed at serving new housing developments in the suburban area within a 10 to 30-kilometre radius. Most of the new capacity was built by the publicly-owned London Transport Board. The privately-owned, main-line railway companies were more reluctant to build new capacity, with most investment aimed at reducing operating costs and improving service quality through electrification.

In 1944, the UK Government published the Greater London Plan, commonly referred to as the Abercrombie Plan[1], named after the chairman of the committee responsible for drawing up the plan. While the timing of the preparation of such a plan might seem surprising given the wartime situation, it demonstrated the Government's appreciation of the potential for active intervention in planning land-use and transport. In contrast with the *laissez-faire* attitude of the pre-war period, a post-war government expected to continue to take the leading role in decisions about the use of resources to meet national objectives after the war was over.

The Abercrombie Plan proposed greater co-ordination of land use and transport planning across an area within 60 to 70 kilometres of London, shifting industry and population out of London, where high population densities and lack of open space were seen as unacceptable in a post-war economy. The Plan proposed a "Green Belt" around London, the development of satellite towns and expansion of existing towns in the south-east. The Plan proposed new rail links, which were developed further by the Railway (London Plan) Committee: its 1946 report included several new main-line railways across central London. The planning policies proposed by Abercrombie were generally adopted in the post-war years, with a shift in London's population and manufacturing jobs out of inner London to the growing towns on the outer fringe of the Green Belt. Of the railways proposed in the Abercrombie Plan, only Route C was eventually built and, although the route in the 1944 Plan from Walthamstow in north-east outer London to Victoria in the centre was followed, the scheme developed by London Transport in the 1960s was built as another deep-level underground line rather than as a main-line, high-capacity railway. The failure to fund and build the infrastructure that formed an essential part of the Greater London Plan provides a clear example of Britain's reluctance to engage in high-level national planning.

3. Transport appraisal methods in the UK, 1965-2000

The establishment of cost-benefit analysis in transport planning: The Victoria Line and English road schemes

The Victoria Line provided the first example of the use in Britain of cost-benefit analysis as a means of justifying investment in a public transport scheme which, by providing a more direct route across central London, was expected to reduce overall fare revenues in an era when fares were related to distance travelled. Foster and Beesley's[1] pioneering study showed a positive net present value for the scheme, with benefits restricted to travel time savings for public transport users and reductions in road congestion, on account of some transport users switching from the car.

The analysis was carried out some years after funding for the project was approved by the Government, and thus in this case did not influence the decision to go ahead with the scheme. However, by the late 1960s the approach was being used by the then Ministry of Transport. COBA, as the Ministry's cost-benefit analysis model was named, became established as a means of determining priorities from a long list of schemes for new motorways and road improvements at a time when road traffic was growing rapidly. But COBA's primary use was to help to demonstrate the benefits of the proposal, at the statutory inquiries held to persuade an increasingly sceptical public of the value of the scheme, and of the rationale for the route chosen.

Following a number of hostile public inquiries, the Government set up an Advisory Committee, made up of academics and other experts, to review the Transport Department's methods. The Committee's 1977 report[2] supported the use of cost-benefit analysis as a means of providing decision-makers with the information they needed. But while endorsing the overall method, they recommended that explicit account should be taken of the environmental and other unquantifiable impacts of road schemes. The Committee also advised the Department to adopt road traffic forecasting methods then being developed, which included fuel price and car cost terms, and to show the effects of uncertainty in the information provided to decision-makers.

During an era in which the majority of transport investment was in inter-urban road schemes, there was no incentive for the Department to make radical changes to the objectives of the appraisal process. Its aims were to help ministers in deciding on priorities and hence on the projects that were to be taken to a public inquiry. And it provided the inspector – who adjudicated over this public debate into the merits of the scheme, to be debated within the constraints of the Government's overall transport policy framework – with a process for informing this debate and reaching a decision. The economic welfare framework remained the paradigm and, mainly in response to SACTRA's recommendations, opportunities were taken to extend the impacts covered in response to developing concerns about transport and the environment. While these methods took no explicit account of the Government's economic development objectives, the schemes that ministers approved each year for construction usually included several with low benefit-cost ratios located in regions of high unemployment. Thus, the extent to which the transport infrastructure programme contributed to wider economic development objectives was determined by political judgement rather than by economic analysis.

Rail investment – minimising full life costs of operating the railway

Most of the investment in rail during this period of road building was focused on the replacement of existing assets at minimum cost. Even the initial Thameslink scheme (1987) - which, by re-opening a link previously used by freight trains, provided for the first time a main-line passenger service running north to south through the fringe of the City of London between King's Cross and London Bridge stations – delivered overall cost savings. The scheme made it possible to combine the operations of what had previously been two routes into a single service and to sell the land on which one of the maintenance depots had been located. No cost benefit economic appraisal was required for a project which reduced the overall costs of running the railway and no attempt was made to estimate the impact of the scheme on London's economy.

Investment in electrification of the commuter routes serving the catchment area to the north of London was also undertaken during the 1980s as a cost-saving measure, routes to the south having been electrified during the inter-war period. A consequence of this programme of electrification was to increase very significantly the level of medium- and longer-distance commuting from the north, where house prices were lower and where a large number of new homes were built, since planning consent to develop these sites was more easily obtained than in London's established commuter belt. The central London termini that serve these routes are all located two or three kilometres from the main employment areas and so these new commuters made use of the underground network in the Central Area to access their workplaces, leading to crowding on this network. Outside London, the major urban public transport investment was in six light-rail schemes in cities where there was an opportunity to replace heavy rail lines and provide better access to the city centre. Although significant for the cities which benefitted, the level of such investment in the UK has been much lower than in most other European countries.

4. Options for increasing London's rail capacity

A response to the increase in rail commuting and crowding - The Central London Rail Study 1988-89

The growth in longer-distance commuting and an overall increase in Central London's employment placed greater pressure on the rail network, in particular on the central area underground lines and on the interchanges at main-line termini. Unlike several other European capitals, London lacked an RER or *Stadtbahn* network of through-routes serving the city centre. In 1988, the Government set up the Central London Rail Study (CLRS)[3] to review options for relieving crowding. Working with London Transport, the organisation responsible for planning and operating London's public transport network, and British Rail's Network South-East, responsible for main-line operations, the Study reviewed a number of options.

The analysis carried out for the CLRS was made possible by the development of a detailed, network-based, four-stage transport model that covered the area of interest. The London Transportation Studies model (LTS), developed by the Greater London Council and the Department for Transport, is a model based on household survey data, detailed network information and transport user cost estimates, combined with origin-destination and route data from interviews of public transport passengers, supplemented and validated through passenger and road traffic counts. Because of weaknesses in the LTS's public transport assignment methods, an additional model, RAILPLAN, was developed to better model passenger choice between alternative rail routes – a key consideration for a study of the case for new rail schemes. Like most models of its time, the LTS made use of exogenous assumptions about the level of employment and its distribution across zones and therefore was not capable of showing the potential development benefits of the scheme. A gap was beginning to appear between the rigorous appraisal and modelling method and the policy-makers' aspirations for the scheme as a means of supporting the growth of economic activity in London.

The analysis set out in the Study's report assumed that a major upgrading programme, to make best use of the existing network, was undertaken. This was a reasonable assumption, as many of the projects were already planned and funded. The options then assessed were, very broadly, between new, deep-level underground lines and the Crossrail schemes, which allowed main-line trains to run underground through the centre of London. The Crossrail schemes included tunnels starting a short distance outside the central area and new stations both beneath the existing main-line termini and at other central-area locations. Schemes to serve East London's Docklands development area were not considered as part of CLRS; they were reviewed as part of the separate East London Rail Study (see below).

The use of cost-benefit analysis as a means of determining investment priorities was well established. The benefit-cost ratios of the schemes were reported in the Study and served as a basis for deciding on the options to be developed in more detail. The benefits were restricted to public transport passenger time savings, including savings in walking and waiting time which were significant in those locations where an interchange was replaced by a through service. Surveys had shown that passengers regarded walking and waiting as more onerous than travel time spent on a train and, on the basis of this evidence, the unit value of in-vehicle time savings was doubled to provide an estimate of the benefits of reductions in each minute of walking and waiting time afforded by new services running directly through Central London. Time spent travelling in crowded conditions was also weighted by an increase in the standard value of time savings. The use of the public transport route assignment model made it possible to estimate changes in crowding levels throughout the network and thus include the benefit to passengers on routes from which users of the new line had diverted. Evidence on the crowding penalty was derived from studies of passengers' willingness to wait for a less crowded, later train rather than board a crowded train.

Further benefits came from a reduction in road congestion as a result of those who switch modes, as estimated through the LTS model, which included a mode choice module. In addition, revenue generated by the additional use of public transport was recorded as a benefit – a measure of passengers' willingness to pay for the improved services. The geographical coverage of the LTS network made it possible to separate the additional revenue generated by Crossrail from transfers of revenue between the different rail operators included in the LTS model.

The Crossrail schemes generally showed higher benefit-to-cost ratios, the indicator used by the Department for prioritising projects, than the options for new deep-level tube lines. They had a higher passenger carrying capacity and reduced the number of interchanges, thus freeing up capacity at main-line termini. In addition, as with the Thameslink scheme, by replacing an operating system which required trains to be turned round at termini with through running, the Crossrail options could be operated at lower cost with less staff and rolling stock. The BCRs of the North-South and East-West Crossrail schemes were estimated at 1.9 and 1.6, respectively, using the 7% real discount rate current at the time.

In common with many transport studies in the UK, the CLRS did not provide the basis for a decision to proceed with the building of a new line. The Study proposed further analysis and refinement of the North-South and East-West Crossrail options. But the main constraint identified in the Study was that of funding. The Government had established a policy whereby the users of public transport schemes were required to pay for the benefits they received from the improvements. The Minister stated in his forward to the Study that there was no case for taxpayers elsewhere in the country to pay for projects that benefitted London's rail passengers. The Study proposed that contributions should also be provided by developers, who benefit through a process of voluntary contributions negotiated by the rail operators. If the increase in revenues from passengers and developer contributions failed to cover the costs of the scheme, the Government would consider making a contribution which did not exceed the value of the external benefits. The economic appraisal did not address options for funding the scheme.

The further work proposed on establishing a means through which transport users might pay for the benefits they would derive from Crossrail was never undertaken. The analysis had assumed that public transport fares would rise in line with the growth in GDP, but no comparison of the impact of an alternative fares assumption, which might serve to fund the scheme, was undertaken. As the further refinements to the route and layout of stations were being completed, Britain slid into economic recession. Central London employment declined and the upward trend in morning peak-period arrivals was reversed. While most of the investment that formed the major upgrading programme, aimed at making the best use of the existing network, was taken forward, the Treasury did not approve any further funding for the Crossrail scheme. A bill, to provide the railway operators with the powers to purchase the land required for the expansion of stations served by East-West Crossrail, was considered by Parliament in 1991. However, because opposition to the line as proposed and because a means of funding it could not be established, the bill did not become law; although the route was safeguarded to ensure that sites required for the scheme would not be redeveloped in a way which would prevent its construction at some future date. The scheme was effectively deferred and little further work was undertaken on developing the East-West Crossrail scheme during the 1990s. Attention shifted to London's Docklands, where a more urgent requirement for additional capacity had been identified.

Transport options for London's Docklands – The East London Rail Study

Plans for the redevelopment of London's Docklands had initially specified relatively low employment densities, locating industries such as printing, warehousing and some lower value-added office support functions in the development area. Access was provided by the Docklands Light Railway, opened in 1987, operating modern, single-vehicle tramcars on a track separated from the road network. Despite an extension to a station in the City at Bank, approved in 1987, and the purchase of two-car vehicles, its capacity was limited.

During the rapid growth in Central London employment during the 1980s, the developers of the Docklands perceived an opportunity to compete with the City of London as an alternative location for the headquarters of firms in financial and business services, a realistic option given the restrictions that the City's land-use planners had imposed on office development within the "Square Mile". While there might have been some aesthetic grounds for this restrictive land-use planning policy, its main consequence was to increase the value of office property in the City.

A number of proposals were made for new public transport links to Docklands to provide both the capacity and the quality of service to serve the density of land use now proposed. A catalyst was provided by the Canadian developers, Olympia & York, who offered the Government a substantial contribution towards a new underground rail link between Waterloo Station and the extensive office developments in their plans for Canary Wharf, some seven kilometres to the East. Their plans included an option for extending this new line to Greenwich in Southeast London. However, the Government, working with London Transport, decided that this opportunity should be used to link any line serving Canary Wharf with the rest of London's underground network and set up the East London Rail Study to review options for the route. The Study proposed extending the Jubilee Line, thereby linking Westminster, Waterloo, London Bridge, North Greenwich and Stratford with Canary Wharf. The scheme was initially estimated to cost £1 billion and the developers agreed to contribute £400 million in instalments, subject to a number of conditions including a specified date for the line's opening. Work on the scheme started following Parliament's approval of the bill giving London Transport the right to purchase the land needed to construct the scheme in 1992. Out-turn costs amounted to £3.5 billion. Because of delays to the scheme's opening and the financial difficulties encountered by Olympia & York and its successors during the recession of the early 1990s, the out-turn present value of developers' contributions was only 5% of the capital costs.

Forecasting passenger demand for the Jubilee Line Extension tested the capabilities of the LTS model, in particular because the Canary Wharf development, on which the scheme depended, was expected to increase the total number of jobs in the LTS study area, whereas the LTS model had only the capability to assess the effects of redistributing an exogenously determined number of jobs. In addition, the economic appraisal methods then current were restricted to travel time savings, weighted to reflect crowding, walking, waiting and interchange time. The BCR, estimated using the then standard techniques, was around 0.9:1, well below the level at which funding would normally be approved by the Treasury. However, approval was given both because of the substantial developer contributions then expected and because of the further regeneration benefits that were not captured in the measured estimate of the benefits of the project. Unlike the Crossrail scheme, the Jubilee Line Extension provided a scheme which met the Government's objective that the beneficiaries, in this case the developers of Canary Wharf, should contribute substantially to its funding. As delays to the scheme and the developer's financial problems reduced the size of the private sector contribution, the Transport Minister, Steve Norris, made it clear[4] that the unquantified regeneration benefits were a significant factor in the Government's continued support for the scheme.

5. Developments in appraisal methods – Widening the scope

Transport and the economy – issues and recommendations

The SACTRA Report 1999

After completing its 1977 Report, the Advisory Committee on Trunk Road Assessment was established as a Standing Advisory Committee (SACTRA) and was subsequently asked to report on several topics on which it had expertise, including methods of incorporating the environmental impacts of transport schemes into the appraisal process and into the implications for modelling and appraisal of traffic generation on roads[5]. This latter reference was made in the context of the Department's then current use of a fixed-trip matrix in modelling highway schemes.

In 1996, the Minister responsible for transport agreed with his Treasury colleagues to ask the Committee to provide advice on the relationship between transport and the economy. As the decision on continuing support for the Jubilee Line Extension to London's Docklands made clear, ministers were aware of the inability of the conventional appraisal methods to capture the regeneration benefits of major new schemes. SACTRA was asked to provide the Department with a better understanding of the increasing body of academic research and of recent developments of land use and other spatial economic models, which offered the prospect of practical application of the theory. The reference required SACTRA to review the Department's well-established cost-benefit appraisal methods and to make recommendations in the event of their needing to be changed to reflect the Committee's findings. In addition, given that road traffic was continuing to increase during the 1990s, the Committee was asked to review the link between economic growth and road traffic and to consider the economic effects of policies aimed at reducing the rate of traffic growth.

SACTRA concluded[6] that there was scope for updating and improving conventional appraisal and modelling methods and recommended that these should be the foundation of the economic appraisal of transport schemes. These conventional methods valued travel time savings, changes in operating costs and in transport operator revenues. SACTRA recommended that transport user benefits should be extended to include the effects of changes in reliability and hence should take account of the reduction in the variability of travel times that resulted from providing more capacity on transport networks. Environmental costs should be valued where good evidence existed. The methods used for forecasting and modelling of business travel and freight traffic should be improved. Where markets were competitive and prices for transport and for the goods and services that use the transport network were set at or close to their marginal costs, conventional cost-benefit analysis, as outlined above and based on the assumption of perfect competition, provided an adequate measure of the scheme's benefits.

SACTRA identified a number of circumstances in which market imperfections were likely to be sufficiently important as to invalidate the estimates from the conventional approach. Among these were imperfections in land and labour markets, as well as conditions in which the prices paid by transport users differed significantly from the marginal costs on account of subsidies or externalities. The Committee suggested that some of the consequences of relaxing the perfect competition assumption effects might be taken into account through developing LUTI or SCGE models. While some LUTI models had been developed for use in Britain, including the MEPLAN and DELTA models, their use had been very limited because of their complexity and because they did not link directly to the Department's appraisal methods. SCGE models were then at an experimental stage and there is still no experience of such a model having been used to inform the business case for a transport scheme. Indeed, SACTRA recognised that SCGE models were more suited to analysis of wide-reaching changes in transport provision or prices rather than enhancing the economic appraisal of even a major British transport scheme.

The Eddington Report 2006

The Government's quest for a better understanding of the long term links between transport and productivity did not end with the SACTRA Report. In 2005, ministers in the Treasury and Department for Transport commissioned Sir Rod Eddington to review transport's role in sustaining productivity and competitiveness. The Eddington Report[7] recommended that policy should focus on improvements to existing transport networks, prioritising schemes which served congested urban areas, inter-urban corridors and international gateways, since schemes on the most economically significant parts of the network were likely to deliver the greatest economic returns. The report supported the Department's appraisal methods, noting that they were being developed to include Wider Economic Benefits and to provide the more comprehensive indicator of value for money, as discussed below. Further endorsement of the Department's economic appraisal methods was provided by the extensive use of the estimated benefit-cost ratios of a large sample of schemes as evidence of the high returns to transport investment. The Report warned against "*grands projets*", on the grounds that they rarely delivered the high ratios of benefits to costs that were typical of many smaller schemes and there was little convincing evidence of the claims made on behalf of such projects for transformational benefits. Although no explicit reference to Crossrail was made, the report recognised the case for new urban rail links where these would deepen the labour market.

The Eddington recommendations did not require changes to the economic appraisal adopted or being developed at that time by the Department. Its main influence, apart from emphasizing the role of transport in delivering increases in productivity, was to rationalise the approach to the delivery of transport schemes. The report recommended the identification of strategic priorities followed by an assessment of the problems and the generation of a wide range of possible options using appropriate appraisal methods to determine priorities for the transport budget. It can be argued that, at least to some extent, these recommendations continue to be met through the adoption by the present Government of the Transport Business Case (see p. 44).

The Department's response to SACTRA[8]

Updating and improving existing techniques

The Department's response to SACTRA's recommendations outlined the work it was already undertaking on updating and improving many of the inputs into conventional cost-benefit analysis. A research programme was set up to review and update values of time savings and of reliability changes. New studies were set up, to estimate the key fuel cost elasticity values, which underpinned the estimate of road transport users' responses to changes in generalised cost. While some further research into LUTI models was undertaken, the Department decided against developing an SCGE or I/O model which included transport costs, given the high cost of collecting the data required, the limitations of the data currently available and the uncertain direct benefits. In reality, a decision to proceed with regional economic modelling would have been a cross-government initiative rather than one which might be taken forward by the Department for Transport alone.

The Economic Impact Report for regeneration of priority areas

A further part of the Department's response was the publication of guidance to scheme promoters on the appraisal of the economic regeneration impacts of a transport scheme, with the assessment of regeneration being restricted to areas already identified by the Government as characterised by high local levels of unemployment. Current appraisal guidance requires scheme promoters to provide estimates of the number of residents of a regeneration area that are employed on account of the transport scheme, and a further estimate of the total number of jobs created, whether filled by local residents or by those from outside the regeneration area. The guidance[9] on drawing up a Regeneration Report includes details of the evidence the Department requires in order to demonstrate that these new jobs were dependent on the transport intervention, were additional and would be taken up by those who would otherwise be unemployed. The information is derived from local data on unemployment, surveys of local firms and planning applications and an assessment of the contribution of the scheme to improved accessibility.

Wider economic benefits

Further work was undertaken by the Department in extending its web-based Transport Appraisal Guidance (WebTAG) to incorporate the wider economic benefits of transport schemes. The aim was to develop and enhance the conventional cost benefit approach rather than to switch to a more comprehensive approach, using SCGE or I/O modelling. After reviewing the recommendations of the

SACTRA report and recent academic studies, the main causes of market imperfections that were not part of the current WebTAG based appraisal guidance were identified. The Department published a Discussion Paper[10], "Transport, Wider Economic Benefits and Impacts on GDP", which set out methods that could be used by transport scheme promoters to estimate the Wider Economic Benefits (WEBs, later re-named Wider Impacts) of a transport scheme. The Paper also provided an assessment of some of the differences between the components of an economic appraisal based on cost-benefit analysis and social welfare and the elements of this economic appraisal that in one way or another form part of the process of drawing up the National Income Accounts to measure changes in GDP.

The Department's 2005 paper, identified four sources of market imperfection that had the potential to influence the level of welfare benefit estimated using the then current WebTAG guidance. These were:

- The potential for providing agglomeration externalities by changing the effective density of an urban area and influencing output through the relationship between effective density and productivity;
- The impact of transport projects on increasing competition in the transport using markets;
- Changes in the values put on transport cost savings because of the presence of imperfect competition in transport using industries;
- Effects on labour supply, through changes in the number of people employed in response to changes in the costs of joining the labour market and through existing workers shifting to more productive jobs.

The paper concluded that the transport network in the UK was sufficiently developed to ensure that there was already adequate competition between transport-using firms and, more importantly, that such market failures that existed would not be influenced by transport improvements. While prices for many consumer goods are likely to be higher in the more remote areas, this is generally a consequence of distance from the centres of production which any reasonable transport improvement is unable to offset. It is of note that the appraisal methods used in Scotland[11], where improving access to remote settlements is a policy priority, includes the option of valuing increased competition.

Quantification of wider economic benefits to support transport appraisal

The Department's 2005 Paper reviewed recent evidence on agglomeration benefits. It had for long been clear that, despite transport schemes in urban areas generally showing lower benefit to cost ratios than the majority of interurban schemes, decision-makers would approve funding for a number of these apparently less worthwhile projects. Costs were high because of the level of urban land prices and higher construction costs when making changes to busy networks in dense urban areas. Yet these higher costs were in part a result of the higher value that firms and businesses attach to a location in a dense urban area, effects that remained unquantified in the Department's appraisal guidance.

