

Maintained Hypotheses and Questions in Search of Answers

29

Discussion Paper 2011 • 29

Marc GAUDRY

Agora Jules Dupuit (AJD)
Université de Montréal, Canada

Émile QUINET

Paris-Jourdan Sciences Économiques (PSE)
École des Ponts Paris Tech (ENPC),
France

This document was produced as a Background Paper for the Roundtable entitled:
*Major Transport Infrastructure Projects and Regional Economic Development – Assessment
and Implementation*, held in Paris on 1-2 December 2011.

*The views expressed in this document are the authors' and do not necessarily
reflect the opinions of the University of Montréal, the ENPC, Paris, or
the International Transport Forum.*

Further information about the International Transport Forum is available at
www.internationaltransportforum.org

**Maintained Hypotheses and
Questions in Search of Answers**

Discussion Paper No. 2011-29

Marc GAUDRY

Agora Jules Dupuit (AJD)
Université de Montréal
Canada

and

Émile QUINET

Paris-Jourdan Sciences Économiques (PSE)
École des Ponts ParisTech (ENPC)
France

[Revised February 2012]

INTERNATIONAL TRANSPORT FORUM

The International Transport Forum at the OECD is an intergovernmental organisation with 53 member countries. It acts as a strategic think tank with the objective of helping shape the transport policy agenda on a global level and ensuring that it contributes to economic growth, environmental protection, social inclusion and the preservation of human life and well-being. The International Transport Forum organizes an annual summit of Ministers along with leading representatives from industry, civil society and academia.

The International Transport Forum was created under a Declaration issued by the Council of Ministers of the ECMT (European Conference of Ministers of Transport) at its Ministerial Session in May 2006 under the legal authority of the Protocol of the ECMT, signed in Brussels on 17 October 1953, and legal instruments of the OECD.

The members of the Forum are: Albania, Armenia, Australia, Austria, Azerbaijan, Belarus, Belgium, Bosnia-Herzegovina, Bulgaria, Canada, China, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, FYROM, Georgia, Germany, Greece, Hungary, Iceland, India, Ireland, Italy, Japan, Korea, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Mexico, Moldova, Montenegro, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, the United Kingdom and the United States.

The International Transport Forum's Research Centre gathers statistics and conducts co-operative research programmes addressing all modes of transport. Its findings are widely disseminated and support policymaking in member countries as well as contributing to the annual Summit.

DISCUSSION PAPERS

The International Transport Forum's Discussion Paper Series makes economic research, commissioned or carried out at its Research Centre, available to researchers and practitioners. The aim is to contribute to the understanding of the transport sector and to provide inputs to transport policy design. The Discussion Papers are not edited by the International Transport Forum and they reflect the author's opinions alone.

The Discussion Papers can be downloaded from

: www.internationaltransportforum.org/jtrc/DiscussionPapers/jtrcpapers.html

The International Transport Forum's website is at: www.internationaltransportforum.org or for further information on the Discussion Papers, please email: itf.contact@oecd.org

TABLE OF CONTENTS

1. INTRODUCTION: FROM A PARTIAL TOWARDS A MORE GLOBAL ANALYSIS 5

2. DEMAND MODELS 7

 A. Relevant markets: do only home-based peak time work trips exist? 7

 B. Shannon’s measure and the logsum to avoid underestimation of demand and surplus 7

 C. Assignment: Do equilibrium algorithms have a unique solution? Are they sensitive to the network loading sequence? Should Wardrop be abandoned? 9

 D. Linear restrictions on the form of utility functions should be dropped for significant LOS changes 9

3. EFFECT ON THE AGGLOMERATION AS A WHOLE 14

 E. Mills’ optimal city should be taken up and updated 14

 F. How to move forward with LUTI models? Polycentricism, aerotropolism and a comparison of their operational dimensions 14

 G. Consolidate what is known about agglomeration effects? 16

 H. Is our knowledge of migrations satisfactory? 16

4. APPRAISAL 17

 I. Are there failings of cost-benefit analysis? 17

 J. How many sides to stations? 18

 K. Should the definition of projects be broadened? 18

5. CONCLUSION 20

 5.1. Hard problems 21

 5.2. Neglected problems 21

6. APPENDIX. SHOULD MODAL PT PATHS BE SPLIT BETWEEN BRANCHES? 23

7. REFERENCES 25

List of Tables

Table 1. BCT estimates for Time & Cost variables in discrete RP urban Logit passenger models 12

Table 2. Main issues and conclusions 20

List of Figures

Figure 1. Classical Linear-Logit vs Standard Box-Cox-Logit Responses 10

Figure 2. Recent urban transit hierarchies 24

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 Questions in Need of Answers, are crystallised around three orientations: demand model properties; overall effects on urbanisation; extensions of traditional appraisal. The conclusion contains a list of hard problems dodged and issues ignored in the discussion.

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 modeling 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 cursorily 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 middle 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 shocks¹. 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 framework².

