# Chapter 4

# Maintained Hypotheses and Questions in Search of Answers

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**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) $$\overline{V_p} - \ln\sum_i \exp(V_i) = \sum_i p_i \cdot \ln(p_i)\ ,$$

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 $Var_v$:

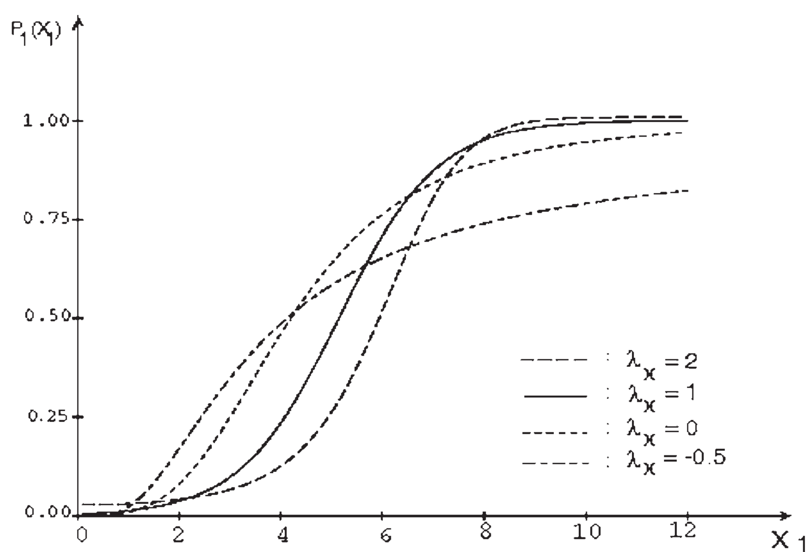
(3-A) $$Var_v^{(\lambda)} \equiv \begin{cases} \dfrac{(Var_v)^{\lambda} - 1}{\lambda}, & \lambda \neq 0, \\ \ln(Var_v), & \lambda \to 0. \end{cases}$$

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 $\lambda_{ik} = 1$, 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 $\lambda_{Time}$ was greater than unity and that on Cost $\lambda_{Cost}$ is smaller than unity. The first result, $\boldsymbol{\lambda_{\mathbf{Time}} > 1}$, 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 $\boldsymbol{\lambda_{\mathbf{Cost}} < 1}$;

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 $\boldsymbol{\lambda_{\mathbf{Time}} < 1}$.

***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** | $\lambda_{Tww}$ | $\lambda_{Tveh}$ | $\lambda_{Fare}$ | $(\lambda_{Time}-\lambda_{Fare})$ | **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 ($\mu_k$ = 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** | $\lambda_{Tww}$ | $\lambda_{Tveh}$ | $\lambda_{F/s}$ | $(\lambda_{Tveh}-\lambda_{F/s})$ | |
| 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** | $\lambda_{Tww}$ | $\lambda_{Tveh}$ | $\lambda_{(I-F)}$ | $(\lambda_{Tveh}-\lambda_{(I-F)})$ | **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 $\beta$ and $\lambda$ 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 **($\lambda_{Time}$ - $\lambda_{Fare}$)** > 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?

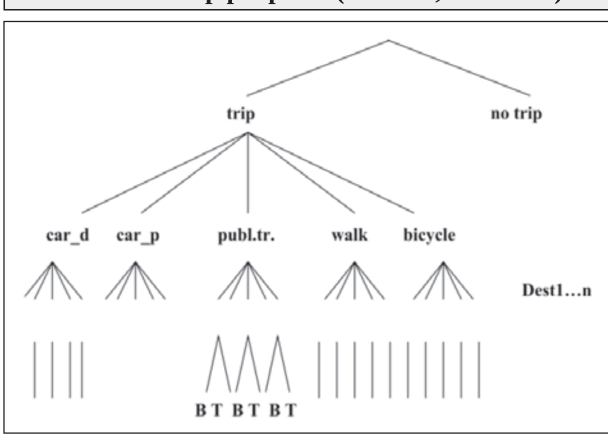
What should one think of the innovation, illustrated in Figure 4.A1.1, whereby the problem of the use of path averages is avoided by the addition of a layer of PT branches defined among PT modes, some of which are "superior" and give rise to a logsum calculation and the others merely serve as their access 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?

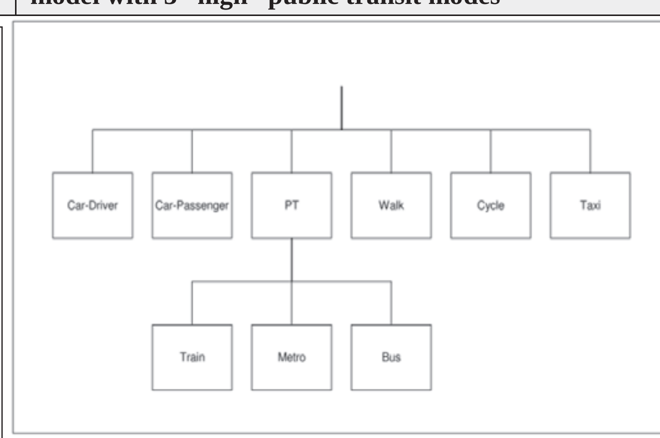
Figure 4.A1.1: **Recent urban transit hierarchies**

**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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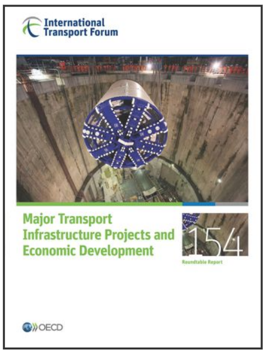


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