Research commissioned by the Department[12] defined a measure of effective density and quantified the relationship between effective density and productivity, a relationship that varied by sector and tended, as might be expected, to be greatest in the finance sector and in the sectors of communications, distribution and transport, all of which tend to locate in city centres. For each employment sector and zone, the measure of effective density depends on the proximity of all other jobs, with proximity measured in terms of the generalised costs derived from the transport model and the level of employment in each zone. The functional form of the relationship is:

$$d_i^{S,k,f} = \sum_{j,m} \frac{E_j^{S,f}}{\left(g_{i,j}^{S,m,f}\right)^{\propto^k}}$$

where:

$E_j^{S,f}$ is total employment for all *k* sectors in zone *j* in the scenario *S* in each forecast year *f*. If land use is held, fixed employment is the same in both the do-minimum and the with-scheme scenarios.

$g_{i,j}^{S,m,f}$ is the average generalised cost of travel from zone *i* to zone *j* in the scenario *S* by mode *m* in the forecast year *f*.

$\propto^k$ is the distance decay parameter, which varies by sector *k*.

The effective density of employment is thus a measure which combines all of the levels of employment and the proximity of jobs in a sector of employment in an urban area to all other jobs in the area. In providing a measure of the extent of agglomeration and of changes in this measure, it stands as a proxy for the value of a set of economic benefits that are external to the individual worker or firm and, hence, are additional to the benefits estimated through the reduction in travel time and other generalised cost savings estimated in the conventional methods. The problems encountered in making unbiased estimates of this elasticity of productivity with respect to effective density, and in estimating the parameter on the distance decay function, have been described elsewhere[13].

The 2005 Paper reviewed the evidence on the existence of imperfect competition in transport-using industries. This showed that, typically, market prices exceed production costs (after following WebTAG guidance on the adjustments to the estimate of the public-sector funding impacts required when expenditure is shifted from a commodity on which VAT or other taxes are paid to an untaxed good, such as public transport fares). The average level of the price/cost mark-up in the UK was around 10% and the 2005 Paper and subsequent draft guidance recommended that all estimates of business travellers' time and cost savings were multiplied by a factor of 1.1 to correct for this market imperfection.

The fourth source of market imperfections, which would result in the underestimation of the welfare effects of urban transport schemes, is that associated with labour supply. The generalised cost of travel to work was assumed to influence the number of people working in much the same way as does the post-tax wage rate. The Department analysed the research on labour supply elasticities with respect to the post-tax wage rate and recommended a value of 0.1. Estimates derived from the transport model of the costs of commuting and the change in these costs attributed to the transport scheme are added to estimates of the average post-tax earnings for new entrants to the labour force. This provides an estimate of the change in the returns from working on account of the scheme, and the elasticity provides the estimate of the extent of the response to this change. A worker's decision to participate in the labour force is determined by the level of post-tax earnings, travel costs and a range of other considerations about the disutility of working that remain unaffected by the transport scheme. However, the productivity of the worker who joins the labour market as a consequence of the new project is measured by pre-tax earnings. The additional tax revenues resulting from higher levels of participation in the labour force count in the WebTAG guidance as an additional welfare benefit, as this effectively allows for a reduction in the taxes paid by all other citizens.

Similar considerations apply to estimating the second labour market impact identified in the guidance, associated with people already in the labour force moving to more productive jobs. Reductions in the cost of working in more urbanised and more productive locations encourage existing workers in less productive locations to transfer to more productive jobs; and access to a larger labour market encourages firms to relocate, contributing to and deriving agglomeration benefits. Although associated with the agglomeration benefits described above, the latter are estimated for existing workers in the urban area that gains benefits from an increase in effective density. The welfare benefits are again restricted to the increase in taxes paid, since it is assumed that, prior to the reduction in transport costs, workers were unwilling to take on the more demanding but more productive roles.

Promoters of major schemes could choose to follow the advice in the 2005 Paper if they perceived that it would help decision-makers understand better the potential magnitude of a source of benefit that had been acknowledged as a point in favour of the scheme but never previously quantified. In 2009, an updated version of the guidance, omitting the discussion of the GDP impacts, was published as a draft section of WebTAG, which included the data sources needed to provide the estimates of each of these Wider Impacts. Even today, six years after the advice was first issued, it has not been made a mandatory part of the Department's requirements for the transport business case. In part, the delay has been due to the new administration's decision to review the previous government's transport decision-making methods and re-cast the economic appraisal process as part of a more comprehensive transport business case.

Present practice in England is to estimate the labour market participation effects, with benefits measured through the additional tax take, and the additional welfare benefits on account of imperfect competition in transport, using product markets for all transport schemes costing more than £20 million. The agglomeration effects are estimated for most of the larger schemes in those locations defined as Functional Urban Areas. The Department has provided a package based on the standard transport user benefit appraisal package (TUBA) to enable these benefits to be estimated directly from the transport model. While this practice is not mandatory, it is generally followed to support the case for the project. The effect of the move to more productive jobs through the redistribution of activity between zones is estimated only for those areas where a suitable LUTI model is available and contribution of this impact is treated as a sensitivity test of the scheme's wider benefits rather than as part of the central estimate. In practice, such models are rarely available and the cost of setting up and implementing a LUTI model generally exceeds the benefits it might provide in terms of additional information.

Wider economic benefits and transport modelling

The full implementation of the Department's draft guidance requires a multi-modal transport model in order to estimate the change in effective density and to estimate the change in overall commuting costs to estimate the labour supply effects. The WebTAG guidance sets out criteria which transport models should meet if outputs from the models are to be used for appraisal purposes. Most, if not all, of those conurbations that are actively promoting major transport schemes all have access to a model which meets the Department's criteria. However, these models, which have been designed for the practical purpose of testing a wide range of transport options, narrowing them down and refining the more promising options, leading to the specification of a preferred choice, focus on travel changes rather than on land use. Labour supply is usually assumed to be fixed and the boundaries of the models are set to coincide with the administrative area of the conurbation. So while the draft appraisal guidance allows for the benefits of increases in the labour supply, these increases in commuting trips are, in most cases, external to the outputs of the transport model. In some cases, the solution to this inconsistency is to allow for the increase in commuting trips to come from zones outside the study area. Around a third of the journeys to work in Central London by rail start outside the London region and these trips are treated as external to the model, with the forecasts derived from an elasticity-based demand model. In other cases, however, the transport model is formulated to constrain both commuting trip generation and attractions, again leading to an inconsistency between the economic theory of labour supply and its treatment in the appraisal of wider benefits.

The benefit of a shift to more productive jobs is restricted to those who change the location of their workplace and therefore is additional to the agglomeration effect. The Department's guidance advises that a LUTI transport/land-use model is used to estimate how firms and workers will change their locations in response to changes in transport costs. An alternative approach has been to base assumptions about land-use changes and employment on planning development proposals that depend on the project and will gain consent only if the project is approved. There are several examples, including that of Crossrail, of this source of benefit having been estimated and added to the benefits attributed to the scheme, However, the practice of attributing all of these benefits of higher output to the transport scheme is questionable, since they also occur on account of land-use changes, which themselves might have external costs or benefits that should form part of an appraisal which considers both the transport and the land-use effects.

Many rail projects are appraised using single-mode models, because there is often insufficient data to cover the use of all modes for all journey purposes across the extensive transport networks, which are potentially affected by a rail scheme in a typical multi-modal model. It has not been possible to combine several multi-modal models covering the relevant areas, as the specification and design of such models which cover dense urban areas tend to differ from those which cover areas where car trips dominate. The Thameslink Project, which improves rail services over a wide corridor - extending around 250 km from the South Coast of England, through London, to the northern extremities of the London rail commuting market -- stretches across an area covered by several different models. Where a suitable multi-modal model is not available, estimation of the wider benefits of rail projects has required the use of sources of data external to the model.

The redistribution of commuting trips has a further impact on the benefits of a scheme since the shift of trip attractions to urban centres is likely to result in commuters changing their mode of travel as well as their destination, shifting from a shorter-distance car trip to a longer-distance trip by rail. The benefits of the resulting reduction in road congestion contribute to the overall case for the project and, as an externality, provide some grounds for subsidising rail commuting. Estimating the impact of this redistribution of trips and the resulting change in road traffic flows provides a challenge to transport modellers. Approximations have to be made where some of the changes occur outside the geographical area covered by the transport model.

Consistency between the transport model and the economic appraisal has long been a key requirement for a well-executed cost-benefit analysis. The economic appraisal is based on the equilibrium changes in transport user costs that are an output of the model. The models used in Britain for transport schemes do not allow for participation in the labour force to be influenced by changes in the costs of working. Most of the models assume that the level of employment in the zones affected by the scheme remains unchanged by the scheme. LUTI models can help to show the possible effects of relaxing this assumption, although they are not generally used because they are costly to implement and maintain. Even where they are used, the interpretation of the estimate of benefits remains unclear. The change in demand for travel on account of the land-use change is the joint product of the transport scheme and the land-use change and cannot necessarily be attributed in full to the transport scheme. It would seem that, at least in the case of modelling and appraisal as practiced in Britain, there are inconsistencies between the estimation of the wider economic impacts and the representation in a transport model of these effects.

The role of the BCR in decision-making - DfT's Value for Money Guidance and the Transport Business Case

The Department's WebTAG-based transport appraisal guidance identifies several classes of impact, classified in the current guidance as effects on the economy, on the environment, on society and on the public accounts. The guidance reflects the Government's policy objectives and the recommendations made in past SACTRA reports. Most of these impacts were measured and valued in money terms as part of the estimate of the change in economic welfare, including the main transport user benefits and, through the use of estimates of the value of a statistical life, most safety impacts. The BCR of a scheme was derived from the costs and benefits that were valued and defined in money terms. It had long been acknowledged that the BCR was only a very partial measure of the social benefits that a scheme might deliver because the BCR omitted many important effects, including most environmental impacts. WebTAG sets out the requirements on a scheme promoter for estimating such impacts and describing them as part of the table which summarised for decision-makers the case for approving the scheme. For example, the impact of a scheme on bio-diversity is described in terms of any impact on a site of special scientific interest, the extent of any impact in relation to the size and importance of the site and the proposed mitigation of the impact. The aim of providing this information is to enable decision-makers to weigh up both money values and unquantified impacts.

In order to provide decision-makers with a more formal approach to making these trade-offs and to inform stakeholders outside the Department about the decision-making process, the Department published new guidance in 2004 on value for money, since updated[14]. The guidance defines a concept of value for money which covers both the conventional estimate of benefits and the environmental and other effects that fall outside the BCR. In addition, it defines categories of value for money. The paper explains that, as a consequence of both the constraints on public expenditure and the absence of any factor in the Treasury's Green Book on appraisal which takes account of the cost of raising public funds, not all projects whose benefits exceed their costs would be approved. Schemes are classified in terms of their value for money in a two-stage process. The first stage is based on the BCR, with a second stage which reviews the additional costs and benefits that are not expressed in monetary terms and hence are omitted from the BCR. Schemes with BCRs of below 1.0 are defined as "poor" value for money and no such schemes would be approved. Schemes between 1.0 and 1.5 are classified as generally "low" value for money and few if any schemes which delivered only low value for money would be approved. Projects with BCRs of between 1.5 and 2.0 are defined as delivering medium value for money and some of these schemes would be approved, whereas schemes with a BCR in excess of 2.0:1 would generally be approved and funded. While this provisional, initial classification of the value for money is based on the conventional measure of the BCR, analysts and decision-makers then review the extent to which costs and benefits that are not valued in the BCR might change the provisional categorisation of the project and shift it into a lower or higher category, defined in terms of its value for money. This guidance on value for money has since been revised and, in recognition of spending constraints, a new category of "very high vfm" has been added for projects with BCRs in excess of 4.0:1. But the overall concept of classifying a scheme according to its BCR, reviewing the unquantified or other effects omitted from the conventional BCR and deriving from this an estimate of its value for money, remains unchanged.

More recently, the Department has published a note[15] which puts the economic case for a scheme into the context of the Transport Business Case. Decision-makers take into account information on five separate considerations:

The Strategic Case, which determines the need for the investment and the case for change in relation to the Government's policy objectives and the strategic fit of the scheme with the Government's policy objectives;

- The Economic Case, as established through the application of cost-benefit analysis in line with WebTAG;
- The Financial Case, which concentrates on its affordability, the arrangements for funding and accounting considerations;
- The Management Case, which examines the planning, delivery and governance of the scheme, and the allocation and management of risk;
- The Commercial Case, which focuses on the procurement strategy and the commercial viability of the scheme, including the allocation of financial risk under the proposed means of procurement and the engagement of the financial market where private sector funding is an option.

The note was published in April 2011. It is still too early to judge whether it will succeed in overcoming some of the short-comings of concentrating on the economic appraisal without always ensuring that arrangements were being made at the same time to manage and procure the scheme in the most effective way, to provide for its funding and to allocate risks effectively. But the history of Crossrail and of the Jubilee Line Extension provides clear evidence of the need to ensure that a sound economic appraisal is accompanied by a thorough assessment of those other elements of the business case that need to be in place order to ensure that the project is built.

6. Wider economic benefits and Crossrail

Crossrail: the revised business case

The decline in rail commuting to Central London, which provided a reason for halting the Crossrail programme in 1990, was reversed in 1995 (see Annex) and its continuing growth and the resulting increases in crowding led to a review of the Crossrail project in 2002. The Government agreed to setting up Cross-London Rail Links (CLRL), a joint venture between the Strategic Rail Authority - the government-sponsored independent body responsible at that time for rail strategy and planning - and Transport for London. CLRL proposed an East-West scheme along the same route through Central London as in the CLRS proposal, with services extending to Heathrow Airport and Kingston in the West and Shenfield and Ebbsfleet in the East. The modelling, forecasting and appraisal methods adopted in the 1989 CLRS were updated to incorporate network changes, current forecasts of the main exogenous inputs to the LTS model and revisions made by the Department to its appraisal methods to reflect the Government's appraisal policy priorities. Demand assumptions included the plans the Government had announced for the expansion of capacity at Heathrow. CLRL's 2003 business case[16] was restricted to an estimate of the transport user benefits using the conventional approach and the project's BCR was estimated at 1.99:1. The appraisal included an estimate of the number of jobs likely to be created by the scheme, on the assumption that, without Crossrail, the forecast levels of crowding would constrain Central London employment and that the Greater London Development Plan assumptions could therefore only be realised if Crossrail was built. Estimates were also made of the scheme's impact on the number of jobs created in the regeneration area served by the Ebbsfleet branch, following WebTAG guidance. No economic value was put on these employment-related benefits.

Crossrail: the Montague Report

The Government referred CLRL's Crossrail proposal to an independent expert review group, chaired by Sir Adrian Montague, who had held senior posts in the City and been Chief Executive of the Treasury's Private Finance Initiative Taskforce. The reference can be explained by the Government's reluctance to approve the scheme without taking into account the lessons that might be learnt from the then very recent example of the Jubilee Line Extension, which opened 20 months later than scheduled and for which costs overran by 63% on the budget agreed when work started on the line. This budget was 79% higher than the original estimate made in 1989 on which the economic appraisal was based.

The report[17] made a number of recommendations. It suggested that the procurement and financing strategies should be developed and options for raising alternative sources of funding should be drawn up and consulted on. It suggested that the structure of CLRL, made up of the Strategic Rail Authority and Transport for London, was not a body which would be incentivised to develop and deliver Crossrail in the most efficient way and the governance of the project needed to be changed to set it on a more commercial footing. It made a number of more technical recommendations because the experts on the Review believed that the proposal to operate 24 trains per hour in each direction through the tunnel under Central London would not be feasible. Outside the tunnelled section, Crossrail trains would share tracks and stations with other suburban and main-line services and any disruption to these services would impact upon the reliability of Crossrail trains and hence the capacity of the Central London section.

The Crossrail Bill was introduced into Parliament in 2005 in order to provide Crossrail Limited, the successor to CLRL, with the authority to purchase the land needed on a permanent or a temporary basis to construct the scheme and to take into account the representations made by other parties with an interest in the scheme. The bill was enacted in July 2008 and received royal assent to become the Crossrail Act, a key milepost in the delivery of the scheme. Initial enabling works started later in 2008, with construction works at Canary Wharf in Docklands in 2009.

An important consequence of the Montague Review was the successful introduction in 2007 of a bill into Parliament that would provide London's Mayor with the powers to levy a supplementary business rate on firms in London to fund Crossrail and other projects. The Business Rate Supplement was first levied in 2010 as a two-pence in the pound levy on all larger London businesses. Of Crossrail's total costs of £14.7 billion, £4.7 billion is to be funded through the BRS, with Transport for London providing £7.1 billion, the Government a direct grant of £4.7 billion, Network Rail £2.3 billion and the rest coming from developers gaining specific benefit from the scheme. This funding for Crossrail was confirmed in the Government's 2010 Spending Review. The gap between the case for Crossrail in the appraisal and the requirement funding was finally closed.

The wider economic impacts of Crossrail

The Montague Review carried out an assessment of the economic case for the project and concluded that the estimated BCR of 1.99:1 was generally sound. The Review concluded that the analysis had followed the Department's guidance. The Review also considered the assessment of the wider benefits that Crossrail was anticipated to provide. The 2003 Business Case reported on the jobs created in Central London as a consequence of removing a constraint on commuting and provided an estimate that these jobs might add between £8-9 billion in present value terms to UK GDP. A provisional estimate of the economic welfare benefits of these additional jobs and of their impact on agglomeration suggested that this effect might add £4.5 billion or around 20% to the benefits of the scheme. In addition, following the WebTAG guidance on the assessment of regeneration, the scheme had the potential to create between 56 000 and 100 000 additional jobs in the Thames Gateway and other regeneration areas with high local unemployment, and where Crossrail would improve accessibility and employment prospects and encourage firms to locate there.

The Review concluded that Crossrail could be expected to contribute to the regeneration of Thames Gateway and help deliver the Greater London Development Plan's objectives. It would also help to maintain London's reputation as the leading location for financial and business services. However, the Review team did not provide a detailed assessment of the methods used by CLRL to estimate the magnitude of the agglomeration benefits and expressed some doubts about the feasibility of deriving a reliable estimate of such impacts.

Crossrail published a revised business case in 2005[18] to incorporate changes in the specification, including the proposals to terminate the Southeastern extension at Abbey Wood in place of Ebbsfleet, some 15 kilometres further to the East and to simplify the operation of Crossrail services to the West of London by terminating at Maidenhead. Estimates of the conventional benefit-cost ratio were updated to take account of new exogenous forecasts and changes made to ensure consistency with the Department's current appraisal guidance. On these new assumptions, Crossrail's BCR was 1.80:1, with the transport user benefits valued at a NPV of £16 billion.

The 2005 Crossrail Economic Appraisal was prepared at the same time as the Department was drawing up the 2005 Discussion Paper on Wider Economic Benefits and the appraisal provided the first opportunity to make practical use of the draft guidance. Indeed, the 2005 Economic Appraisal at times anticipated the guidance and consultants working for TfL provided their own estimates of some of the parameter values that were used in estimating the size of these sources of benefits. The outputs from the transport model used by TfL provided the estimates of the changes in generalised cost between zones and by mode required to estimate the effect of the scheme on effective density and on participation in the labour force. The published Economic Appraisal was consistent with the values in the 2005 paper and included sensitivities using values derived from research conducted for TfL. The benefits of agglomeration using the Department's estimate of the change in productivity with respect to effective density of 0.059 were estimated at £3.1 billion, an addition of 20% to the benefits of the scheme. Using an elasticity of 0.075, as estimated by TfL's consultants, the value increases to £4.5 billion. The increase in labour force participation was estimated using the labour supply elasticity value, wage levels and tax rates set out in the 2005 Paper and estimates of changes in commuting costs derived from the model. A further addition to the benefits from the conventional estimate was the effects of imperfect competition, restricted to changes in travel time for those travelling on business. These two additions made up a further £0.8 billion of benefits.

No suitable LUTI model was available that could be used to estimate the land-use changes that might follow from the responses of firms and workers to the reduction in the costs of access to central London and hence the economic benefits of the move of workers to more productive Central London jobs. TfL adopted an alternative approach by assessing the extent to which the lack of capacity constrained the growth of employment in Central London and hence how the increase in capacity provided by Crossrail would lift the constraint on the expansion of Central London employment. A forecast of Central London employment to 2026, based broadly on past trends, was established and this forecast was assumed to be unconstrained by the transport network's capacity.

Having established an unconstrained forecast of employment, the nest stage of the analysis was to estimate the extent to which prospective commuters would be crowded off the network. Analysis of cordon crossings and of select links on the underground and rail networks showed a clear relationship over time between growth in demand and the level of crowding, with evidence of growth being constrained by crowding. From this it was possible to estimate a constrained growth scenario, and a less constrained alternative with the Crossrail scheme in place. Since the increase in the labour supply had already been estimated using the elasticity-based approach, all of the increase in Central London's employment, attributed to the relaxing of the capacity constraint, was attributed to people moving from other locations to more productive Central London jobs. The 2005 Economic Appraisal estimated benefits of £3.2 billion, accounted for by the shift to more productive jobs, due to the capacity provided by Crossrail using the Department's estimate of a 30% premium on output per job in Central London. TfL's analysis suggested a higher premium, which has been used in subsequent analysis to generate a range of benefits.

The inclusion of these wider impacts increased the overall BCR in the Crossrail 2005 business case from 1.80 to 2.60, with a range of 2.3-3.2 based on different assumptions about the elasticity and other values used in the estimates of these wider benefits. Evidence of the value of Crossrail's wider benefits had the consequence of shifting the project from those defined as delivering medium value for money into the high value-for-money category.

The work undertaken by Crossrail and the project's consultants provided a valuable and practical test of the Department's paper on Wider Economic Impacts. It helped to codify the assumptions that the Department later published in the 2009 WebTAG unit on the Wider Impacts sub-objective to ensure that the methods could be applied and that schemes would be appraised on a consistent basis. It demonstrated the extent of the wider benefits, showing by how much they increased the conventional estimate. But the analysis was more than an exercise aimed at putting into operation a new and untested part of the appraisal guidance. It seems unlikely that a decision to proceed with the next phase a major project such as Crossrail would be made entirely on the basis of a still somewhat untested development of the Department's appraisal methodology. But this evidence of the extent of the wider economic impacts and of the value for money that the scheme would deliver, coming at a crucial stage in the scheme's evolution, was clearly a factor in the decision to go forward with the Crossrail Bill and with legislation to raise a business rate supplement as one source of funding for the project.