Under these conditions, the principles of economic appraisal have to be reconsidered, In terms of positive knowledge, demand modeling 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 modeling, the effects on urban structure and modifications required of traditional appraisal methods.

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 consume public goods produced by another jurisdiction without such externalities influencing the pricing.

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.

A. 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 frequency³ 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 entrepreneurship⁴. 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.

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

As the prevailing mode choice models are Logit, logsums⁵ 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.

³ In air markets, business trips have been 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.

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 characterized 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 \bar{V}_p , the probability weighted utility (of all rail paths), with dire consequences for the mode choice or demand model if requirement $V_c - \bar{V}_p > -1$ fails (as it often does) and Daly's (1999) positivity condition is not met:

$$(1) \quad \left[\frac{\partial \bar{V}_p}{\partial V_c} = p_c (1 + V_c - \bar{V}_p) \right] > 0 ;$$

- (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):

$$(2) \quad \bar{V}_p - \ln \sum_i \exp(V_i) = \sum_i p_i \cdot \ln(p_i),$$

a path aggregation theorem (PATH) which is a special case of a more general formulation whereby all weighted averages of paths characteristics (with weights normalized 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, 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 summarized 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 2 of the Appendix 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 Appendix, it is still by no means fully satisfactory, even under the assumption that it makes sense in cases of plethoric PT supply such as the Paris region where some 10 PT modes are present and common sense rather suggests use of a Multinomial structure to explain choice among transit paths.

C. 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 generalized 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 solution⁶ the uniqueness and reproducibility of solutions (even before raising the issue of path aggregation) must be explicitly considered for any generalized 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 programs away from equilibrium assignment and towards the use of Logit based assignment: a case in point, the forthcoming EMME 3 program (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 non linear options such as Kirchhoff's distribution formula (Fellendorf & Vortisch, 2010), equivalent to Abraham's Law in France, as well as Box-Cox specifications.

D. 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 :

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

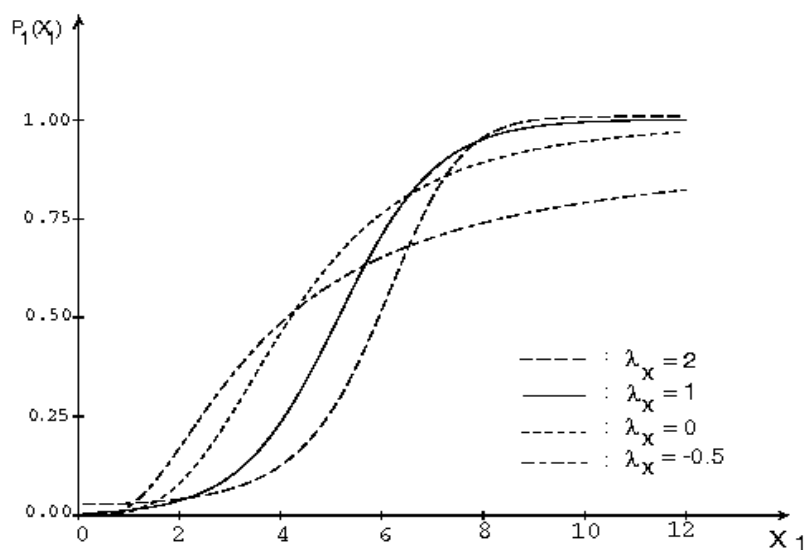
and notably to the variables of interest for transport project appraisal, primarily Time (for passengers) and Fare (for freight), present in the random utility function (RUF) which can then be written explicitly:

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

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

As already mentioned above, non linearity, as illustrated in Figure 2 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 1. **Classical Linear-Logit vs Standard Box-Cox-Logit Responses**



Asymmetry is therefore critically important 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 LOS changes considered are far from marginal, 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 2, prevailed in the careful Logit empiricism justified by the seminal foundation paper of Random Utility Models (Abraham, 1961)⁷ 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.

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 non linear: the first Channel Tunnel studies (Setec, 1959), explicitly based on a RUM model derivation and justification, compared linear and logarithmic Logit forms (see for details Gaudry & Quinet, 2011) and French engineers assigned the name "Abraham's law" to a Logarithmic Logit path choice formulation based on a generalized cost expression without path AGC.

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 non linear: 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 BART⁸ case (McCarthy, 1982), linearity has been found wanting, as demonstrated in summary Table 1, where:

- 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, $\square_{Time} > 1$, means that the slope of the demand curve decreases (become flat) at an increasing rate with Distance for Time, in contrast with Cost where the demand falls (become flat) at a decreasing rate with Distance because $\square_{Cost} < 1$;
- ii) **Marginal utility of time and money is not constant, even in Gai Paris:** the previous observation holds in particular for the 5 models for the Paris region⁹ (Models 20, 21, 32, 33 and 34 in Table 1);
- iii) **Contrast with intercity models:** the results of Table 1 in fact come from a Survey of some 50 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 $\square_{Time} < 1$.