The Department's methods and recommended values were subject to critical review, in some instances by those with an interest in strengthening the case for Crossrail and other London schemes. A 2007 paper prepared by consultants on "the Economic Benefits of Crossrail[19]" described the estimate of the wider impacts made in the 2005 business case as "highly conservative". This report challenged the assumption in the Crossrail business case that growth in demand was capped in 2005 at 2026 levels, in line with WebTAG guidance for rail projects. The analysis in this consultants' report, which did not form part of the business case, quantified the effect of an alternative higher estimate of output per head in Central London, which better reflected the specialist nature of the City's financial sector and its role as a location for company headquarters. In addition, the consultants estimated the effects of assuming continuing growth in employment post-2026 on the benefits associated with the move to more productive Central London jobs. Forecasts for Central London employment in the longer term were based on the current employment densities in certain zones in New York, Paris and Tokyo, each of which is well in excess of current London levels in broadly comparable areas. The higher densities observed in these competitor cities were assumed to be achieved by 2070 in the City, Westminster and Docklands, respectively. The effect of these changes to the assumptions used in the 2005 business case would double the economic benefits of the scheme.

Further updates to the Crossrail economic appraisal were carried out in 2010 and 2011 to reflect changes in scope and design and in the scheduling of works as well as changes to the exogenous inputs to the appraisal and modelling, in particular the reduction in the rate of economic growth forecast for the UK. The 2010 economic appraisal was updated to inform decisions on the future of the scheme in the context of the cuts in public expenditure which were made in the Government's October Spending Review. For this reason, costs already incurred were omitted. The benefit-cost ratio from continuing with the scheme, including wider benefits, ranged between 4.07 and 7.74, with the upper end of the range taking TfL's estimate of the premium on Central London output in the estimate of the benefits of the move to more productive jobs. A second difference between TfL and the Department is in the values put on time savings. But these differences apart, the Crossrail 2011 business case follows the Department's appraisal guidance and this has helped decisionmakers to determine priorities between Crossrail and other projects and reach an understanding about the implications of a decision to proceed with the scheme or to stop it.

Crossrail – London as a world city

The Crossrail scheme is a joint venture between Transport for London and the Department for Transport. It acquired this special status because the main-line suburban railways to be linked by the tunnel through Central London are operated by private-sector train operating companies (TOCs) under franchises let by the Department. The Department specifies the levels of service to be operated and invites TOCs to bid for a franchise, usually of seven years but in some cases for longer. TOCs retain all revenues and so bids are generally for subsidy since most franchises in the London commuting area operate at a loss. The infrastructure outside the tunnel is owned, maintained and managed by Network Rail, the private sector, not-for-profit company that owns all main-line rail infrastructure. London's underground network is owned and operated directly by Transport for London. Transport for London's interest in Crossrail is explained by TfL's exclusive responsibility for public transport within the very congested central area. In addition, Crossrail relieves congestion on several busy TfL underground lines to the East and West of Central London, thus requiring TfL's participation in the planning of Crossrail. TfL is therefore an essential partner in the planning and development of Crossrail.

There is also a strong political dimension behind TfL's participation. There is competition between different regions and conurbations for the limited transport budget. The Greater London Authority (GLA), the administrative body that has responsibility for planning and transport policy in London, with the operation and management of the transport network undertaken by TfL, has, since its establishment in 2000, made a strong case to ministers in central government for their support of Crossrail. The GLA recognises the value of good research as a means of improving the evidence base of the analysis used in the decision-making process, and has been active in commissioning studies to investigate the economic benefits to London's economy of Crossrail and other transport schemes. London is not alone in this initiative; other conurbations have also taken new approaches to demonstrating the value of transport to their economies. Indeed, it might be argued that the setting up of the GLA in 2000 provided one of the catalysts for the continued development of the scheme. The role of a strong and influential champion for Crossrail cannot be underestimated. The proposals put forward in the 1989 Central London Rail Study lacked an organisation which could act as leader for the scheme and as its promoter. The interface between London's transport network and the main-line railway ensured that neither of the rail operators took on the role at that time, each preferring to see money spent on their own network rather than on one that cut across the two.

The interface between the Department and TfL provided by the Crossrail business case has identified a difference in policy objectives of some analytical interest. Transport projects funded through the grant given by the Department to TfL are appraised by TfL, and the Department has no role in determining priorities on the TfL network. The size of the grant is determined by a number of factors, including operating and maintenance costs and expected revenues on TfL's network. The economic returns to new projects form only a small part of the overall decision. Although TfL generally follows WebTAG appraisal guidance, it uses a value of non-working time savings that is 29.3% higher than the national average value and a value of business time savings 58.0% higher. The Department has for long used a national average value for time savings as a very approximate means of ensuring an element of fairness or equity in the distribution of the national transport budget across the more and less prosperous regions of the country. And there are very real political considerations in the case of a decision to treat one voter's non-working time savings as more valuable than another's. The premium on the national average value adopted by TfL simply reflects the higher average earnings of London residents when compared with the national average. The 2003[20] value-of-time study found a time series income elasticity of 0.8, which is used in WebTAG guidance for forecasting the growth in transport user benefits. The evidence on cross-sectional values is less conclusive.

Moreover, any London-specific value should reflect the characteristics of London Transport users and the extent to which, for example, higher housing costs might limit their willingness to pay a premium on the national average value in line with their higher earnings.

A consequence of this difference in the value put on the time savings and associated benefits of Crossrail is that the 2010 and 2011 Crossrail Business Case Updates provide two separate estimates of scheme benefits, with the lower one based on WebTAG national average values and the other using the London-based value. Although the results are presented with a brief explanation of the reasons for the difference, it is clearly unsatisfactory that a scheme of national importance is presented as having two different central estimates of the size of its benefits.

7. Alternative metrics to the welfare approach

The GDP effect of a project

Despite the theoretical advantages of cost-benefit analysis, many policy-makers remain sceptical of its merits. The outcomes of a scheme appraised using cost-benefit analysis cannot easily be audited to demonstrate whether or not it has delivered all of the expected benefits. Indeed, as discussed below, analysts have found it very difficult to demonstrate, through *ex-post* evaluation of a selection of projects, whether the project has delivered any of the benefits claimed of it. Some policy-makers, often those with a private-sector business background, take issue with the concept that their objective should be to implement projects and policies aimed at maximising net economic welfare subject to a budget constraint. The priority given by governments to raising the rate of economic growth is second only to policies for cutting the budget deficit. Transport ministers want to know how a project will contribute to economic growth, which they see as a relevant indicator of its likely success of being funded by a hard-pressed Treasury. In current circumstances, a GDP-based measure is likely to be more persuasive than a measure of welfare benefits, described by a transport minister of many years ago as "fairy gold".

The literature on transport and GDP is extensive and the purpose of this paper is to go no further than to outline its relevance to decisions on Crossrail and other British transport projects. In its response to SACTRA, the Department decided against developing economic models, including input/output and SCGE models, that could, at least in theory, be used to demonstrate the impact of changes in transport costs on GDP and the implications of raising the revenues required to fund these interventions. There were no existing models covering Great Britain that might be updated or adapted for the specific purpose. It would not be possible to construct any such models without extensive new data and this would require winning over other government ministers who had no immediate need of such a model. Although the EU IASON Project had shown the Department's analysts how a SCGE model might be applied at a strategic EU level, a review of SCGE models commissioned by the Department[21] confirmed the view that development of such a model to meet the Department's requirements would not be a feasible option.

One objective of the 2005 Discussion Paper "Transport, Wider Economic Benefits and GDP[22]" was to inform the debate about cost-benefit analysis and GDP. The Government's Transport Innovation Fund, which provided finance for transport schemes and other projects for which local authorities made bids, was set up while the paper was being drafted. Scheme promoters were required to demonstrate how their proposals might promote growth in the local economy and the paper provided advice on how this might be done.

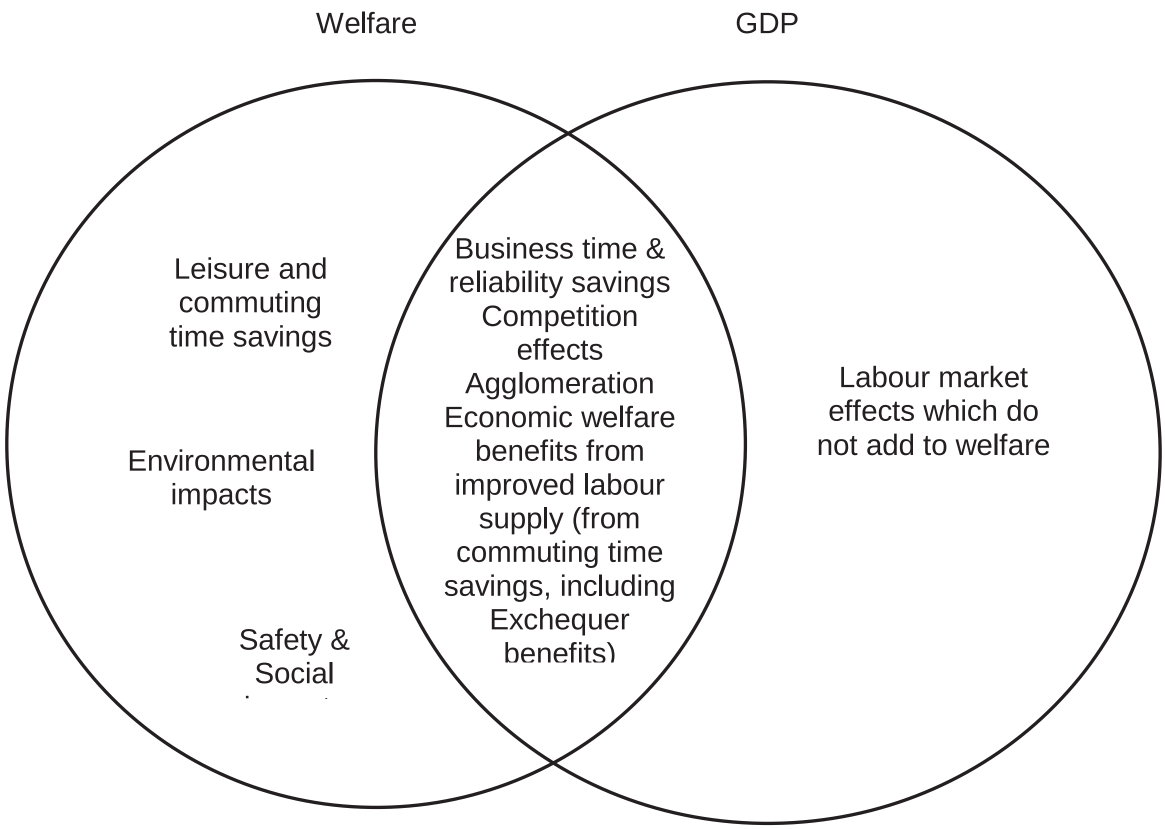
The Venn Diagram, used in the 2005 Paper to distinguish between welfare and GDP-related benefits, is reproduced below. All agglomeration and competition effects, all business time and cost savings and the welfare-related benefits of improved labour supply count in both the economic welfare calculus and contribute through the increase in economic efficiency to GDP. The paper identified labour supply effects that added to GDP but were not part of the increase in economic welfare. All of the additional wages, generated by the transport-induced increase in labour supply, count as a GDP effect. However, the welfare-based measure, assuming a perfect labour market, makes the assumption that those who join the labour market or shift to more productive jobs were always in a position to take these jobs but chose not to do so because of the disutility of work. They were induced to do so because of the reduction in the generalised cost of travel to work, given the rewards from work in terms of the post-tax income. In addition to this source of benefit, estimated conventionally through the rule of a half, there is the additional welfare benefit (which also counts in the GDP effect) of the additional tax on the earnings of these workers.

Additional tax revenue can be regarded as a welfare gain because it allows for the enjoyment of a greater quantity of public goods or a reduction in the overall burden of tax. The tax in this case is additional, generated by the increase in employment and productivity, and is not a transfer.

The 2005 Discussion Paper accepts that the commonly used means of estimating the rate of growth of GDP in successive years, the output gap and changes in the trend rate, are all measured in terms of percentage changes, an approach which is inconsistent with the net present value-based measure provided from the transport-related estimate of GDP effects. A footnote to the paper suggests that "*…it is rare but legitimate to describe these (GDP) effects – which are essentially changes to trend GDP – in NPV terms*." Commentators might indeed concur with the Department on the rarity of such descriptions of GDP. Moreover, the absence of any counterfactual, which would show the GDP effects of not proceeding with the scheme and hence of lower public spending, does not form part of the calculus. Despite these limitations on the measure, this measure of the GDP effect per £'s worth of

NPV of spending was persuasive in discussions between transport ministers and the Treasury on the funding of major transport schemes, including the two major London schemes of Thameslink and Crossrail, both of which remained largely unaffected in the Chancellor's 2011 spending decisions.

Figure 1.1. **Distinction between welfare- and GDP-related benefits**



Source: Department for Transport (2005).

The increase in Gross Value Added in a conurbation by transport – outline of the method

The Department's 2005 paper has encouraged alternative approaches to estimating a transport scheme's contribution to the wider economy, especially in the context of the Transport Innovation Fund. The requirement encouraged Greater Manchester to develop an alternative approach which largely focused on the local and regional Gross Value Added rather than providing an estimate of the net national effects. Although the Greater Manchester TIF bid failed, largely because a postal referendum showed that voters did not support peak period road pricing that was part of the transport package, the method for estimating the impact of transport proposals on Manchester's economy have been developed into an operational tool.

The Greater Manchester Passenger Transport Executive (GMPTE), working with the consultants KMPG, developed a means of estimating the impact of a scheme on Gross Value Added within the study area. Thus the metric differed from the DfT's use of a measure of economic welfare and the

BCR as a means of prioritising investment. The GVA-based measure was used to rank options within the package of possible measures, to demonstrate their impacts on the local authorities within the region covered by GMPTE and to indicate to local tax payers and to central government the contribution to the region's economy of the investment package of transport and land-use changes.

The KPMG model relaxes the assumption about fixed land use and provides a means of estimating how firms as well as workers respond to improved accessibility. Improved accessibility encourages more productive firms to replace those which deliver a lower value added. There are many low-value added, low-employment density activities on the fringes of the central areas of large conurbations – car-repair and other workshops, printing and scrapyards, for example. Cross-sectional data showed how the mix of economic activity changes as accessibility increases, and this change in the mix of economic activity results in more productive jobs.

An elasticity of productivity with respect to rail connectivity of 0.11 was estimated and this effect was disaggregated into the change in productivity within sectors (0.9) and the effect on productivity of changes in sectoral mix (0.2). The second contribution to increased GVA was attributed to business location decisions as a result of improved rail connectivity. There is a strong link between the density of employment in terms of jobs per kilometre and rail connectivity, with a 10% increase in the latter, leading to a 13% increase in employment. The elasticity value varies by sector and by region – it is highest for business services and banking. Thus improvements in accessibility increase both output per head and the number of workers in the zones benefiting from the improvements.

The modelling developed for GMPTE does not help to separate those jobs which have relocated from other areas from those which are net additions. Much of the increase in GVA, while of benefit to the study area, is a result of transfers from other less productive locations. The proportion of jobs in each sector that might be described as footloose was identified by defining a minimum number of jobs per resident in each region and sector. The study showed that 14.1% of all jobs in the region were not located so as to serve local residents and firms, and thus defined the overall size of the market that had the potential to relocate in response to changes in accessibility.

A study commissioned by the, now defunct, Northern Way Consortium of local authorities and other interested groups in the North of England from the Spatial Economic Research Centre at the London School of Economics[23], followed broadly the same approach, using a measure of accessibility based on generalised cost, which distinguished between road and rail in determining economic mass or effective density. The wage equation, linking productivity to economic mass, was derived from micro-data on individuals rather than on aggregate estimates by place and level of economic mass. By controlling for the characteristics of individuals, the SERC method effectively separates the effects of a location being more productive because of agglomeration economies from the consequences for GVA of people who are more productive in any location, and who move to a location that has become more attractive on account of a reduction in transport costs. While this approach has the potential to separate the redistribution effect from the pure agglomeration economies, it does not, of its own, help to show the origin of this redistribution.

The increase in Gross Value Added in a conurbation by transport – assessment

The models outlined above provide an alternative approach to the measure of GDP per £'s worth of public sector cost. It is not a substitute for that metric since it measures changes at an urban or regional level and is not intended to serve as a measure of the net effect on national GVA. It has certain advantages as a metric. For many local decision-makers, GVA is a concept that they feel better able to understand than welfare benefits and for this reason it could be argued that the quality of decision-making is improved. The method provides some indication of the expected spatial distribution of the changes in economic activity and can help to show where housing developments and other spatial policies are well integrated with the location of employment. It provides the potential for more comprehensive modelling of the effects of a proposal on CO_2 since there is a potential to link the transport-related emissions, derived from the transport model, to the changes in land use using data on the use of energy for domestic and other purposes by residential and commercial density.

However, certain welfare benefits, such as reductions in all travel time other than for trips to and in the course of work, are omitted, despite the contribution of such activities to the overall quality of urban life. Moreover, it could be argued that the model shows the potential increase in GVA rather than a best estimate. The increase follows from a combination of the improvements in accessibility and other programmes of investment, some of which might require a public sector contribution or impose externalities on those who work or live in the urban area and all of which require decision-makers and developers willing to implement plans to change land use to complement the changes in accessibility.

The use of a GVA or GDP per £'s worth of spending metric provides a means of ranking projects and prioritising those to be implemented out of a pre-determined budget. But the metric lacks the essential output from a well-conducted cost-benefit analysis, which is to determine whether the project is worth building in the first place. There is no equivalent of the value-for-money metric which can help to influence the size of the budget. Its merits are in its ability to provide more and different information about schemes that have already met the minimum value-for-money requirements.

A critical assessment of the methods is made difficult by the lack of published papers that provide details of the estimation methods and values used for the elasticities, which relate accessibility to productivity and employment density. The problems of identifying causality in such relationships are well known, as are the difficulties in separating improvements in accessibility from all of the other changes taking place.

8. Evidence of wider economic benefits: Ex-post evaluation

Despite the claims made for the ability of transport schemes to transform the economy of urban areas, there are few British studies that provide a conclusive demonstration of the contribution of any specific scheme. Experience has shown that carrying out the "after" part of a "before and after" study is a complex and costly task with limited benefits in terms of improving forecasting and appraisal methods, including the methods used to estimate the wider economic impacts. While most of the earlier British studies focused on highway schemes and their effect on regional development[1], two recent studies are of more relevance to London rail schemes and their wider impacts.

Transport for London commissioned an extensive Impact Study of the Jubilee Line Extension[2], which opened in 2000.The modelling and economic appraisal of this scheme was described above in the context of the East London Rail Study. The evaluation study provided extensive data on the use of the line, trends in property prices, employment and rental values and comparisons of the current data on passenger flows with the forecasts made for the ELRS. The increase in land prices was seen as a potential source of funding future schemes. But the study could not provide an assessment of what might have happened in terms of the level and geographical distribution of employment in the absence of the line. The development of Docklands provided a unique opportunity to extend London's financial business district. It concluded that the density of development and levels of employment in Docklands would have been lower without the line but there was no way of quantifying this effect or attributing causation.

More recently, the Department for Transport commissioned a longitudinal study[3] to investigate the relationship between improved accessibility and increased productivity. The study was restricted to road schemes which had been completed between 1998 and 2003. Estimates of the transport cost savings that occurred as a result of these road schemes were linked with a dataset of firms according to their workforce, output, sector and location. The changes in productivity of those firms that had experienced the greatest improvements in accessibility to employment were compared with other firms. The analysis, aimed at investigating the extent of agglomeration benefits, found no significant effect on productivity for these firms of changes in accessibility to employment and hence in effective density. The researchers concluded that this finding did not imply that agglomeration benefits did not exist. They suggested that such effects are difficult to detect because of the small size of the elasticity of agglomeration with respect to productivity – a 10% increase in agglomeration results in a productivity increase of around 0.15. Road schemes increased effective density by an average of 1.8% in the area within 10 km of a road scheme, again suggesting that the effects were too small to identify in the study. The study was restricted to estimating the wider benefits of the transport schemes; it did not address how the transport cost savings which benefit firms that use the new infrastructure influence costs and productivity.

Neither of these evaluations of transport's wider impacts has provided evidence that might improve our understanding of the magnitude of these benefits or the mechanism whereby transport schemes deliver them. In the case of London's Docklands, the Jubilee Line Extension was part of a plan for the complete redevelopment of the area, coupled with a vision for its future as a place where international headquarters would locate. While this vision has been realised, the Study could not separate transport's role from the many other influences that led to the success of Docklands.

9. Conclusions

Cost-benefit analysis has been long established in the UK as a means of providing decision-makers and the public with information about the impacts of a transport scheme and about the strength of the business case so as to help determine priorities between schemes and hence allocate the Department's capital budget. The Department for Transport is responsible for providing guidance on the methods to be used by scheme promoters in England and this is done through WebTAG. The methodology, while retaining the paradigm of economic welfare, has been developed to reflect policy priorities. Within this admittedly restrictive framework, transport's impact on the economy is estimated through welfare impacts additional to the conventional cost-benefit analysis. This impact is made up of the benefits from increased agglomeration, the effect on the value put on the benefits on account of imperfect competition in transport using product markets and labour supply effects. The methods remain firmly based on the principles of cost-benefit analysis, a framework used throughout government departments in the UK and which is codified in the Treasury Green Book[1].These wider impacts are net additions to national economic welfare. The Department has provided guidance on what it has defined as the GDP effects of a transport scheme, based on business cost savings and additional output on account of the response of labour to lower commuting costs and of firms to changes in accessibility, but while these may be of strategic relevance to decision-makers, they remain separate from the economic case for a scheme. Unlike cost-benefit analysis, this approach does not demonstrate whether the benefits of a project exceed its costs by a margin big enough to make it a project which delivers high value for money.

The Crossrail scheme was developed as a solution to the growing problem of crowding on London's commuter rail services. The initial proposal in 1989 was appraised using conventional cost-benefit methods. For a number of reasons, including an economic downturn, the lack of a champion for the scheme and the failure to resolve the decision on the funding of the scheme, the scheme did not then go ahead. When the scheme was revived in 2003, the Department had started to develop its guidance on wider economic benefits and the Greater London Authority, acting as a champion for the project, took up the guidance and enhanced it to reflect the constraints imposed by crowding on the supply of labour to Central London and firms' willingness to locate there. The inclusion of wider economic benefits demonstrated the strength of the economic case for the scheme. With these benefits added, it would deliver high value for money. This analysis also provided evidence on the benefits of Crossrail to business, which may have contributed to the introduction of the Business Rate Supplement which helped to ensure a funding package for Crossrail.

Existing appraisal methods, supplemented by the inclusion of wider economic benefits, have been adequate in the case of Crossrail. Crossrail adds 6% to rail capacity at the Central London cordon. Over this decade, a further 18% is being added through projects to upgrade most of the existing underground lines, rebuild several busy Central London stations and lengthen many main-line commuter trains. Crossrail is already responsible for the redevelopment of offices and other buildings in the vicinity of the stations along the route. But, unlike the Jubilee Line extension to Docklands in the 1990s, Crossrail is not transformational in terms of delivering a step change in capacity to zones which were previously difficult to access. Crossrail stations are all at locations already well served by the London Underground or main-line rail networks.

WebTAG has the advantage of providing estimates of the wider economic impacts which can generally be derived from the transport model and align well with most decision-makers' views about how transport might affect the economy. Estimation of these effects and incorporating them into the analysis used to support the business case for a scheme is not always simple. There are well-documented problems in estimating the relationship between effective density, however measured, and productivity. The treatment of labour force participation in terms of a simple elasticity with respect to a definition of the returns from work conceals the complex interaction between the actions of firms and the decisions of workers in response to changes in transport costs. Because of the cost of implementing and maintaining LUTI models, they are not sufficiently developed and used in England as to provide a standard approach to estimating the effects of the move of workers to more productive jobs and of firms to more productive locations in urban centres. Nor are the existing LUTI models integrated into the economic appraisal process, with the consequence that they fail to provide decision-makers with a full assessment of the costs and benefits of the land-use changes. An added complexity arises when specifying the geographical area to be covered by the model and hence the scale and scope of estimates of these wider effects. The British approach to transport has generally been to make incremental changes rather than one of comprehensive national planning. The last attempt at a national plan, the Ten Year Plan for Transport, published by the Labour Government in 2000, proposed extensive investment in roads, rail and local transport, only parts of which were delivered as proposed, although the Plan's objectives of reducing the growth in traffic congestion have largely been realised by the economic recession and increases in fuel costs. This incremental approach to resolving the country's transport problems further explains the reliance on cost-benefit analysis and the absence of a good case for developing alternative approaches.

These are not grounds for complacency. There is a continuing debate between land-use planners and transport economists about the relevance of transport appraisal methods. The debate has focused on the reliance on time savings as the indicator of the majority of the benefits of any scheme. Critics of the Department's approach have argued that time savings are quickly converted into other benefits, most typically, in the case of urban schemes, the ability of commuters to live further from their place of work and purchase more housing space, while firms relocate to take advantage of increased accessibility. It is clear that decision-makers would find it useful to have more and different information on the wider impacts of transport schemes, and in particular on those very few which are intended to transform the economy in the area served by the scheme. This additional information also enables the promoters of the scheme to make a better case when seeking to obtain funding and consent to build it.

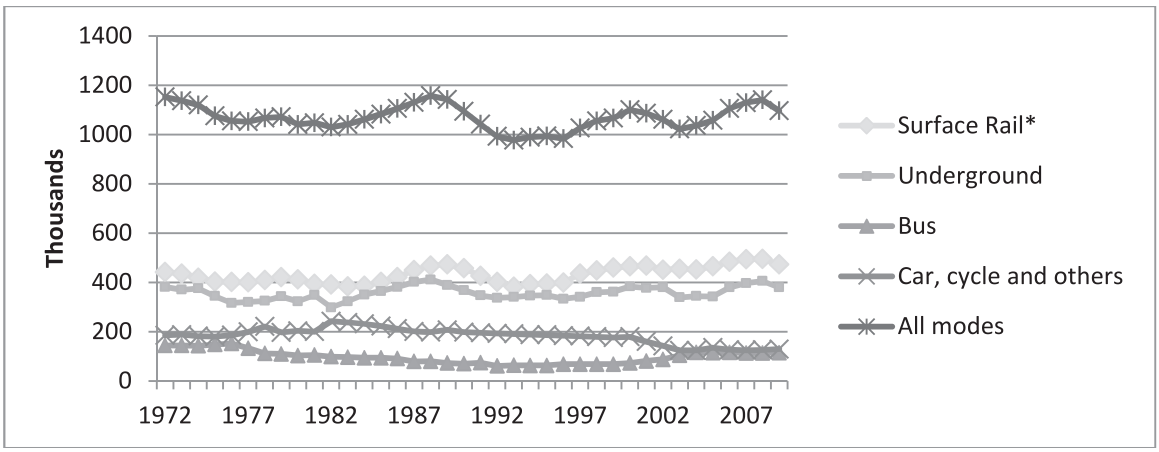
However, there is no consensus on what additional information would be of value to decision-makers other than the mythical crystal ball, which even a hardened politician might be reluctant to uncover. Despite the priority given to economic growth, an indicator of a transport scheme's contribution to raising the trend rate of GDP is not, on its own, a metric that would make for better decisions. While it is clear that a well-defined land-use model, which supplements the transport model, could provide decision-makers with a better understanding of the likely outcomes of a scheme and of its potential to deliver further changes, land-use modelling does not form part of standard practice in England.

There is a good case for a review of the land-use models currently available in the UK to establish the extent to which they might help to provide, either in their existing forms or after some modification, some of the information about the spatial impacts and responses to improvements in accessibility that are omitted from the current appraisal methods. There would also be merit in comparing how these models estimate the redistribution of economic activity with the estimates made in the Crossrail appraisal and in the work for Greater Manchester and the Northern Way. The outcome of such a review would be very uncertain. The restrictive nature of land-use planning policy in

England constrains many of the modelled responses to improved accessibility, thus reducing the benefit of using such a model. Inclusion of the costs and benefits of the land-use changes to complement the transport appraisal raises other challenges, in particular in distinguishing whether the land-use change benefits are additional to those in the transport model. In a world of generous research funding, research into these issues would prove an interesting and challenging task, albeit one with very uncertain outcomes. However, funding for the present programme of research is very restricted and there are many competing priorities.

Annex 1.A1

Figure 1.A1.1: **People entering central London during the morning peak, 1972-2009**



* People transferring from rail to underground or bus at mainline stations in central London are recorded as surface rail passengers.

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Chapter 2

The Greater Paris Metro Project: Characteristics and Challenges

Jean-Claude Prager[1]

Abstract

In this brief introduction, the author will highlight the two important characteristics of our project and our overall challenge of carrying out a robust assessment of its socio-economic impact, and then he will ask four questions which seem to him to be fundamental.

The Greater Paris Metro represents a considerable structural change which will cut a number of journey times by 50%. This metro thus poses new questions about the scale of threshold effects in public transport.

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1. The large scale of the planned investments

In this brief introduction, the author will highlight the two important characteristics of our project and our overall challenge of carrying out a robust assessment of its socio-economic impact, and then he will ask four questions which seem to him to be fundamental.

The Greater Paris Metro represents a considerable structural change which will cut a number of journey times by 50%. This metro thus poses new questions about the scale of threshold effects in public transport.

The Greater Paris driverless metro is made up of about 175 km of new lines and roughly 60 stations. It will expand the size of Paris' current metro network by 70% and will make it possible to carry 2 million travellers per day (the current metro network extends for about 215 km with 300 stations and carries 4 million passengers every day). Trains on the Greater Paris metro will move at an average service speed of 65 km/h, which is three times the current service speed of the metro. The frequency of metro trains will be flexible, with intervals of as little as 85 seconds between trains at peak times.

Today, 70% of journeys in Île-de-France are made from suburb to suburb, and 80% of the latter journeys are made by car. The Greater Paris Metro will also make it possible to avoid passing through Paris when going from one suburb to another and will reduce passenger numbers on all lines of the current metro network by 10-15% on average. The burden on some lines of the network could decrease by as much as 25%, as in the case of Line 13, and 30% on the central part of the RER. It will be possible to travel to the three airports and TGV stations easily from all points within the Paris region. It has also been ascertained that between 10% and 15% of users will abandon their cars and take to public transport.

The general outline of the project was approved by the Government in August 2011.

2. The Greater Paris project is also a major development project

The explicit aims of the Greater Paris Metro are to encourage the economic development of the capital region by improving the attractiveness of the area, the operation of the job market, interaction between socio-economic actors, and the creation of a network of centres of excellence and development across the region.

Our project thus forms part of a new policy of growth and innovation in the Île-de-France region. This policy also entails restructuring the region's major universities and an innovation strategy in line with the priorities set out in the European Union's Lisbon Strategy, and a strengthened housing construction policy to support this growth. This policy is intended to address the issues raised by the shortfall in the return on investment of the region's innovation powerhouse by comparison with Tokyo, London and New York. The region has considerable potential: the number of researchers, the diversity of its industry and services, its rich fabric of artisans and small and medium-sized enterprises, the power of its industrial sectors, its attractiveness to foreign investors, the number of major company headquarters, and its strength as a world-class financial, cultural and tourist hub. Yet the innovation powerhouse of the Île-de-France region yields a lower economic return than those of London, Stockholm, New York and Los Angeles, not to mention Silicon Valley, due to the inadequate interaction between research and the business world in the Île-de-France region, among other reasons.

In addition, the areas of the region are highly disparate and poorly connected to each other and their airports, and as a result, the lack of internal mobility within the region is an obstacle to the movement of ideas and workers and the optimisation of initiatives and human resources. A city, understood as an urban area, is the perfect example of a place that makes connections between actors possible and facilitates them. The infrastructures envisaged by the Greater Paris project are apt to facilitate interconnections between areas, and hence to boost the efficiency of the exchange of people and ideas and encourage agglomeration forces.

3. The challenge: adapting evaluation methods to a large-scale project

The first aim of the infrastructure is, therefore, to contribute to a positive "growth shock" for the region and the country, over and above the usual benefits of transport investments.

In France, as in most OECD countries, infrastructure projects which are financed with public money are subject to a public inquiry, which includes an evaluation of the economic and social effectiveness of the operation. This project evaluation includes a provisional assessment of the benefits and disadvantages caused, whether directly or otherwise, and an estimated rate of return for the local authority. The assessment calculates the updated amount of all anticipated monetary or monetisable costs and benefits and also impacts that cannot be quantified, or hence expressed in monetary terms. The evaluation must state the project's impact on the various economic operators concerned, customers of the future metro, businesses, the State and other public authorities and, more generally, the entire population.

The first evaluations of the socio-economic returns – which were carried out in 2010 using standard approaches to evaluating improvements in accessibility and agglomeration effects – pointed to a promising return from the project. However, we have not yet been able to quantify all of the effects of this new metro, and the margins of uncertainty for the calculations are quite great.

To appraise the socio-economic impact of such an innovative project, which anticipates the future growth of the region in all of its aspects, we must therefore evaluate phenomena which we know are being debated by experts. We are in a grey area of knowledge and the calculations are inevitably subject to a high degree of uncertainty. Our aim is therefore firstly to explain the terms of the debates on the basis of current knowledge.

In this brief introduction, the author will present some important issues which concern us.

Question 1: The role of mass transport infrastructure in the growth of areas is a debate which is still inadequately documented

Since one of the reasons for creating the Greater Paris Metro is its impact on growth, it is crucially important to provide points of reference with regard to the link between transport infrastructures and economic growth. The overall link between the level of public capital and growth, such as between transport infrastructures and growth, is documented in general terms even though the overall conclusions may spark lively or even somewhat ideological debates. The literature tends to conclude that there is a positive link between infrastructures and growth in the long term. The elasticities that have been calculated may be significant. However, the impact of infrastructures when considered separately is highly dependent on the exact nature of the infrastructures and calculation methods. In a nutshell, it can be highly variable.

The issue of the mutual influence between transport investments and the growth of areas is a matter of debate; there is a causal relationship in both directions. On the one hand, urban development is supported and anticipated by means of transport facilities, and in the other direction, some infrastructures help to shape and anticipate the expected development of cities. Since they are usually difficult financial choices, decisions concerning infrastructures are based on criteria of rapid returns and therefore tend to favour the construction of transport networks in areas which are already densified. So it can be said that infrastructures which respond, *ex post*, to the transport needs created by development, which "support" this development, apparently produce a bigger economic impact and return in the short term than infrastructures which anticipate the development of urban areas and tend to shape them because the number of people using them is necessarily lower at first, until their long-term effects on urban structuring make themselves felt.

In the past, some transport infrastructure planning decisions have had considerable long-term effects. For example, one may ask what the urban growth of large metropolises such as London, New York and Paris would have been like and what the forms and costs of congestion in them would have been today if the first key decisions on their metro networks had not been taken during the second half of the 19th century. It would be interesting to have an *ex-post* economic assessment of these decisions and to compare them with the calculations that could have been performed, *ex ante*, on the basis of traffic forecasts made according to mobility and location behaviour at that time. Perhaps such studies have been carried out, but we are not aware of them.

The issue, therefore, is being able to characterise these major projects in advance, and the way in which their economic effects can be assessed.

Question 2: How to characterise major infrastructures and assess their effects?

These major infrastructures, which constitute very long-term decisions, such as the Greater Paris Metro, are disruptive infrastructures which may be described as "public policy shocks". They raise the issue of the limitations of applying standard transport models.

Major transport infrastructures are actually much more than mere incremental improvements to existing networks; they are infrastructures which are unique by virtue of their immediate consequences, especially in the long term. This is true in the case of, for example, creating complete bypasses around metropolitan regions which are still partially served, or creating the first rail-based public transport system in a metropolis which did not previously have one (e.g. the metro networks of London, New York or Paris at the end of the 19th century), or creating a system with highly innovative features (high frequency, automation, high speed, etc., as in the case of the Greater Paris Metro).

For these infrastructures, it may be considered that the overall effect is markedly greater than the sum of the effects taken separately from their components and that we are dealing with steeply-curved parts of demand functions where the effects can be very great and underestimated by models which, all too often, are still linear.

For example, the construction of a peripheral circular ring should normally have effects greater than four times the economic impact of building a quarter of this ring. The difficult part is assessing the economies of scale in the production function, and to what extent and under what conditions these economies of scale may manifest themselves. Specifically, it is necessary to measure the difference between the impact of, for instance, 200 km of additional extensions to metro lines and that of a new and different system; for example, a set of radial and interconnected lines such as the RER in the 1960s or rings as in the case of the Greater Paris project, with radically different technology, allowing for much greater time savings than the usual 5% or 10%. We must also assess the conditions in which these economies of scale can be amplified by appropriate urban policies or, conversely, in what conditions competition may arise within a single mode of transport, a phenomenon known in industrial organisation as “cannibalisation”.

The economic and social effects of major projects are multiple and complex, and standard calculations of increases in accessibility based on transport models only capture some of the impacts, even if one decides to incorporate aspects which are not normally clarified, such as increases in productivity related to agglomeration effects, supporting the emergence of new, secondary centres.

A parallel can be drawn with analysing the economic impact of a radical innovation. To assess the value of this innovation, it is necessary to measure repercussions in very varied fields of economic activity, which arise only in the long term and were not necessarily foreseeable when the innovation came about.

To clarify the public decisions to be made in this area, it is necessary to consider all possible effects over the very long term and to try to establish their relative importance without exceeding the bounds of scientific plausibility.

Question 3: How to measure the effects on prosperity caused by urban facilities?

Major public transport infrastructure projects have a significant effect on the form of cities, but this effect is ambiguous. Transport infrastructures simultaneously encourage urban sprawl of an entire city and a certain amount of densification around stations, which experience surplus demand for land.

The driverless metro network must, therefore, also contribute to polycentric development (polycentrism being the opposite of monocentric polarisation).

As is the case with most other cities, the urban sprawl of the Paris region is linked to the way in which the conflict between housing areas, land prices and travel costs and times is settled. A certain preference for private transport was, *de facto*, encouraged between 1960 and 2000 by population growth, the improvement in living standards, the fact that petrol prices remained relatively low despite oil shocks, the construction of two major ring-road infrastructures, and the near-absence of any regulatory or tax measures tending to keep urban sprawl in check. These dispersal factors were sufficiently powerful to counterbalance the polarisation or control of urban sprawl that should have been caused by the construction of the Réseau Express Régional network, associated with a new towns policy which was adopted during the 1960s.

The context of the Greater Paris project is different. The use of available land within the small inner suburbs of Paris and the improvement in the density of the public transport network, have already made it possible to support a certain amount of re-clustering of population and employment. The aim of our project is to ensure that population and employment growth, which will represent 15% to 20% of the current population and employment levels, will primarily be concentrated, over the next twenty to thirty years, in ten or so secondary centres. These centres will have full urban functions and will be well-connected to each other and to the Île-de-France urban centre, thanks to an ultra-fast and efficient means of transport. The choice that has been made is not to block urban sprawl, which would require the implementation of very strict regulatory measures and could lead to a loss of social efficiency, but to accept the continuation of the controlled spatial development of the urban area. Oil price forecasts suggest that petrol prices will remain high, and this will therefore boost the return to public transport in the long term.

The regulations concerning infrastructure projects require us to assess these effects in terms of social wellbeing.

Effects are firstly seen in the expectations of economic operators, especially land agencies, and the value of land. The effect also continues over the long term, once the infrastructure has been created. Polarisation is more marked around stations and nodal points of transport systems in terms of population density and land values. It seems to be all the greater when the investment is a strategic decision for future development than when it supports continued urban development which is already under way or existing needs which are poorly catered to.

We will calibrate land-use models which are simulation models, such as UrbanSim, or general equilibrium models such as Relu Trans, to evaluate the effects that the metro's creation will have. We know what these solid and established techniques can give us and are counting a great deal on the support of Professors Anas and Waddell, who are the fathers of these analyses, to help us to evaluate these complex issues.

Aside from the overall analysis of foreseeable effects, the literature is relatively modest when it comes to quantifying the economic benefits of greater control over urban development. The existing literature tends to support the idea that the urban policy proposed for Greater Paris is a second-best option. But our challenge is to quantify these benefits. We need to know what polycentric development will bring in terms of social wellbeing and reducing wealth and income inequalities as opposed to monocentric or diffuse urbanisation. Parts of the answer already exist, as far as polarisation of economic activities is concerned, thanks to the literature on agglomeration effects. The effects on residential polarisation are less well documented.

Question 4: How to estimate the effects of improving the international competitive position of the Paris urban area?

Analysis of the impact on growth must distinguish between internal growth of areas and growth linked to greater attractiveness of the metropolis in terms of mobile resources (major property investments and industrial or research investments). This major issue concerns the geographical factors of urban development and the role played by the expectations of economic operators in the long-term growth of cities. We can already see an increase in the external and international attractiveness of the urban area through multiple contacts. The announcement of a major policy and a new policy of stimulation are a signal which is changing the expectations of economic operators, and especially industrial and property investors who can anticipate the future advantages of locations, contribute to polarisation around transport nodes and hence boost the economic and social effects of urban agglomeration. But empirical evidence of the influence of infrastructures on the attractiveness of mobile resources is still poorly documented even though this is probably one of the keys to the surplus potential growth of the urban area.

Part of our problem, therefore, stems from the difficulty of evaluating the effect on our share of the market of "footloose" international activities with high added value.

In conclusion, for the time being, our response can only cast partial spotlights on these complex issues, bearing in mind the need for diversified approaches in the absence of a central method which is recognised by all.

Chapter 3

The *Grand Paris* Project: Tools and Challenges

André de Palma[1]

Abstract

A number of reflections are set out on the formulation of issues relating to the challenges and costs of security policies. This formulation process, as shown by a brief historical overview, varies significantly according to the persons or bodies expressing themselves (private individuals, insurers, businessmen, public authorities, etc.).

Likewise, the recognition today that security must be treated as a public good, an issue on which diverging interests clash, calls for a differentiated analysis of modes of formulating preferences and the way such modes are articulated.

The report shows how economic analysis proposes new approaches and new issues with which to discuss the aggregation of the perception of infrequent events with severe consequences.

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1. Introduction[1]

The purpose of this Round Table is to assess the economic effects of major transport infrastructure projects. The term "major projects" is used to designate qualitative leaps, be it the mapping out of new road or rail rings to link disparate radial penetration routes or the introduction of more targeted innovations, tackling frequency, speed or automation.

As our hosts wisely remind us, there is more involved here than extending the list of the direct effects of such projects in terms of enhanced accessibility. One must also factor in the productivity gains arising from agglomeration effects, without neglecting the indirect effects, which involve the shifting urban structure and the modulation of growth.

On what conditions can we deliver growing economies of scale and ensure complementarities in public-private partnerships? How should we take part in discussions to define well-being indicators that can supplement and redefine growth indicators? These are new directions for our research.

In this article, we shall summarise a number of major aspects of the project that concerns us here, as it relates to transport infrastructure and its interaction with urban dynamics.

But first, let us briefly review the main features of the *Grand Paris* adventure. In September 2007, the French President, Nicolas Sarkozy, enshrined the idea of a "new comprehensive development project for Greater Paris". One provision of the Act of 3 June 2010 was to establish the *Société du Grand Paris* (SGP) as lead contractor in charge of designing the transport project and getting it built.

This project will consolidate and make trade-offs between a number of different ideas. A regional train or express metro will link Charles de Gaulle and Orly Airports and will endow the region with rings around the outer periphery, without neglecting the south-west and its centres of excellence (Palaiseau, Saclay, Versailles). The aggregate daily flow is soon expected to reach millions of travellers.

This undertaking is the result of assessments in the realms of economics, demographics and urban planning:

- The GDP of the Île-de-France region grew by an average of 2% per year between 2000 and 2008, which is low in comparison with the 3 to 4% of New York or London. Furthermore, despite economic vitality, few jobs are being created.

- Population growth in the Île-de-France is around the national average, as a result of strong natural growth but negative net migration, due to heavy outflows to other parts of the country.

- The urban spread induced by the *Villes Nouvelles* ("New Towns") policy is substantial, resulting in poor mass-transit services, high road-congestion costs, passive and active spatial segregation and a decline in agricultural zoning. Large differences in population density can be observed between Paris (25 000 per km^2) and the outer periphery (1 000 per km^2), but recent trends, between 1990 and 2006, show rapid growth on the periphery. Public services and infrastructure are distributed poorly.

- There are numerous trips from suburb to suburb, many of which are in passenger cars[2], including trips to airports and railway stations.

- Greenhouse gas emissions need to be controlled.

The project links eight major development hubs in the Île-de-France and is lending support to their growth (see Section 4). It is estimated to generate population and job growth of, respectively, 1.5 million and 1 million by 2030[3]. Thanks to this new infrastructure, mobility and services will be extended by connections with all existing lines and an expansion of suburb-to-suburb services. An indirect aim of the project is to generate economic and urban vitality, especially in the project areas cited above, some of which are currently isolated. The projected cost is estimated at some EUR 20 billion[4].

In this article we shall describe how integrated land-use and transport interaction (LUTI) models may be used to assess the (local, regional and international) impacts of transport infrastructure projects.

2. Modelling large urban systems

Introduction

The new wave of modelling large urban systems is in fact grounded in a tradition of theoretical reasoning, the main thrusts of which we shall outline briefly below. This is not a history (dealt with masterfully by Thisse, 2011), but it can be used to reconstitute the pathways that led to models which seek to describe large cities.

From an agricultural economy to an urban economy

A number of the key concepts that led to the urban economy had been examined in works published since the beginning of the 20th century on spatial organisation in connection with farming operations and the distribution of urban hierarchies (von Thünen, 1826; Lösch, 1940; Christaller, 1933). An agronomist, von Thünen, uses a system of concentric rings to describe the mechanisms of land allocation through a bidding process (land being allocated to the highest bidder in a context of perfect competition). An economist, Lösch, begins with an isotropic plane in which self-sufficient entities maximise their accessibility to certain goods and services, and he explores the gradual organisation of the circulation of goods, services and persons.

The monocentric model

The application of these ideas of bidding and optimisation to the framework of urban economics can be associated with Alonso (1964)[5]. Alonso (along with Richard Muth and later Edwin Mills) helped to establish the monocentric model of the city, in which all workers travel each morning to a single working location known as the central business district (with regard to this, see the review by Quigley, 2008). This model, which assigns jobs to the city centre, therefore describes only the residential choices of households. It is nonetheless still useful for understanding household location and urban spread mechanisms (see preliminary studies by Chiappori, de Palma and Picard, 2011).

Short term *vs.* long term

Recent literature shows how the introduction of cordon pricing in the Île-de-France can affect the structure of the city, urban spread and congestion (de Palma *et al*., 2011). These authors use a monocentric model with automobile traffic congestion. This model was adjusted to the data available from the Île-de-France to explain urban spread. Comparable studies were conducted over the short term (holding household residence constant) and the long term (residence variable). These show that pricing effects are only half as great in the short term as over the long term. This figure is only a rough approximation, yet it indicates the utility of factoring in the relocation processes of households and businesses.

Incorporating major policy choices entails detailed modelling of transport systems as well as business relocation modelling (which is disregarded in the monocentric model but included in the more complex polycentric models). This militates for the integrated transport/land-use models that we shall be discussing later.

In a more elaborate model, it is necessary to introduce the spatial externalities that affect households and businesses. Symmetrically, the mobility decisions of households and businesses effectively alter (and are affected by) density values and thus, externalities. These externalities, which are difficult to quantify (except in respect of congestion), are to a great extent disregarded by too many models - theoretical and applied alike; let us cite de Palma *et al.* (2007), who measure local externalities and their effects on residential choices.

Spatial competition – monopolistic and oligopolistic

Urban economic models have long disregarded competition from differentiated products. And yet such competition was factored into the equation nearly a century ago by H. Hotelling (1929)[6]. His highly simplified model was exclusively spatial, although the beach on which his ice-cream vendors moved about could be reread as a range of differentiation amongst products.

Product differentiation modelling has found an empirical counterpart in discrete choice models, the estimation of which is now operational. This approach achieved clear-cut success in residential location choice applications. Amongst the work in this field is that of Ben-Akiva and Lerman (1985), who popularised discrete choice models in the realm of transport. At the same time, differentiation concepts have come into their own in the field of urban economics, thanks to the work of Alex Anas. This initial differentiation-based approach, which has become central to a majority of applied urban economic models, disregards competition, which nonetheless lies at the heart of the Hotelling model.

Oligopolistic competition between firms that sell differentiated products and are spatially located was described for the first time by de Palma *et al*. (1985). To our knowledge, this approach has not yet been developed in connection with urban models. Nevertheless, these ideas have found a niche in one applied spatial context – that of international trade (Fajgelblum *et al*., 2011).

Not that competition is absent from urban economics: it came in massively in the form of monopolistic competition (intermediate between perfect competition and a monopoly situation), introduced by Chamberlin (1933) and analysed by Dixit and Stiglitz (1977). These ideas were taken up by the new geographical economics.

This description includes enterprises that have only slight market power, and it is well-suited to a great number of small businesses, although less so to a number of large enterprises, each having monopoly power. Whether this approach can be used to describe competition between businesses within a major metropolitan area such as Paris, London or New York, is still open to question. We feel that, in a sense, the choice of monopolistic competition is tantamount to overconfidence in the market. But this issue remains more empirical than theoretical.

Lastly, competition between large metropolitan areas, which is often forgotten by urban economics, is probably another instance of imperfect competition: it would, in fact, be a gross oversimplification to assume that competing cities, such as London and Paris, constitute uniform options for multinationals wishing to establish their headquarters.

3. The non-linear models approach

Introduction

The notion of developing operational models to describe the urban phenomenon, and later urban dynamics, came into its own with the advent of fairly powerful computers. Here, we shall mention a number of the essential elements that we feel have been somewhat neglected in recent years.

An initial attempt to model urban forms was carried out by the (static) Metropolis model (Lowry, 1964). This simulation tool combines two types of space allocation: a residence location model and a location model for jobs and services. Here, a city's growth depends on the expansion of its basic, industrial sector, which determines the distribution of households and the resultant jobs. Basic sector jobs are constant, and in this sense the tool is a static one.

Urban dynamics

The history of large urban dynamics models begins officially with the work promoted by the Club of Rome, and thus the models of J.W. Forrester, whose celebrated *Urban Dynamics* was published in 1969. For the first time, it was thought possible to describe systems on a 1:1 scale (or almost) and to factor in a complexity inaccessible to analytical models.

These approaches claimed inspiration from the work of Ludwig von Bertalanffy and Norbert Wiener. Very soon, use was made of systems theory, which explored systems of interactions in terms of “boxes” and “arrows” to describe the processes of amplification and attenuation. The purpose of these studies was to regulate by introducing feedback loops: system inputs are a function of output values. To an economist, this conception of the propagation of effects evokes the dynamics of the Keynesian multiplier. From this perspective, a city is a large, non-linear system modelled from the standpoint of regulation, so that in this case the work of urban designers, engineers and planners is to understand and make adjustments to regulation systems. The aim is to optimise management of the complex and highly non-linear system that is the city.

Validation

The data available for adjusting such a model were in many cases too few and insufficiently detailed to ensure the desired behaviour. This weakens the procedures for adjusting the model’s parameters. Later, these procedures would be partially replaced by econometric estimation, which is more complex. But for the case at hand, the parameters were too numerous to adjust, making it impossible to devise satisfactory models.

Interdisciplinarity

Despite the pessimistic aspects, this first wave of modelling was useful because it liberated economics and urban planning from their rigid confines and exposed them to reality. It gave these disciplines applications with which to tackle the complexity of urban systems head-on. In this sense it played an ecumenical role.

From modelling to reality

Even so, all this expertise full of promise failed to satisfy the hopes that had initially been placed in it: the city was still a vastly unpredictable system, and managing it was more often a matter of pragmatic policy and experience than the application of advice and recommendations stemming from any scientific expertise. But the wheel was turning.

We believe there were multiple reasons for the failure of this systemic modelling. Among the reasons explaining the relative failure of systems theory as a tool for regulating the city as a thermometer regulates temperature, we shall adopt the following:

Validation

Urban systems cannot be reduced to a series of non-linear equations reflecting the qualitative behaviours present as best they can. It is also necessary to look to a microscopic analysis of individual behaviours, which by nature are highly heterogeneous: the analysis of individual choices. This analysis came a bit too late in this first epoch: its true development came only after the emblematic work linked to the Club of Rome.

Indeed, econometric decision models did not make their operational debut until the 1980s, and it was not until the 90s that they became commonplace (they can now be estimated very easily, with no need for user programming, by employing commercial software such as SAS, GAUSS, ALOGIT or STATA, or shareware such as R or BIOGEME).

As we shall see, this does not mean that discrete choice models can be used in conjunction with complex urban models. Much remains to be done before they are fully integrated.

Aggregation

The relationship between individual and aggregate behaviours is an issue that must lie at the core of our thinking. Yet this has, to a large extent, been disregarded by specialists in regional and urban economics (Schelling, 1971, being one notable exception), in contrast to the practice in other branches of economics, in which aggregation issues attract the attention of researchers, who probe relentlessly, for example, the relevance of the so-called "representative" individual.

Avoiding aggregation

The response of urban economics has increasingly been to shift from a somewhat *ad hoc* aggregated behaviour (using Cobb-Douglas aggregated functions) to an individual description of behaviours. In a sense, the viewpoint of urban economics is often that of "small is beautiful". What, in fact, would be a more realistic world than one in which models have as many equations as agents: households (if not individuals) and businesses? Micro-simulation models, used more and more nowadays, illustrate this idea. For example, in the realm of transport, the aim is no longer to describe flows of identical vehicles, but of drivers, each of whom has objectives and individually distributed reaction speeds. In such models, each driver reacts according to the state of his or her immediate environment.

But when putting these models to the test, what is of concern to us is to ascertain whether they are capable of explaining macroscopic processes, such as a shock-wave moving at low speed (depending on reaction time and a safe distance) in the opposite direction from traffic. If a driver arriving at 100 km/h off the motorway brakes suddenly (e.g. because a rabbit jumps out in front of the car), does the screen of the model show, as in reality, a braking front spreading backwards at roughly 20 km/h, which corresponds to a macroscopic process? The answer to that question depends on the model, and it is affirmative for a number of micro-simulation models of automobile traffic. In our view, alas, there is still no solution to this problem (which is neglected by modellers of urban systems). Clearly defined strategies for testing and validating such models against shocks or drastic changes in policy must still be formulated. We shall come back to this issue later.

The systematic approach highlighted the importance of the non-linearities introduced by loops. Nevertheless, it is not enough to have succeeded in constructing a non-linear system; it is still necessary to know how to analyse its properties and ascertain the behaviours to be analysed. The matter of aggregating heterogeneous preferences in a highly non-linear system remains the core challenge of urban systems.

Change of scale: the example of structuring

To study the aggregation of behaviours is to describe the arrangements stemming from the aggregation. Are such arrangements bound to be disordered? No, because the thermodynamics of systems subject to non-equilibrium constraints have taught us that isolated systems alone are forced to see an increase in their entropy (we shall understand their degree of disorder). In contrast, non-isolated systems, which exchange energy or matter with the outside world, can see a decrease in their internal entropy production.

Physics and chemistry have given us outstanding examples of ordered structures emerging, on the basis of local interactions. Everyone has heard about the Belousof-Zhabotinsky experiment (see YouTube), which features macroscopic spatio-temporal structures, unstable states undergoing complex transitions, sometimes linked by points of bifurcation, and between which there can arise periodic transitions, if not macroscopic chemical chaos (see de Palma and Lefèvre, 1983a and Prigogine, 1996).

The authors of these papers have also studied the behaviour of colonies of ants, which may participate, unbeknownst to them and in some cases by the millions, in constructing gigantic edifices, the outfitting of which goes beyond – and way beyond – the cognitive and memorial capacities of an ant's brain. Are not such patterns mirrored by traffic jams, rhythmic applause in a concert hall or rumours of the spontaneous organisation of events through Facebook, for example? Clearly, such situations constitute extreme cases, archetypes that need to be tempered (here, see the approach of Mansour and de Palma, 1984).

The case of cities

In the case of cities, the rules of thermodynamics for isolated systems should not be applicable, and one does not in fact observe a shift towards disorder. It is therefore necessary to alter one of the premises of our problem. The second principle is compatible with the appearance of ordered structures under certain conditions: non-equilibrium constraints and the presence of interactions described by non-linearities[7]. Thus, just as an economic system that continuously gets richer (even though no economic agent produces added value) is suspect, so is any idea of a city that would structure itself with no description of its dealings with the outside world.

Models based on non-linearities and the system's interactions with the outside world emerged under the name of "dissipative structures" (i.e. structures that dissipate energy organising or structuring themselves, via interactions with the outside world). The concept of dissipative structure was introduced by Prigogine of the Brussels School (see Nicolis and Prigogine, 1977). It is close to the "synergy" concept introduced by Haken (see Haken, 1993 and Weidlich and Haag, 1987). In this new reference framework there arises the essential question of the stability of the states of such dynamic systems. In other words, to what extent can small causes trigger large effects in these macroscopic states? For example, is it possible that a reform of parking prices within Paris, or congestion charging in the very centre of Paris, could have effects throughout the Île-de-France?

Studies on *Grand Paris* have thus far disregarded traffic conditions and the companion measures to be instituted. Yet it could be contended, as we do, that the effects of the *Grand Paris* project will be felt not only in the areas adjacent to the new infrastructure, but throughout the Île-de-France and beyond, in neighbouring regions. It is now possible to think system, to think local – but also non-local – interactions, in conjunction with analysis of non-linear and open systems, governed by a dynamic that is still fairly short-sighted but that goes well beyond the static and local visions of urban economists and their precursors, however systemic they may have claimed to be.

Self-organisation

Of course, residents are free to choose where they want to live, but apart from cases of anarchic urbanisation, such as, for example, the *favelas* of South America or the first gold rush to California, a series of engineering works, legislation and regulation governs such a dynamic. No-one can say that Haussmann's work played no role in the urban development of Paris, let alone claim that if

Haussmann had not existed, things would have followed the same course, the city being guided by forces of History beyond our capabilities for action.

The most recent wave of models is grounded, far more seriously, in a dual approach based on individual behaviour and collective behaviour.

The balance between these two levels of interaction is tricky to achieve and to describe. We shall briefly describe two tools – RELU-TRAN and URBANSIM – which clash on many points while both being geared to the same objective: to describe, and if possible predict, the dynamics of large metropolitan areas.

4. Setting the parameters of *Grand Paris* studies

Carving out *Grand Paris*

One of the *Grand Paris* project's objectives is to reorient the region's economic development. A long tradition of centralisation has concentrated the bodies of power in Paris, thus polarising the city centre to the detriment of its peripheries, relegated to the role of residential suburbs.

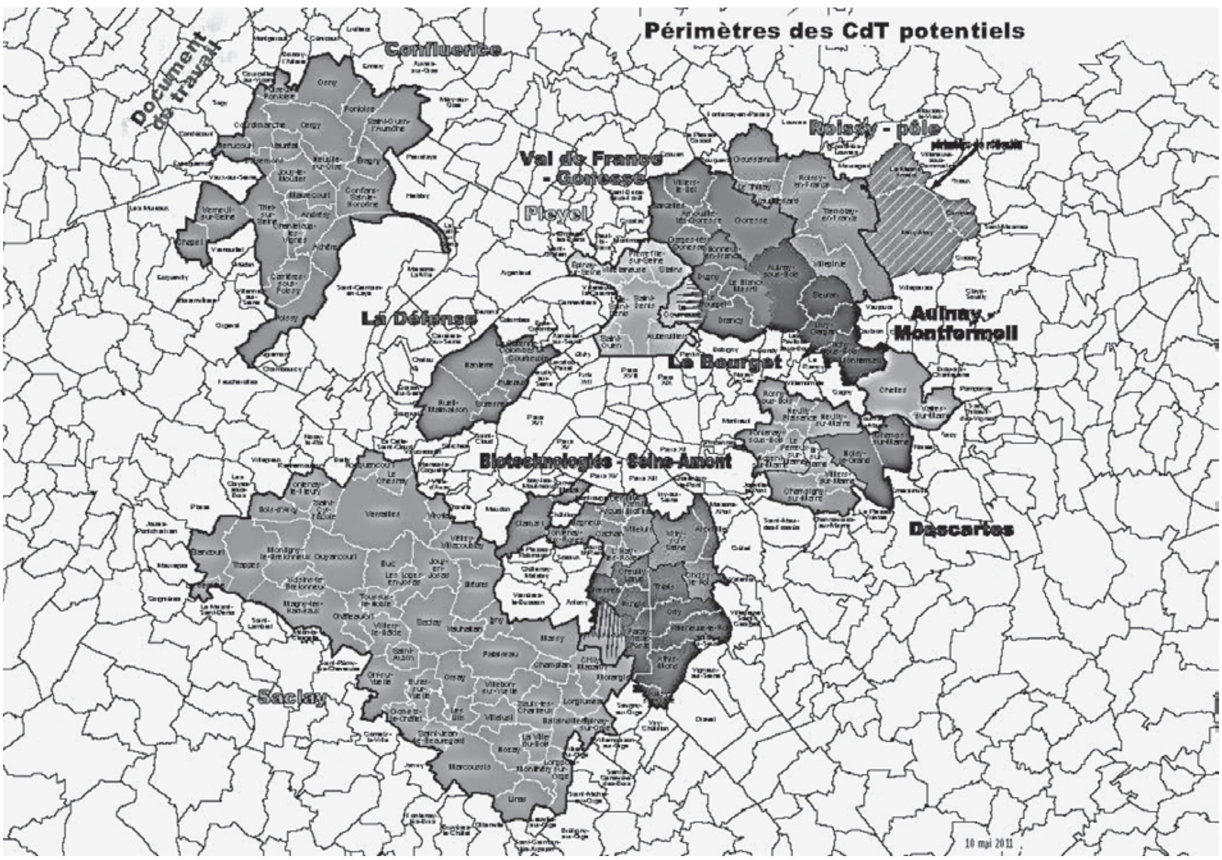
For several decades, the tendency has been shifting towards decentralisation. But an addiction is not broken overnight. It will come as no surprise that the bold planning of the mid-20th century spoke of industrial decentralisation, and even of the industrialisation of country areas. It soon became understood that it was necessary not only to speak of under-industrialised regions, but that centres of gravity had to be assigned to the new maps that were to be drawn. *Counterweight cities* – as the large towns or metropolitan areas, designed to serve as a balance to Paris, were called – were obliged to interconnect their internal and regional spaces (Cohen, 2002).

The "new towns" experiments of the 1960s-80s showed the limits of the policy of developing population centres. As a result, the Government decided to develop centres of employment and research. This decision took shape with the establishment of competitiveness clusters, certain functions of which were subsequently taken over by territorial development contracts (CDTs). In June 2011, the *Société du Grand Paris* launched an initial call for tender for assessing the socio-economic consequences of the *Grand Paris* project. Team co-ordination entails harmonisation of working methods and consensus as to the carving out of the areas to be studied. The Île-de-France comprises 1 300 communes, and the 20 districts of Paris correspond to large communes in the broad sense.

UrbanSim can process a combination of 1 300 areas (communes), whereas RELU-TRAN, which is more highly aggregated, can ideally model some fifty areas. A consolidation of communes into aggregated areas was proposed by the research team constituting one of the project's components. The starting point is the CDTs established in June 2011. After that, groups of communes are to be built around these CDTs, based roughly on the carving out of districts. Lastly, isolated/blocked-in communes are to be assigned to one of the already constructed areas – by default the neighbouring district to which it is most similar in terms of population density and located in the same *département*, or to a neighbouring CDT located in the same *département* if there is no choice. The perimeter of the CDTs has fluctuated considerably over time, with successive political and administrative decisions, and it has probably not stabilised. The proposed aggregated zoning thus differs at the margin from the official perimeters, in order to ensure coherence and socio-economic uniformity within each area, transcending political and economic divisions as well as stability in the definition of the areas' perimeters.

Initially (in 2009), there were seven development clusters[8]. Since 29 June 2011, there have been ten, namely: Confluence Seine-Oise; Est de la Seine-Saint-Denis; Est-parisien Cité Descartes; Gonesse Val de France; La Défense; Le Bourget; Plateau de Saclay; Roissy-Villepinte-Tremblay; Saint-Denis Pleyel; and Biotechnologies Seine-Aval (Figure 3.1).

Figure 3.1. **Potential CDT perimeters**



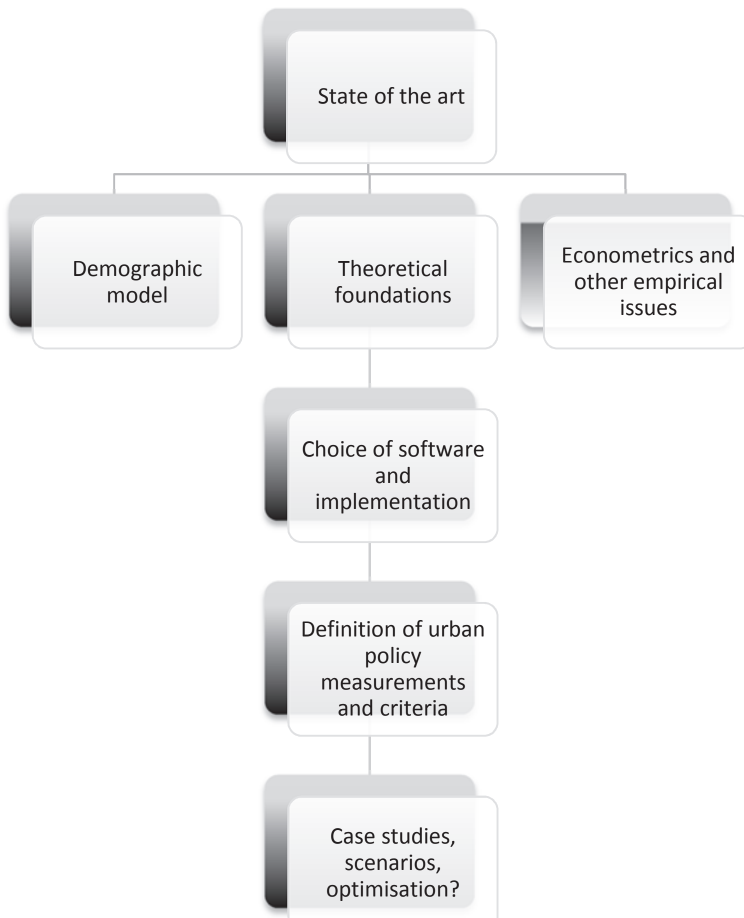
Source: DRIEA.

The perimeter of the ten *Grand Paris* competiveness clusters incorporates 150 communes of the Île-de-France region (170 including the twenty districts of Paris, the capital constituting an eleventh development cluster).

Organisation of research

It is difficult but necessary to impose a framework for the analysis of studies on *Grand Paris*. The major component elements of this are shown in Figure 3.2. This framework, while imperfect, can be used to map studies within a single diagram, which we hope will enhance thinking.

Figure 3.2. **Diagram of project analysis and evaluation tasks**



Angles of attack

State of the art

The premises of the operational models that have been developed have been drawn, more or less explicitly, from the broad theoretical corpus of urban, regional and spatial economics, and more recently from geographical economics (addressed succinctly in Section 3). Three disciplines should ideally be used in combination: (1) the economic/geographical corpus of regional sciences; (2) econometrics; and (3) engineering and data processing as applied to the development of large models. Greater collaboration is needed between these disciplines so as to avoid a series of pitfalls, the most extreme of which are a theoretical model with no possibility of confrontation with data and an operational model based on *ad hoc* – or even opaque – assumptions (which thus leave no room for discussion) and yielding no measures that overlap the concerns of theoreticians.

Data storehouses

Since the emphasis here is on a quantitative approach, analyses are dependent on data: transport, population and demographic trends, employment, land use and land prices. It is a known fact that data access and sharing are all too often an obstacle to modelling.

Factoring in the long term

Studies to ascertain the impact of major infrastructure have a 10-, 30- or even 50-year time frame. Long-term forecasting therefore plays an essential role here. The main considerations are:

- Economic trends in terms of growth (data extrapolated "on the fly" or not), but also shifting preferences: How could consumers' craving for utility vehicles have been foreseen?

- Changing technology. For example, what will the consequences of new information and communications technologies be on working conditions, mobility and agglomeration economies?

- Demographic changes, especially as shown by the long-term (from 30 to 50 years) models developed by the Institut National d'Études Démographiques, which has built up proven expertise in these fields. Factoring in the long term also entails the possession of projected rates of economic growth, employment, unemployment and so forth. In both cases, projections should ideally present multiple scenarios providing inputs for the modeller. These inputs will be provided by the SGP once they have been compiled by the competent institutions.

Endogenous variables vs. exogenous variables

A crucial issue is whether variables are endogenous or exogenous. Studies on *Grand Paris* would adopt the idea that the demographic growth of Île-de-France is exogenous to economic development. Yet this is only partially the case, since a whole series of decisions that affect demographics are linked to the economy: marriages, divorces, births and women's participation in the labour market can hinge on housing conditions and mobility. Moreover, immigration into and emigration from the Île-de-France depend on the region's economic health. Such feedback loops are complex, and it is not certain that they can be incorporated into demographic models at a detailed spatial level any time soon.

Choice of software

No software can do everything, but fortunately the tools are complementary. With respect to transport and land-use models, two tools have been adopted to date for the *Grand Paris* project:

- RELU-TRAN, developed by Alex Anas (see Anas and Liu, 2007), is a general equilibrium model (for an introduction to general equilibrium models, we refer the reader to Brocker and Mercenier, 2011), which works in a semi-aggregated manner (50 areas and several hundred transport network nodes in the case of the Île-de-France).

- URBANSIM(E), developed in connection with the European SustainCity project, constitutes the European version of URBANSIM (see Waddell, 2007 and Borning, Waddell and Forster, 2008). This is a micro-simulation model that describes the behaviour of agents (households and businesses), land prices and modes of land use.

Both models adopt extreme positions with regard to dynamics: RELU-TRAN assumes that the system is in equilibrium, while URBANSIM(E) considers a process of adjustment from year to year which does not explicitly model the anticipation of agents.

Formulating urban policy criteria

Since these models give us no perception of the future *per se*, it remains to be ascertained how they can be used. Three types of use can be distinguished (de Palma, 2009), each of which has its virtues.

- A first type of use is calculation, i.e. extrapolation. Its starting point is the principle that it is prudent to think that future states will prolong the trends which we detect with varying degrees of accuracy in the recent past. Infrastructure investments are thus frequently based on assessments made on the fly, on the basis of log-linear extrapolations of the growth rates of population and demand, for example. What actually happens? Such is its problem.

- A second type of use consists of choosing objectives. This is clearly proactive and interventionist. Here, the starting point is the future: objectives have been assigned, and the task is to ascertain how to proceed, i.e. how to mobilise resources to achieve those objectives. For example, the choice of managing mobility based on a goal of cutting greenhouse-gas emissions by 75% is an application of management by objectives. What must one do right? Such is its imperative.

- A third type of use is to try to assess the local and overall sensitivity of the tools adopted. This will pay close attention to their elasticity with respect to changes, not only in control parameters, but also in exogenous parameters. In its simplest version, it is a mere exercise in comparative statics. But if we assume that urban systems are truly non-linear, we therefore know - without being able to conclude anything from it - that small causes can produce large effects and that changes in regime can occur. What can one feel from things? Such is its quest.

Case study and scenarios

All of these considerations are of interest to policymakers if they are presented properly. The assessment criteria are many. Too often they focus on physical measurements (such as levels of congestion and pollution and urban density).

- These values can be enhanced by assigning them monetary values. Obviously, there arises the usual conflict between monetary values based on econometrics and those based on directives, which are less precise but also less subject to manipulation (for example, recommended discount rates or social values for time). Indices combining these values are more informative.

- These values are also enhanced by being combined in indices. Accessibility therefore plays an essential role in assessing infrastructure (see Poulit, 1974 and Weibull, 1980).

- Aggregated measurements are possible and desirable. They are not neutral. The social welfare function, which stipulates how the various values for variables can be added together, is in fact determined by the importance that the modeller wishes to assign to the city's various agents and players.

- Lastly, and although our discussion is not exhaustive, it is essential to analyse equity (vertical, but above all horizontal, i.e. spatial), which is often forgotten or ill-defined. This dimension is examined in Trannoy (2011) in connection with cost-benefit analysis. That discussion takes different orientations, depending on whether transfers between agents are possible or not. Trannoy considers measures that factor in equity issues according to the sharing of benefits and infrastructure costs.

A variety of evaluation criteria are conceivable, including rules based on the maximum-minimum cost for access to services (the min-max criterion). As is often the case, it is not difficult to find examples for which the fair location of a public service is also totally ineffective: efficiency and equity do not go hand in hand.

The treatment of uncertainty

The sources of uncertainty when modelling a project such as *Grand Paris* are legion, and this raises the following questions:

- At what level should error terms be introduced, and how should these be specified to get the best fit between the structure of the models used and the reality being analysed?
- Are parameter values consistent across the various modules of an integrated model?
- Is knowledge of the present suitable?
- What are the errors in the projections of the states of reference?

The biases inherent in modelling can be tackled by performing a comparative study of the results of multiple models, comparing different scenarios, simulating qualitatively different events or explicitly acknowledging the existence of an uncertainty that will need to be factored into the analyses.

Lastly, there are a great many situations in respect of which the modeller cannot assign probabilities to events. In such cases one speaks of uncertainty. This does not mean that no modelling is possible, as we shall see later.

Let us elaborate on the meaning of these various ways of treating uncertainty. First we shall present what is derived from the scenarios. Each scenario characterises a situation that is deemed probable. Building consistent scenarios is always tricky, but a discussion with practitioners can lead to a better understanding of all the various configurations. A second way of factoring in the non-deterministic nature of the future is to simulate events. Here we use Monte Carlo simulation methods. It is therefore important to incorporate correlations between future events, such correlations being crucial to obtaining realistic scenarios. In this case, the future is seen as a set of possible trajectories (several hundred thousand simulations are needed to yield significant results, from which relevant information must be derived on the basis of indicators).

In the presence of uncertainty, min-max or minimal regret criteria can be used as well.

Whatever its nature, the treatment of this uncertainty must be looked at critically. Presumably, it is necessary to be able to obtain the most probable modelling value for which these uncertainties can be translated into low and high ranges associated with the results obtained (see the example presented in Table 3.1).

Table 3.1. **Simplified form of modelling results**

	Lower range	**Most probable value**	**Upper range**
Accessibility			
Agglomeration effects			
Own dynamic			

Indices that are more elaborate can provide a better representation of the risk. These notions are the "value at risk" or the "conditional value at risk", which entail calculating the distribution of infrastructure rates of return. It should be noted that in the presence of risk or uncertainty, basic notions such as the internal rate of return are less able to remain operational in the presence of substantial fluctuations.

The presence of fluctuations raises questions about the bias that the "averaged" vision of the results may introduce. For example, let us take the case of a LogSum function, represented here as Ω(C), which hinges on the transport cost vector *C*. Numerous studies use the average cost, without reporting on the amplitude or value of the biases generated.

And yet it is easy to demonstrate that the use of LogSum in cases where costs are random will introduce a positive bias, i.e. that:

$$E\big(\Omega(\mathrm{C})\big) > \Omega(\mathrm{E}(\mathrm{C}))$$

This inequality results from Jensen's inequality and from the fact that LogSum is a convex cost function. In other words, accessibilities are underestimated when stochastic costs are replaced by average costs in accessibility formulas.

To summarise, if uncertainty is to be integrated consistently, the sources of uncertainty should be identified during the modelling process, and results should be presented with confidence intervals; indicators of results should be tailored to the degree of variability of measurements; and the direction and amplitude of bias should be controlled when deterministic variables are replaced by average values of random variables.

In conclusion, let it be noted that deterministic descriptions can, under certain conditions, be meaningless (see Mansour and de Palma, 1984). These authors show that by taking the stochastic version of a deterministic process, one can obtain a probability distribution, the least probable values of which correspond to the solution to the deterministic problem. The scope of interactions determines these conditions.

Proximity effects

Three types of proximity effects can be discerned:

(1) The profitability of business enterprises depends on the proximity of labour. Microeconomic theory suggests that salaries should in fact be adjusted to labour transport costs.

(2) Business productivity diminishes with the proximity of other businesses in the same category, given price competition.

(3) Businesses nonetheless tend frequently to select nearby locations. Technological spillovers depend on spatial proximity: exchange of information is in practice heavily affected by spatial proximity. Here, agglomeration forces are at work.

We shall see below how these ideas were factored into integrated land-use and transport interaction (LUTI) models. This list will remain incomplete as long as agglomeration effects are not factored in.

5. Agglomeration effects

Introduction

Cities are formed by combining two types of force: agglomeration effects and "disagglomeration" effects. Disagglomeration effects are simple to describe and to quantify. They are responses to negative externalities generated by high levels of congestion associated with local pollution, noise and accidents. These effects are factored into existing transport models. Their incorporation into mobility and residence choices poses difficult but solvable econometric questions.

Remarkably, the situation is more complex when one speaks of agglomeration effects, which respond to positive externalities. Agglomeration effects correspond to an increase in business productivity (or a decrease in costs) as a function of the concentration of agents (see, for example, Anas, Arnott and Small, 1998). These effects, while real, are ill-defined. They are often hidden behind the benefits of face-to-face contact (which will be difficult to explain to the Internet or teleconferencing generations). One might ask why this present ITF Roundtable could not have been organised as an exchange of articles to be annotated. But watch out: this may be just what will happen ten years down the road.

Moreover, the established fact of the existence of clusters of innovative businesses would suggest that it is in these firms' interest to locate in a common neighbourhood. This is true of the Research Triangle in North Carolina, which houses nano-technology firms, of Massachusetts Route 128 near Boston, and of Silicon Valley in the San Francisco Bay. The development of these three clusters and their induced regional effects were made possible by geographical proximity and local synergies: how, for example, could funds be raised and "business angels" found if young entrepreneurs have no opportunity to present their ideas in person? Employees have similar needs in terms of schedules, schools and so forth, which induces agglomeration effects. Clearly, Internet makes it possible to send e-mails to all ends of the earth for the same price, and yet the fact remains that many e-mails are sent locally. Space induces the organisation of economic activities. And if local masses in turn modify spatial distances, this effect confirms, and does not contradict, the critical role of location.

These clusters, which are also to be found in *Grand Paris*, will be fully meaningful only if they trigger regional development; conversely, the neighbouring regional and urban densities encourage the development of clusters. *Grand Paris* deploys a complicated equation, linking accessibility, urban development and technology clusters[9].

Empirical estimation

If P is productivity and C is urban concentration (often associated with densities), then the elasticity of productivity with respect to urban concentration is:

$$\epsilon = \frac{\frac{\Delta P}{P}}{\frac{\Delta C}{C}}$$

This elasticity is the ratio of the variation in productivity to the variation in urban concentration. If the elasticity is positive, it reflects agglomeration effects. Of course, this formula does not stipulate why these agglomeration effects are produced (via face-to-face, pooling of knowledge, espionage, technological spillovers, etc.).

Nevertheless, recent studies have shown that elasticities have often been overestimated: the gain in productivity that is observed in an urban environment, attributed to agglomeration effects, may stem from the fact that workers who are more highly skilled are attracted more by dense urban areas.

This hypothesis was tested by De La Roca and Puga (2010), who showed that if the worker effect is kept constant (by controlling the skills level of individuals), the elasticity of productivity with respect to density is lower.

These authors also discussed productivity gains as a function of time and location history. They concluded that some of the effects attributed to location result from a learning curve, as shown by the continuous growth in gains related to skill. They also show that these benefits are, in part, geographically mobile, as illustrated by the partial disconnect in salaries: e.g. a decrease for a worker migrating from Madrid to Santiago, who will still be paid more than workers in Santiago.

The productivity differs in the Ile-de-France, for several reasons. They differ by sector, partly due to the fact that the densities vary, and are stronger in the core than in the periphery. Assume, for example, that one expects the creation of 500 000 jobs in the Ile-de-France as a consequence of the *Grand Paris* project. Given that the current employment figure is over 5.2 million, with the *Grand Paris*, the density of jobs will increase by about 10% and, consequently, the productivity of existing jobs will also increase. The elasticity of productivity with respect to density is in the order of 2% (we thank Pierre-Philippe Combes and Miren Lafourcade for providing the figures on agglomeration economies). This means that a 10% increase in the density of workers will increase productivity by about 0.2% (which translates into a little more than 1 billion euros). Where these gains will take place, how fast and in which sectors, remain open issues.

Agglomeration effects in LUTI models

- RELU-TRAN. According to Alex Anas[10], there are three different kinds of agglomeration effect in RELU-TRAN. The concentration of the activities of agents (businesses or households) is determined by spatial heterogeneity (for example, in-homogeneities inherent in transport networks); by interdependency between economic agents (who are dependent on transport costs, which increase with distance); and by positive synergies between agents (households and businesses that reap greater economies of scale, for example, if they serve larger markets).

- UrbanSim(E). Agglomeration effects can be incorporated into UrbanSim(E) in sub-models for the location of households and businesses.

For households, econometric analysis shows that residential location criteria depend on amenities, but also on population densities. Analysis of the data shows that households are sensitive to local densities, but also to the make-up of the population. This would imply that these models may potentially produce non-linear dynamics (see Section 3) and bifurcations. Basing their work on the interactive Markov chains approach, de Palma and Lefèvre (1983a and 1983b) studied the impact of positive and negative externalities in connection with a theoretical discrete choice model. Factoring agglomeration effects for businesses into UrbanSim(E) is possible but has not yet been done.

6. Econometric precautions[11]

The multinomial logit model and sampling of the alternatives

To estimate agent location models (for households or businesses), a multinomial logit model is used frequently (see Ben-Akiva and Lerman, 1985 and Anderson, de Palma and Thisse, 1992). According to this model, the probability that agent *i* locates in area *j*, offering local amenities Z_j, is given by the following formula:

$$\mathbb{P}_j^i = \frac{e^{Z_j \beta_i}}{\sum_{j' \in \mathcal{J}} Z_{j'} \beta_i},$$

where β_i is a parameter vector corresponding to the marginal utilities of local amenities (preferences specific to household *i*). This vector can be dependent on the characteristics X_i of the household to reflect the observable heterogeneity of preferences; it can include random terms corresponding to the non-observable heterogeneity of preferences. In this latter case, one speaks of mixtures of polytomic logit models, of which random coefficient models are among the most commonly used.

Ideally, local amenities are measured at a narrowly-defined geographical level corresponding to a commune, an IRIS[12] or a neighbourhood. In some cases, there are too many options *J* to be able to estimate the model described by the multinomial logit model. This problem can be circumvented easily thanks to the option sampling technique: a small set of areas ϑ_i (typically about ten) are chosen at random, and for each household *i* the probabilities for this option subset are estimated:

$$\tilde{\mathbb{P}}^i_j\left(\mathcal{J}_i\right) = \frac{e^{Z_j\gamma_i}}{\sum_{j'\in\mathcal{J}_i} Z_{j'}\gamma_i}.$$

This procedure is both realistic from a behavioural standpoint and manageable econometrically. Assuming the independence of irrelevant alternatives (IIA), the parameters γ_i estimated with option sampling constitute unbiased estimators of the parameters β_i corresponding to the case in which each household's full range of choice is universal.

If the number of dwellings is unequal from one area to another, a correcting term corresponding to the size effect $\log(N_j)$, where N_j represents the number of dwellings in area *j*, should be added to the list of local amenities. If one disregards the individual characteristics of dwellings, which are generally not observable, the dwellings of any one area may in fact be considered similar (hence the advantage of selecting sufficiently small areas). In this case, all of the dwellings in area *j* have the same probability of being chosen by a given household *i*. Noted $\bar{\mathbb{P}}^i_k$, the probability that household *i* would choose a dwelling *k* located in area *j* (local amenities therefore equal $Z_k=Z_j$) equals:

$$\sum_{k\in j}\bar{\mathbb{P}}^i_k = \sum_{k\in j}\frac{e^{Z_k\beta_i}}{\sum_{j'\in\mathcal{J}}\sum_{k'\in j'} e^{Z_{k'}\beta_i}} = N_j\frac{e^{Z_j\beta_i}}{\sum_{j'\in\mathcal{J}} N_{j'}e^{Z_{j'}\beta_i}} = \frac{e^{Z_j\beta_i+\log\left(N_j\right)}}{\sum_{j'\in\mathcal{J}} e^{Z_{j'}\beta_i+\log\left(N_{j'}\right)}}.$$

In the above expression, the coefficient of $\log(N_j)$ is equal to unity, but that constraint disappears when the variance of the residuals is normalised to $\pi^2/6$, as is customary in a multinomial logit model. Moreover, households may have preferences for the size of the area, measured by $\log(N_j)$, which constitutes an additional reason for not normalising the coefficient of $\log(N_j)$ to one.

If dwellings are distributed unequally from one area to another and one wishes to draw options at random, the efficiency of estimations can be improved by the importance sampling technique, which consists of drawing options with a probability proportional to N_j.

Embedded logit model

Assumption IIA is generally subject to caution in a location model. It is tantamount to assuming that if an area that had a 10% probability of being chosen by household *i* becomes inaccessible, then the probability of each of the other areas increases by an equal amount. But it is known that some areas are more substitutable between themselves than others and that when one area becomes inaccessible to a given household, the probability that the household will locate to another area increases more than proportionally in respect of areas that are more substitutable, and less than proportionally in respect of areas that are less substitutable. A simple solution is to construct an embedded logit model in which this household chooses a neighbourhood of a commune in an area: if this neighbourhood turns out to be inaccessible, the choice will shift to another neighbourhood of the same commune, etc. Observation shows that when households relocate they have a strong tendency to remain in the same *département* (see de Lapparent, de Palma and Picard, 2011).

Endogeneity of prices in a location model

An increase in local demand for housing triggers a rise in property prices. Conversely, all else being equal, an increase in local property prices causes the local demand for housing to decrease. When one wishes to estimate the price elasticity of demand for housing, one is therefore naturally confronted with the problem of the endogeneity of property prices.

In the presence of endogeneity, one simple solution is to make use of instruments – in this case the variables that influence property prices but have no direct effect on demand at fixed property prices. Yet all local amenities are necessarily going to influence property prices and demand for housing at constant property prices. It is therefore difficult to find an instrument in this context. In the event that housing and offices are in imperfect competition for land use, one might suppose that local taxation of businesses (but not of households) would be a potential source of such instruments.

7. Conclusions

The scope of research into the economic and social dimensions of *Grand Paris* is now open. The initial results of LUTI models are expected in the coming months. It will be interesting to compare these findings with those obtained in respect of other comparable large metropolitan areas, such as London, Moscow, New York, Tokyo or Beijing. The project's broad outlines having been finalised and approved, what remains to be done, above all, is to find ways to turn this adventure into a series of surprises and favourable encounters.

The diversity of the players mobilised by this idea whose time has come inspires some optimistic – or at least mystical – ideas.

It is a known fact that one of the ideas pervading civic-minded discussions is yet another idea that seems like it could come straight out of thermodynamics: *Density can be measured; intensity is felt*. If social diversity, access to housing and work and the visibility of urban landscapes are still attainable goals, it is because we are lucky enough to live in a part of the country that is blessed with a wealth of diverse and varied capabilities, where it will not be true that there is not enough for everyone.

If we are to be receptive to these visions of the future, let us conclude by reiterating our three rules for proper use. Attentive readers will unfortunately have understood that they hardly give us any other choice except between the cane of the blind man's wanderings along the water's edge, the prospects of the boundless sea of destiny beheld by the diver, or the cautious – if not mistrustful – toe of the tourist occupied with prying on other bathers.

In a period of instability, subject as everyone is to strong non-equilibrium constraints, be they politicians, managers or entrepreneurs, the researcher – if unable to yield to the signs he thinks he can read in the stars or to heed the call of his destiny – will endeavour to see which way the wind is blowing.

The psalmist, who knew a thing or two about lines in the sand and grandiose destinies, was wise enough to stay mum before undecipherable and deceptive futures:

Thy way is in the sea, and thy path in the great waters, and thy footsteps are not known.

With respect neither to the past, which we attempt to decipher, nor to the future, which we strive to construct, are we assured of knowing where and how our efforts meet the reality of collective processes. This harsh conclusion is imperative each time we proffer the results of a calculation.

Notes

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2. These represent 70% of motorised trips in the Île-de-France. In addition, the modal share of public transport within the Paris city limits is 64%, versus only 23% and 10% in the inner and outer peripheries, respectively.

3. According to INSEE, independently of this project, one million additional people would be living in the Ile-de-France in 2030 if recent demographic and migratory trends continued (Leon, 2006).

4. For the Arc Express project (60 kilometres long), the estimated cost is EUR 5 billion for the priority sections (north and south) and EUR 6 billion for the entire beltway.

5. It will be noted that this type of bidding mechanism is at the core of the urban general equilibrium model, MUSSA (this mechanism being explained by Martinez, 1996).

6. However, see the historical note by Dos Santos and Thisse (1996) on W. Launhardt, Hotelling's predecessor back in 1885.

7. Pierre Mongin, one of the *Grand Paris* stakeholders, recently stressed the fact that it was essential to model a city as an open system.

8. http://www.wmaker.net/grandparis/Les-7-poles-de-developpement-du-Grand-Paris_a277.html.

9. See also the reports from ITF Round Table 140, *The Wider Economic Benefits of Transport*, in particular by D. J. Graham and G. Weisbrod/B. Alstadt: www.internationaltransportforum.org/Pub/pdf/08rt140.pdf.

10. *Source*: slides prepared by Alex Anas for *Grand Paris* in 2011: A Regional Economy, Land Use and Transportation Modl, RELU-TRAN. and Transportation Model, RELU-TRAN.

11. Readers less familiar with technical issues may skip directly to the last section.

12. There are 1 300 communes and 5 200 IRIS in the Île-de-France.

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Chapter 4

Maintained Hypotheses and Questions in Search of Answers

Marc Gaudry[1] and Émile Quinet[2]

Abstract

We propose a series of kick-off points related to the economic appraisal of large urban infrastructure projects, taking some account of the specifics raised by the Grand Paris Express (GPE) regional automatic metro. The points, in the form of Maintained Hypotheses or Question in Need of Answers, are crystallised around three orientations: demand model properties; overall effects of urbanisation; extensions of traditional appraisal.

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1. Introduction: From a partial towards a more global analysis

A partial analysis carried out at the margin

Traditional project analysis is built on demand modelling and the derivation of consumer surplus assumed to correctly account for social surplus if the rest of the economy functions optimally. In the case of large projects, this partial analysis, limited to the transport market, becomes insufficient to capture their consequences, due to numerous sources of non-optimality.

This economic analysis, in fact, assumes that the projects build at the margin. Limited to demand analysis, it focuses on the mode and itinerary choice stages. It deals somewhat cursively with the generation and distribution stages, often reduced to the constancy of the origin-destination matrix and concerned primarily with home-based work trips.

The equivalence of consumer and social surpluses

In terms of appraisal, excepting accounting for externalities, the core of the analysis is the estimation of consumer surplus. The latter is a correct sum of transformations to the economy attributable to the project if, and only if, the rest of the economy is at an optimum, an hypothesis never holding strictly but positively failing in the case of large urban projects.

The specifics of large urban projects

First and foremost, the non-marginal nature of large urban projects realistically implies the existence of induced demand, making the assumption of the constancy of the origin-destination matrix untenable, even in the short term.

Moreover, such projects imply, in the medium term, relocations and transformations of urban structures (Thisse, 2011). Such transformations occur very differently from expectations of perfect competition and pricing, to say nothing of the optimal management of public goods. For instance, housing markets are notoriously imperfect, with large sections determined by the redistributive preferences of public authorities. In addition, some positive externalities are generated in urban areas alongside the traditional negative ones: agglomeration effects bias the traditional calculus.

It is also the case that large projects have a probably longer life than small ones, if only due to their greater resistance to random shocks[1]. Taking the distant future into account adds to these difficulties because it requires more a prospective analysis than a forecast, however well-reasoned out, of current trends.

In these conditions, partial analysis cannot account for the consequences of the project and traditional cost-benefit analysis breaks down (DfT, 2008).

It should be added that the specifics of the decision process also have their role. It involves — even more that for intercity projects — numerous parties among whom the decision is collective and combines mutually agreed and random components: users, associations, pressure groups, public authorities. Governance is itself fragmented with diverging components largely configured by the institutional framework[2].

Under these conditions, the principles of economic appraisal have to be reconsidered, In terms of positive knowledge, demand modelling has to be reviewed and the links between transport and the economy made explicit, a job avoided when the optimality of the economy could be assumed as an approximation. At the normative level of decision-making, cost-benefit analysis has to be adapted to the specifics of the decision process.

To develop an analysis of the effects of the project on the economy, it is necessary to solve at least the problems listed in this kick-off document, making sure to exercise due care with respect to the specific characteristics of the "Grand Paris Express" (GPE) automatic metro.

We successively discuss demand modelling, the effects on urban structure and modifications required of traditional appraisal methods.

2. Demand models

Demand models determine derived transport flows under the assumption of given activities. Four dimensions of large investments threaten this exogeneity: the relevant markets in fact affected, the representation of public transport (PT) options within the model structure, the properties of assignment algorithms and the form of utility functions.

Relevant markets: do only home-based peak time work trips exist?

As in many other cities, the current demand models used for Paris, ANTONIN-2 (Stif, 2004) and MODUS-2 (DRIEA-IF, 2010), are still very much based on the 50-year old Chicago Area Transportation Study (CATS, 1959-1962) ambiance and primarily focus on peak-hour work trips. An updated framework is needed.

This means that urban travel and O-D surveys must deal with trip purposes other than work. This is done quite often in many cities for shopping trips but extremely rarely for, say, tourism, personal trips and off-peak travel, week-end and holiday trips. Contrary to intercity markets, where rapidly changing prices and low-cost services allow for and contribute to the development of new and longer trips by making frequency[3] and destination choices fill planes, urban market analysis is chained to the work trip AM peak, to fixed fares and to the absence of service innovation despite the apparent occasional success of many one-day, free-fare experiments showing the potential for non-work trips.

We will not deal here with transit market structure issues, but public transit boards (*Autorités organisatrices* in France) seldom favour the development of alternate dial-a-ride small buses, collective taxis (jitneys) or innovative, low-cost transit services based on part-time labour and private entrepreneurship[4]. Current demand models naturally reflect the regulated suppression of low-cost innovative urban transit alternatives and of other privately supplied service developments that might flourish if the problem formulation extended beyond that of the morning peak commute served by regulated monopolies.

Shannon's measure and the logsum to avoid underestimation of demand and surplus

As the prevailing mode choice models are Logit, logsums[5] should long have been used to explain trip frequency in equations (aggregate of discrete) where it should represent the utility of PT supply, as they generally are in intercity markets.

But danger lurks in standard practice, which deals reasonably well with mode choice but fails to give a proper representation of the transit and road networks. As both modes are characterised by multiple paths between origin-destination pairs, it is frequently the case that ***weighted averages of path characteristics*** are used in the demand or mode choice model. It can be then shown that:

(i) **Daly's positivity condition**: if p_c is the choice probability of path *c*, modifications of V_c, the utility of path *c* (for, say, the train mode), can lead to changes of opposite sign in $\overline{V_p}$, the probability weighted utility (of all train paths), with dire consequences for the mode choice or demand model if requirement $V_c - \overline{V_p} > -1$ fails (as it often does) and Daly's (1999) positivity condition is not met:

(1) $$\left[\partial\overline{V_p}\big/\partial V_c = p_c(1+V_c-\overline{V_p})\right] > 0 \;;$$

(ii) **A path aggregation theorem**: the difference between a logsum measure of the utility of multiple path use and an average measure built from probability weighted characteristics is exactly equal to Shannon's measure of information, corresponding to minus-one times entropy (Gaudry & Quinet, 2011):

(2) $$\overline{V_p} - \ln\sum\nolimits_i \exp(V_i) = \sum\nolimits_i p_i \cdot \ln(p_i)\,,$$

A path aggregation theorem (PATH) is a special case of a more general formulation, whereby all weighted averages of paths' characteristics (with weights normalised to sum to unity) always underestimate the utility of multiple path use, and this independently from the mathematical form of the V_i Logit utility functions of the path alternatives: this is a matter to be addressed shortly.

Use of weighted averages of path characteristics instead of path aggregation means that demand and mode choice models become insensitive – and even misleading should (1) fail – precisely where the GPE project would make important changes. There is no way GPE economic benefits can be demonstrated if models exclude a valuation of plurality and limit themselves to path averages.

Some urban models have attempted to handle the choice among transit paths by substituting for Multinomial structures the insertion of a hierarchical PT layer, where the utility of some "higher" transit modes is summarised by their logsum and "lower" transit modes merely serve as their access means. This is, for instance, the case in SAMPERS for Stockholm (Transek, 1999) and in PRISM for Birmingham (Rand Europe, 2004), as illustrated in Figure 4.A1.1 of the Annex where this recent innovation is discussed. The construction of such hierarchies among PT modes, still a rare occurrence despite long-established hierarchies among modes, could mitigate Shannon aggregation error arising from the use of path averages. However, as explained in the Annex, it is still by no means fully satisfactory, even under the assumption that it makes sense in cases of plethoric PT supply, such as in the Paris region, where some ten PT modes are present and commonsense rather suggests use of a multinomial structure to explain choice among transit paths.

Assignment: do equilibrium algorithms have a unique solution? Are they sensitive to the network loading sequence? Should Wardrop be abandoned?

A blind eye to Dafermos' critique

Path costs are always generalised costs. If equilibrium methods are used to model path choice, two acute problems arise. First, even in the simple case where time and cost intervene linearly, user equilibrium is unique only if users have a single value of time or if the ways cost and time change with flow on each link are identical (Dafermos, 1983). Moreover, as in Wardrop's equilibrium link flows are unique but itineraries are unknown and not analytically derivable from the optimal solution[6]. The uniqueness and reproducibility of solutions (even before raising the issue of path aggregation) must be explicitly considered for any generalised cost assignment; in particular, the solution must be independent from the loading sequence of the network.

The slow death of Wardrop user equilibrium

Under these conditions, and given the necessity of identifying all itineraries effectively used in conformity with the above-mentioned path aggregation theorem (PATH), one should expect a movement of analysts and commercial programmes away from equilibrium assignment and towards the use of Logit-based assignment: a case in point, the forthcoming EMME 3 programme (Florian & Constantin, 2011) should include a Logit transit path choice, an option already found in Cube Voyager (Citilabs, 2008) and VISUM (PTV AG) packages, the latter of which includes a nonlinear option, such as Kirchhoff's distribution formula (Fellendorf & Vortisch, 2010), equivalent to Abraham's Law in France, as well as Box-Cox specifications.

Linear restrictions on the form of utility functions should be dropped for significant LOS changes

Curvature and thresholds: is marginal utility really constant?

For demand models applied to large projects, the ability to deal with cuts in transit travel time by half among large numbers of non-CBD oriented origin-destination (OD) pairs, or other major changes in the Level of Service (LOS), is fundamental. Such decreases in travel time raise the possibility of so-called modal split "thresholds" perhaps undetectable if changes were made not all at once but successively. Matters of demand curvature become unavoidably critical when non-marginal changes in transport conditions are considered.

Do thresholds or, more properly stated, asymmetries of Logit response exist?

Assignment is multivariate, but do the variables appear linearly in utility functions? Most specifications of LOS variables used by Logit practitioners are in fact nested special cases of the Box-Cox transformation (BCT), usually applied to any strictly positive variable Var_v:

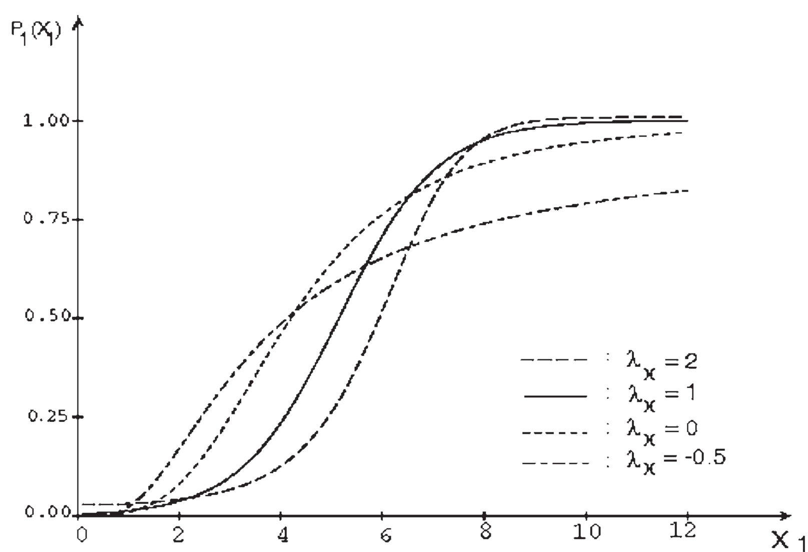
(3-A) $$Var_v^{(\lambda)} \equiv \begin{cases} \dfrac{(Var_v)^{\lambda} - 1}{\lambda} \quad , & \lambda \neq 0, \\ \ln(Var_v) \quad , & \lambda \to 0. \end{cases}$$

and notably to the variables of interest for transport project appraisal, primarily Time (for passengers) and Fare (for freight), present in the random utility function (RUF) which can then be written explicitly:

(3-B) $$V_i = \beta_{i0} + \sum_k \beta_{ik} X_{ik}^{(\lambda_{ik})}$$

As already mentioned above, non-linearity, as illustrated in Figure 4.1 for the binomial case, means that the reaction curve to improvements in variable X_1 associated with alternative 1 will be asymmetric with respect to its inflexion point: it would be symmetric with an inflexion point at $p_1 = 0.50$, only if the data supported for (3-B) the unlikely assumption of constant marginal utility $\lambda_{ik} = 1, \text{ for } \forall i, k$:

Figure 4.1. **Classical Linear-Logit *vs* standard Box-Cox-Logit responses**



Asymmetry is therefore vital, given that in forecasts of important changes in LOS everything is, so to speak, in the curvature, to the extent that there is no real disagreement on what the important variables are and in view of the fact that the LOS changes considered are far from marginal[7], consisting, for instance for the GPE, in a division by two of travel time.

In fact, the asymmetric logarithmic response, implying a curve situated above that of the linear response for [1 < X_1 < 5.5] in the case illustrated in Figure 4.1, prevailed in the careful Logit empiricism justified by the seminal foundation paper of Random Utility Models (Abraham, 1961)[8] formulated precisely for path choice analysis, as it did in the first mode choice analyses (Warner, 1962). It is reasonable to think that the first Paris-Lyon TGV line services exhibited this type of response, where the forecasted change in market share (as one goes from 2 to 4) amounts to many times that of the linear model built from the same variables.

If one prefers a Mixed Logit specification, it could be argued that, if regression coefficients have distributions, forms of the variables should, in all logic, have them as well: in fact it has been shown that Mixed Logit specifications might often work precisely because the underlying utility is nonlinear: Orro *et al.* (2005, 2010) have indeed demonstrated with Box-Cox Mixed Logit model simulations (using two BCT, on Fare and Travel time) that the recent popularity of the Multinomial Mixed Logit may well be due to the fact that the true relationships are not linear and should have their curvature estimated rather than postulated, as many micro-economists might have long suspected.

The Box-Cox Logit record in urban areas, including six for Paris

But do response asymmetries exist in urban markets, and is marginal utility constant in *Gai Paris*? Every time the form of urban mode choice utility functions have been tested by BCT, except for the very special BART[9] case (McCarthy, 1982), linearity has been found wanting, as demonstrated in summary Table 4.1, as follows:

i) **Absolute values of BCT in urban markets**: wherever the BCT for Time and Cost were tested without an equality restriction, the BCT on Time λ_{Time} was greater than unity and that on Cost λ_{Cost} is smaller than unity. The first result, $\boldsymbol{\lambda_{Time} > 1}$, means that the slope of the demand curve decreases (flattens) at an increasing rate with Distance for Time, in contrast with Cost where the demand falls (flattens) at a decreasing rate with Distance, because $\boldsymbol{\lambda_{Cost} < 1}$;

ii) **Marginal utility of time and money is not constant, even in *Gai Paris***: the previous observation holds in particular for the five models for the Paris region[10] (Models 20, 21, 32, 33 and 34 in Table 4.1);

iii) **Contrast with intercity models**: the results of Table 4.1 in fact come from a survey of some fifty urban and intercity models where BCT were used on more than one LOS variable of the modal utility function (Gaudry, 2011). In the intercity models, all estimated from Revealed Preference (RP) data, one generally finds the opposite result on the absolute value of the BCT on Time, namely $\boldsymbol{\lambda_{Time} < 1}$.

Are suburban trains and subways slow high-speed trains?

If this result holds in further cases less centred on work trips than those documented in the Survey, one will have found a structural difference between urban and intercity markets – the speed at which Time demand sensitivity falls with respect to Distance: at an increasing rate in urban markets and at a decreasing rate in intercity markets[11]. This would mean that suburban trains and metros are not slow TGVs and that TGVs are not fast suburban vehicles.

Table 4.1. **BCT estimates for Time & Cost variables in discrete RP urban Logit passenger models**

Column		***1***	***2***	***3***	***4***	
Time and Cost terms; expense specification						**Source**
Sydney (2 modes)	**Purpose**	λ_{Tww}	λ_{Tveh}	λ_{Fare}	$(\lambda_{Time}-\lambda_{Fare})$	**Hensher & Johnson, 1981;** see (2)
CBD trips (car and train)		see (1)				
17. Northern suburbs (1971)	Work	1 000	0.50		0.00	Table 1, Col. 1 (μ_k = 001)
Washington, DC (2 modes)						**Koppelman, 1981**
18. City-wide (1968)	Work	2.57		0.56	2.01	Table 2, Col. 6
Paris region (6 modes)						**Gaudry, 1985**
19. City-wide (1976)	Work	1 000	0.50		0.00	Table 3
						Hivert *et al.*, 1988
20. Orly airport origin (1986-1987)	Private	1.08	1.08	0.42	0.66	Model 5.2, p. 46
Paris region (2 modes)						**Lapparent, 2004**
21. City-wide (1997, 11 variables)	Work	1.19	1.19	-0..9	2.08	Table 4.8, p. 135
Santiago de Chile						**Pong, 1991; and Gaudry, 1994**
A-1. CBD corridors (9 modes)						
22. Las Condes & San Miguel	Work	**0.13**	**1.37**	**-0.56**	**1.93**	Series I-B-G; see (3)
B-1. City-wide 1991 (11 modes)						**Parra Granifo, 1995**
23. Peak AM trips 7:30-8:30	Work	0.32	1,000	0.82	0.18	Table 4, Col. 1; see (4)
24. Off-peak AM trips 10:00-12:00	Work	0.31	1,000	0.69	0.31	Table 4, Col. 2; see (4)
25. Peak AM trips 7:30-8:30	Study	0.21	1,000	-0.01	0.20	Table 4, Col. 3; see (4)
Time terms and [Cost/Income] ratio term; expense specification						**Pong, 1991, and Gaudry, 1994**
A-2. CBD corridors (9 modes)	**Purpose**	λ_{Tww}	λ_{Tveh}	$\lambda_{F/s}$	$(\lambda_{Tveh}-\lambda_{F/s})$	
26. Las Condes & San Miguel	Work	**0.12**	**1.30**	**0.55**	**0.75**	Series I-A-G
						Gaudry *et al.*, 1989
27. Las Condes (1983)	Work	0.44	1.56	0.23	1.33	Footnote 3 p. 156
28. Adding San Miguel (1985)	Work	0.33	1.57	0.60	0.97	Footnote 3 p. 156
B-2. City-wide 1991 (11 modes)						**Parra Granifo, 1995**
29. Peak AM trips 7:30-8:30	Private	0.46		0.53	-0.09	Table 4, Col. 5; see (6)
30. Off-peak AM trips 10:00-12:00	Private	0.54		0.64	-0.10	Table 4, Col. 6; see (6)
31. Off-peak AM trips 10:00-12:00	Study	1.00		0.25	0.75	Table 4, Col. 4; see (6)
Time terms and [Income - Cost] difference term; expense specification						
Paris region (2 modes)	**Purpose**	λ_{Tww}	λ_{Tveh}	$\lambda_{(I-F)}$	$(\lambda_{Tveh}-\lambda_{(I-F)})$	**Lapparent *et al.*, 2002**
32. City-wide (1997, 5 variables)	Work	1.17	1.17	-0.03	1.20	M-2 model; see (8)
						Lapparent, 2002
33. City-wide (1997, 5 variables)	Work	-0.05	1.11	0.07	1.18	M-2 model, p. 27;
						Lapparent, 2003
34. City-wide (1997, 16 variables)	Work	1.07	1.07	0.85	1.92	Table on page I; see (9)

(1) The value 1 000 denotes an untransformed variable appearing linearly in a model.
(2) In a previous analysis based on a single suburb subset (Hensher & Johnson, 1979), the authors had found an optimal BCT value of 0.05 close to the logarithm but with a linear-probability model, not a Logit model.
(3) The income measure used is the net hourly wage rate.
(4) The Time variable denotes walk time.
(5) The Fare is divided by the net hourly Wage rate, in accordance with the Train-McFadden (1978) specification.
(6) The Time variable is a generalised time with weight of 1 for In-vehicle, 2 for Walk and 4 for Wait times.
(7) The Net Income term is obtained by subtracting Cost from Income.
(8) In Model 32, an equality constraint is imposed on the coefficients of total Time elements; it is relaxed in Model 33.
(9) In Model 34, eight socio-economic dummy variables are added to the specification of Model 33. In consequence, the BCT on the Net Income variable becomes 0.85, i.e. almost linear and not significantly different from 1.

Value of time and small changes in trip Time or Fare

Consider the typical modal utility function estimates for a mode, say rail, containing at least Time and Fare, and replace these expense terms by Distance, Price and Speed, keeping the maximum likelihood estimates of the β and λ parameters. The value of time (VOT) may then be written in such a way as to bring out the role of Distance *D*:

$$(4) \quad VOT \equiv \frac{\partial T_{rail} / \partial X_{rail,\,Time}}{\partial T_{rail} / \partial X_{rail,\,Fare}} = \frac{\beta_{rail,\,X_{Time}} X_{rail,\,Time}^{(\lambda_{rail,\,X_{Time}}-1)}}{\beta_{rail,\,X_{Fare}} X_{rail,\,Fare}^{(\lambda_{rail,\,X_{Fare}}-1)}} = \frac{\beta_{rail,\,X_{Time}} \left[V_{rail,\,Speed}^{-1}\right]^{\lambda_{rail,\,X_{Time}}-1}}{\beta_{rail,\,X_{Fare}} P_{rail,\,Price}^{\lambda_{rail,\,X_{Fare}}-1}} D_{rail}^{\lambda_{rail,\,X_{Time}}-}$$

.

Interestingly, the same survey shows that one finds **(λ_{Time} - λ_{Fare})** > 0 in both urban and intercity models; namely, a value of time (VOT) that increases with distance[12]. The few cases where this does not seem to be true pertain to countries where average intercity distances are very long (Canada and Sweden) and perhaps to trip purposes other than work. It is therefore of some import to decide if this finding of a VOT that increases with Distance holds for all urban trip purposes.

In any case, the BCT solves the old question of whether small gains in travel time should be valued in the same way as large ones: the VOT in (4), never constant, varies continuously with Distance (trip length).

3. Effect on the agglomeration as a whole

Ed Mills' optimal city should be taken up and updated

As pointed out long ago by Martin Beckmann, an optimal city would have an endogenous network topology but also other dimensions, notably the third, that of height. Circular, homogeneous cities, where all jobs are in the CBD, are of little interest to reproduce the three dimensions of cities, where various regulations and constraints apply to the solution, the network topology is also limited and the production functions are highly varied.

Such requirements are apparently only met by Ed Mills' approach (1972, 1974) where all activity levels, including transport flows with congestion, are optimally assigned in a three-dimensional city. As there is a proper maximisation formulation with constraints, a total cost for the city exists, as do optimal heights of all buildings and shadow prices for rents by floor. Also, the optimal assignment varies with the production technology and various activities can have specific production functions that may change over time. Amazingly, although enriched by taking multiple transport modes into consideration (Kim, 1978) and by many other developments (Moore II & Kim, 1995), it never bloomed into a full urban simulation tool and it is fair to say that its absence is sorely felt today.

Current work on carbonless cities might provide an occasion to treat greenhouse gas emissions as parts of the production functions rather than as an add-on external cost without consistency and own productivity.

How to move forward with LUTI models? Polycentricism, aerotropolism and a comparison of their operational dimensions

There exist numerous models coupling transport supply, land use and the distribution of economic activity, and they have been classified with care [cf., for instance, Waddell *et al.* (2007); Bröcker and Mercenier (2011); or Wegener (2011)], allowing for distinctions based on their main hypotheses.

One of the most significant distinctions for appraisal purposes appears to be between simulation and equilibrium models. In the former (properly called LUTI), the interaction between transportation and land use is iterative: these models are by definition dynamic – the adjustments of transport, land prices and location occurring at different model stages – and there is no equilibrium in the strict sense of the term. By contrast, general equilibrium models, based on microeconomic assumptions, allow for comparative static analyses.

Their respective advantages and handicaps have been analysed, for instance, in de Palma (2011) and in de Palma & Beaude (2011). For appraisal purposes, dynamic models are difficult to calibrate and, in the absence of equilibria proper, fit with difficulty in a cost-benefit framework. General equilibrium models describe two fictitious situations – with and without the project – in the absence of any certainty that the time path between them is achievable. A theoretical study might of course go further than these intuitive judgments and could provide useful insight on such comparative advantages.

Polycentrism

In particular, one might wish to verify the extent to which LUTI models can simulate the development of poles situated on GPE-type intersecting Great Circles, where the territory common to both circles consists in a central zone (that of Paris) characterised by strict height, size and road access restrictions. This ability is fundamental if one might move away from a configuration whereby poles are mere satellites dependent on the central location.

Aerotropolism

To obtain a complete appraisal, and incorporate the impact of a qualitative jump in the international competitive position of the Parisian region, it is necessary to account for the development of activities linked to air transport, possibly induced by the implementation of effective PT links among the airports and the rest of the conurbation. This explicitly aeropolistic dimension[13] of the GPE project raises the possibility of new selective growth in high value-added activities, supported by high value-added immigrants in services of increasing interest in times of rapid de-industrialisation.

Operational dimensions

It would also in practice be as important to test the sets of secondary hypotheses that come with each approach. Many such large models require decisions taken as the computer program is developed and which have decisive consequences in terms of the functioning of the model, its adaptability to the data at hand and the consequent results. Beyond in-depth tests of the programmes themselves, the exercise might ideally involve more than one agglomeration and would notably examine:

- the relevance of the main hypotheses with respect to institutional and socio-economic frameworks;
- data requirements and the usual trade-offs between detailed and zone-aggregated options, including the conservation of travel demand model properties wherever zonal aggregation is effected;
- respective results, if only as a check on orders of magnitude and to determine the relevance of the outputs for cost-benefit analysis.

Uniqueness and reproducibility

In addition, a comparative analysis would provide some perspective on our understanding of the basic functioning of these models. Technical questions concerning the uniqueness of solutions and their reproducibility have to be raised for activity, transport flow and LOS results. Moreover, to the extent that CES-type production or demand functions are involved, it matters to find out whether the fact that simple power transformations, contrary to BCT, do not maintain the order of the data (Johnston, 1984, p. 63) affects the results, or not.

One great model or separate tools?

Should the component models assembled in LUTI systems be the object of enrichments and deepening with respect to all key components which determine variables pertaining to land markets, household location and the modelling of firms (birth, development, death), or should general LUTI systems prevail and capture future efforts? Opinion is no doubt divided on whether these paths should be developed in parallel, with hopes of mutual benefits, or unequally, even with the closure of one option.

Consolidate what is known about agglomeration effects?

Important econometric work has been accomplished of late on agglomeration effects. A basic bibliography matching a general presentation, oriented towards applications, may be found in Prager and Thisse (2008) and one finds summaries of main results (e.g. Mackie *et al.*, 2011, Turner, 2009) as well as evidence of progress made (Combes *et al.*, 2009), all demonstrating the liveliness of research in this area. Our interest in appraisal requires raising some points lest they constitute tripping stones for such purposes.

A first query pertains to the different variables more or less equivalent to, or standing for, agglomeration effects: density, accessibility, transport time or cost. In particular, if some linkage is established between productivity and density, is it legitimate to consider that reductions in transport costs are equivalent to increased density? The answer is fundamental to the matter because transport projects may lead to changes in density but, first and foremost, reduce transport time and cost.

Another question has to do with the robustness of the econometric results, in particular with respect to simultaneous equations biases: could endogeneity partly explain the high dispersion[14] of estimates? It might be relevant to study whether the variance is due to the specifics of agglomerations or countries or to differences among sectors, notably between services and industries, and to disentangle inter- from intra-sectoral components.

The establishment of the relative size of the different potential causes - such as diffusion of new ideas, externalisation and diversification of services provided to firms and increased market reach - could ease their integration into surplus calculations.

Is our knowledge of migrations satisfactory?

Migrations are a central preoccupation of local authorities in large conurbations, all competing with comparable agglomerations nationally and internationally, notably in terms of their attractiveness for populations, this attractiveness apparently considered as a source of local wealth and success.

But national authorities tend to be concerned with regional balance and it is not unusual to conceive national authorities of European countries as concerned both with the relative position of their national capital and with that of the drain on foreign countries, two generally conflicting objectives. Authorities are of course sensitive both to the quantity and quality of migrants, notably their labour force participation rates and levels of qualification. This concern applies, *mutatis mutandis*, to international capital flows.

For these reasons, the economic appraisal of large projects obliges economists to have some knowledge of migrations but it comes as no surprise that their knowledge of migrations and their determinants is at best sketchy and weak (Lewis, 2010). Generally, migrations are the weak link in demographic studies and generate the highest levels of uncertainty in forecasts, a predicament that seems to hold for both intra-national and international migrations.

Knowledge of the impact of transport improvements on migrations is weaker still. Some rare studies (e.g. Turner, 2009; Crafts, 2009) give a sense of the direction of effects but the elasticities are fragile and based on small samples. Again, endogeneity does not ease the statistical task: over the historical long term, has a city's population increased because of transport improvements or were the modes improved to meet population growth?

4. Appraisal

Does cost-benefit analysis have failings?

Implementation of cost-benefit analysis of large urban projects deserves to be regenerated, both as an application technique and as an embodiment of a decision process (Vickerman, 2007a; 2007b).

Concerning the former, a first difference with the usual case has to do with the especially long life of major infrastructures. In Paris, the Pont Neuf has been important for traffic for 500 years and Haussmann's cuts in the dense urban texture to open up the *grands boulevards* was the departure point of a development in urbanisation that, to this day, structures regional land prices and the orientation of activities at the street block level. In these conditions, is it reasonable to derive present value over a

50-year horizon, as done currently? And if the horizon is moved further out, what discount rate is adequate? The comparable question in the context of global warming consequences is also that of the proper discount rate: *à la* Nordhaus or *à la* Stern?

This matters all the more that relative prices may well change in the long term due to changes in preferences (such as interest in the environment) or to technological change that could modify the transport-communications trade-off, as with teleconferencing, flexible working hours and working from home. But relative prices might also change due to the scarcity, for instance, of oil reserves, or to changes in the stability of the parameters found in models, painstakingly estimated from past and current situations, for, e.g., the value of time, early or late departures, or automotive fuel.

In the case of large projects, all of this argues for an overall shift from forecasting to prospective analysis: by taking into account futures that might strongly differ from extrapolated trends, whereby scenarios with increased differentiations can be considered, as opposed to those proposed today.

Note that theoretical difficulties appear in integrating into cost-benefit analysis elements that were left out when consumer surplus coincided with social surplus. Consider the case of employment, for which the elegant British solution to the valuation of a decrease in the number of unemployed persons consists in using the net change in public expenditure, the sensitive determination of which is left in the hands of the analyst.

A similar problem arises with respect to migrations: what is the proper variation in social surplus following the installation in Paris, induced by a major infrastructure, of an unemployed individual from Central France? And what is the answer if this unemployed individual comes from abroad[15]? It is tempting to use the variation in GNP, an indicator for which these valuation problems will not arise, as pointed out by Worsley (2011).

This indicator is all the more relevant in that it meets the concerns of political decision-takers who are much less concerned by the social surplus than economists and are essentially preoccupied by activity levels and redistribution in the wide sense of the word; if not by kick-starts given to different parts of the city, winners and losers, or social cohesion and the mitigation of problems of strained neighbourhoods. Such matters are not addressed by economists even if they have things to say about them.

These examples indicate that intelligent presentation of project effects supplementing traditional cost-benefit analysis is probably an important element in the making up of decisions concerning each case. This shifts the centre of gravity of appraisal from normative towards positive economics, no less demanding a practice for economists.

How many sides to stations?

The special role played by stations in projects may in certain cases become entirely central. They, of course, generate peaks in land values and might attract major developments, as observed for high-speed rail stations, as well as generating considerable added value. Attempts are made to capture this value added in order to finance the projects and rumour has it that the overwhelming part of the profits of Japanese railways is generated by stations. But it cannot be said that those attempts at value capture have been very successful, at least in Europe.

Stations are also, by definition, *loci* of intermodal exchanges, a property much desired by decision authorities. Intermodal exchanges can be greatly facilitated by technological innovation deployed around stations and capable of affecting the efficiency of a new line. Examples of bad organisation of stations also exist; for instance, the Orly-Val system serving Orly Airport, where the defects in the station's organisation imperil the profitability of the investment.

Last but not least, stations are also two-sided markets, a market feature requiring particular regulation of pricing on the two sides (here travellers and retail stores passed by), adding to the reasons for studies of the economics of stations.

Should the definition of projects be broadened?

Pricing will affect interactions that are naturally strong between the project proper and its surroundings: agglomeration effects will be influenced by the pricing. The project definition itself should comprise signals on the intended pricing which will also influence the implementation of the investment and its financing: Public-Private Partnerships, for instance, can greatly influence project cost, financing and the necessary associated risk assignment and coverage.

It is also clear that the project definition should include associated regulations: the Saint Michel Bridge linking the then Royal Palace to the left bank of the Seine, built in 1387, was supported by a concession allowing for the construction of housing on it (Bezançon, 2004). The primary dimension of regulations pertains to planning (the definition of zones, the allowable volume of buildings) but fiscal regulations are also involved. For instance, one finds in many countries that subsidies to households and tax rules for firms run counter to market trends and have major impacts on trip-making.

More generally, interactions between projects and urban decisions occur in both directions. Typically, public regulations are assumed to be exogenous and attempts are made to derive location and transport decisions in those conditions. It might be relevant to consider, in the opposite direction, that transport infrastructure can affect town planning and fiscal decisions. Studies that make public policies endogenous are rare but some are found in road safety. There is indeed no good reason to assume that public authorities will never affect the rules and regulations of the planning authorities, even if their current stand forbids any immediate action in this direction. Short of making public policies properly endogenous, various possibilities might well be defined by the opinions of experts.

Finally, project definitions could include the intended distinct phases of implementation, which raises the question of the additivity of the component parts. But this question can in principle be answered by modelling studies that will determine if the effects are additive over time or whether some economies of scale arise. In the absence of modelling possibilities, the analysis of past experience can be a welcome guide to the answer.

5. Conclusion

We have proposed a list of unresolved problems, of missing knowledge and of hoped-for progress in the context of an enlargement of current cost-benefit practice, to include economy side effects. We have posited our points with the intent of sustaining controversy:

In terms of demand modelling:

1. All trip categories should be accounted for and trip-making behaviour should be fully explored.
2. The non-marginal character of changes implied by large projects requires the abandonment of linearity restrictions imposed on utility functions.

In terms of impacts outside of the transport market (urban form and economic development):

3. It is important to take stock of the various LUTI approaches and to explore systematically their operational properties, such as uniqueness, reproducibility, etc.
4. It would be worthwhile to extract useful orders of magnitude from the flowering of recent econometric studies of agglomeration effects and to better understand their components.
5. Migrations are an apparent effect of major infrastructure investments but their determinants are poorly understood. Unfortunately, there appears to be no straightforward way of filling this gap.

In terms of appraisal technique:

6. How should indivisibilities and the very long term be incorporated in cost-benefit analysis?
7. How can the many-sided possibilities of stations be better accounted for?
8. What is involved in the definition of projects to be appraised?

Annex 4.A1

Splitting MNL path choices among PT modes between branches?

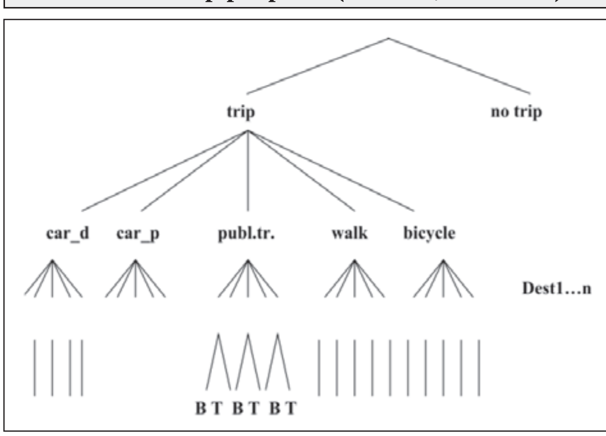
What should one think of the innovation, illustrated in Figure 4.A1.1, whereby the problem of the use of path averages is avoided by the addition of a layer of PT branches defined among PT modes, some of which are "superior" and give rise to a logsum calculation and the others merely serve as their access means? This solution, still used very rarely, is not altogether satisfactory:

i) **Access merely displaced**: the new layer simply kicks the multiple path access problem downhill: for instance, SAMPERS 1999 was using an access algorithm (the optimal strategy implemented in EMME/2) that is deterministic in spirit[16], with the result that access to Train and Bus were "unstable" or sensitive to epsilon-variation: the mandated 2003 model revision resulted in a suppression of the innovative transit layer (Transek, 2003, 2004);

ii) **A baker's even dozen**: which are "high" and which are "low" access modes in a place like Grand Paris with four different types of bus (Ordinary, Bus Rapid Transit (BRT), T-Zen[17 18], local mayors' minibuses), two kinds of tramway (large ones on rails, with high windows; smaller ones on tyres) and of metros (ordinary and automatic) and regional express (RER) trains of quite different characteristics, axle-weight and suspension "feel" and comfort. If a hierarchy is considered, which of these 10+ means are the high modes and which the low modes merely serving as access to the higher modes and requiring a path access model of their own? Are modes "low" in the morning and "high" in the evening – is the hierarchy directional?

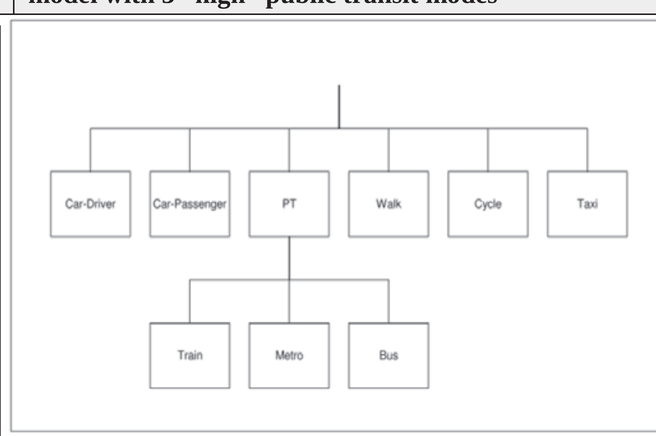
Figure 4.A1.1: **Recent urban transit hierarchies**

A. Structure of regional SAMPERS 1999 models for non-work trip purposes (B = Bus; T= Train)



Stockholm Region

B. Choice hierarchy in PRISM West Midlands 2004 model with 3 "high" public transit modes



Birmingham Region

If hierarchies, unfortunately non-nested in a statistical sense, seem altogether unwise in situations of plethoric transit options, this does not mean that multinomial path choice becomes easy. Note in passing two important difficulties that can be overcome in the current state of techniques:

i) **Effects common to all paths**: it is possible to identify a common alternative-generic constant (AGC) in Multinomial Logit path choice problems, and more generally all alternative-specific constants (ASC) in Logit mode choice problems (Gaudry & Tran, 2011);

ii) **Consistent non-linearity of LOS variables**: there are many ways to test for non-constancy of marginal utility of LOS (Frequency, Time, Cost) variables in Logit utility functions[1]. No matter which method is used (we survey below work done with Box-Cox transformations), the logsum solves the old problem of compatibility between the form of LOS variables previously appearing in both path choice and mode choice parts of the model structure.[2]

Notes

1. Ancient Egypt has left the Pyramids, massive graves of the pharaohs, and smaller but still impressive tombs of kings and queens, but there is no trace of the small graves of the numerous *fellahs* who built the former.

2. Housing located in a certain local jurisdiction consumes public goods produced by another jurisdiction without such externalities influencing the pricing.

3. In air markets, business trips have been in the minority for more than 15 years in many advanced countries.

4. For a discussion of the theory, see Klein *et al.* (1997).

5. Already in use to explain shopping trip destination choice in both ANTONIN-2 and MODUS-2 models.

6. Sometimes authors use very astute devices (e.g. Bar-Gera, 2006) to compensate for this lack.

7. Although the specification of the RUF are linear in the derivations of choice models based on the Normal and Rectangular distributions published by Abraham in 1961, the immediate applications were nonlinear: the first Channel Tunnel studies (Setec, 1959), explicitly based on a RUM model derivation and justification, compared linear and logarithmic Logit forms (for details, see Gaudry & Quinet, 2011) and French engineers assigned the name "Abraham's law" to a Logarithmic Logit path choice formulation based on a generalised cost expression without path AGC.

8. His utility functions estimated with BART data appeared linear whether one used two modes (Car and Bus, before BART) or a more complex break-down of the public mode into three sub-categories (after BART). This finding remains an exception and we could not determine from the paper whether peculiarities of local pricing (such as bus fare varying over a very narrow domain) could explain the result or whether the justification implied a particular attitude to urban Distance.

9. In a recent piece on the availability of modes and mode choice in the Paris region, Lapparent (2010, p. 382) recognizes the insufficiency of his *ad hoc* log linear utility functions and the need to re-estimate them with BCT. His exploratory choice was dictated by the emphasis of his paper, which bears primarily on the endogeneity of the choice set.

10. The Survey also tries to make sense of these gross BCT values by splitting them between a component expressing optimism, neutrality or pessimism in the *attitude to Distance* (or an *attitude towards risk*) and another component expressing the *attitude towards the trip characteristic* itself, in the spirit of prospect theory.

11. According to Jara-Diaz (2007, Equation 2.34, p. 61), VOT should always increase with Distance.

12. See Kazarda & Lindsey (2011).

13. This dispersion is not without echoes of endogenous growth result variability in the aftermath of Aschauer's early work.

14. The problem, generally speaking, is how to count the variation in the surplus affecting a foreigner.

15. The idea is that transit users always walk to the stop or station that generates the lowest generalised path cost for them.

16. Among the 1 433 bus lines covering 24 660 km of routes, many are complementary with the rail system but many are in competition with it.

17. T-Zen buses, in service since 2011 in the Paris area, benefit from dedicated Bus Rapid Transit (BRT) lanes but have tramway-type doors and windows. Are they significantly distinct from tramways on rubber wheels? Fish or fowl?

18. For instance, in a Probit model for the region of Paris, Palma and Picard (1995) use cubic forms on Time in a model.

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This report discusses the state of the art in understanding the economic effects of major transport infrastructure projects. It examines the limits of socio-economic cost-benefit analysis (CBA) and reviews the development of complementary and alternative approaches to assessing the benefits of investment in large, transformative projects.

CBA has proved a reliable tool for ranking projects that are similar and for assessing investments that make marginal improvements to the transport system. It is much less suited to projects designed to transform the economy or for comparing transport investments designed to enhance regional economic productivity with non-transport uses of public funds to promote growth. In particular CBA does not capture all the wider benefits of transport investments, notably agglomeration effects and responses in labour markets to improved access to jobs. At the same time, the benefits of investment can be communicated with most audiences much more effectively in terms of impacts on jobs and GDP than time savings and net socio-economic welfare benefits – the language of CBA.

For all these reasons attention in many jurisdictions is focusing on examining wider economic effects, in addition to standard project appraisal. The microeconomic and macroeconomic tools available to do this have improved markedly in the last decade but are far from mature and require significant resources. For large public investments, particularly where projects are designed to drive development and transform productivity rather than simply release bottlenecks in the existing transport network, the additional evaluation effort is worthwhile and critical to identifying the full value of the project. This report focuses on practical appraisal tools developed for assessment of the Grand Paris super-metro and London's Crossrail project.

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