Are suburban trains and subways slow High Speed Trains? If this result holds in further cases less centered 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 markets¹⁰. This would mean that suburban trains and metros are not slow TGV and that TGV are not fast suburban vehicles.

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 3 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

Table 1. **BCT estimates for Time & Cost variables in discrete RP urban Logit passenger models**

Column		1	2	3	4	Source
Time and Cost terms; expense specification						
Sydney (2 modes)	Purpose	<input type="checkbox"/> _{Tww}	<input type="checkbox"/> _{Tveh}	<input type="checkbox"/> _{Fare}	<input type="checkbox"/> _{Time} <input type="checkbox"/> _{Fare}	Hensher & Johnson, 1981; see (2)
<i>CBD trips (car and train)</i>		see (1)				
17. Northern suburbs (1971)	Work	1,000	0,50		0,00	Table 1, Col. 1 ($\square_k = 001$)
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	-0,89	2,08	Table 4.8, p. 135
Santiago de Chile						Pong, 1991; and Gaudry, 1994
<i>A-1. CBD corridors (9 modes)</i>						
22. Las Condes & San Miguel	Work	0,13	1,37	-0,56	1,93	Series I-B-G; see (3)
<i>B-1. City-wide 1991 (11 modes)</i>						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						
<i>A-2. CBD corridors (9 modes)</i>	Purpose	<input type="checkbox"/> _{Tww}	<input type="checkbox"/> _{Tveh}	<input type="checkbox"/> _{F/s}	<input type="checkbox"/> _{Tveh} <input type="checkbox"/> _{F/s}	Pong, 1991, and Gaudry, 1994
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
<i>B-2. City-wide 1991 (11 modes)</i>						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)

attitude towards risk) and another component expressing the attitude towards the trip characteristic itself, in the spirit of prospect theory.

Time terms and [Income - Cost] difference term; expense specification						
Paris region (2 modes)	Purpose	\square_{Tww}	\square_{Tveh}	$\square_{(I-F)}$	$\square_{Tveh} - \square_{(I-F)}$	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)
<p>(1) The value 1,000 denotes an untransformed variable appearing linearly in a model.</p> <p>(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.</p> <p>(3) The income measure used is the net hourly wage rate.</p> <p>(4) The Time variable denotes walk time.</p> <p>(5) The Fare is divided by the net hourly Wage rate, in accordance with the Train-McFadden (1978) specification.</p> <p>(6) The Time variable is a generalized time with weight of 1 for In-vehicle, 2 for Walk and 4 for Wait times.</p> <p>(7) The Net Income term is obtained by subtracting Cost from Income.</p> <p>(8) In Model 32, an equality constraint is imposed on the coefficients of total Time elements; it is relaxed in Model 33.</p> <p>(9) In Model 34, 8 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.</p>						

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 :

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

Interestingly, the same survey shows that one finds $(\square_{Time} - \square_{Fare}) > 0$ in both urban and intercity models, namely a value of time (VOT) that increases with distance¹¹. 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).

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

3. EFFECT ON THE AGGLOMERATION AS A WHOLE

E. Mills' optimal city should be taken up and updated

As long ago pointed out by Martin Beckmann, an optimal city would have not only 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 and when various regulations and constraints apply to the solution, where the network topology is also limited and where the production functions are very varied.

Such requirements are apparently only met by Ed Mills' seminal approach (1972, 1974) where all activity levels, including transport flows with congestion, are optimally assigned in three-dimensional city. As there is a proper maximization 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 to-day.

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

F. How to move forward with LUTI models? Polycentricism, aerotropolis 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 alii* (2007), Bröcker & Mercenier (2011) or Wegener (2011)), allowing for distinctions based on their main hypotheses.

One of the most significant distinction for appraisal purposes appear 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 analyzed for instance in Palma (2011) and in 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) characterized 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 dimension¹² 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 deindustrialization.

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 are 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 programs 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) matters for 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 determining variables pertaining to land markets, household location and the modeling of firms (birth, development, death), or should general LUTI systems prevail and capture future efforts? Opinion on whether these paths should be developed in parallel, with hopes of mutual benefits, or unequally, even with the closure of one option, is no doubt distributed...

¹² See Kazarda & Lindsey (2011).

G. 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 & Thisse (2008) and one finds summaries of main results (e.g. Mackie *et alii*, 2011, Turner, 2009) as well as evidence of progress made (Combes *et alii*, 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 dispersion¹³ 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, externalization and diversification of services provided to firms, increased market reach, could ease their integration into surplus calculations.

H. 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 to the quality of migrants, notably their labor 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 some knowledge of migrations but it comes as no surprise that their knowledge of migrations and, even if some progress is made (e.g. Nowotny, 2011), their determinants is at best sketchy and weak (Lewis, 2010). Generally, migrations are the weak link of demographic studies and generate the highest levels of uncertainty in forecasts, a predicament that seems to hold for both intra-national and international migrations.

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

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 population of a city increased because of transport improvements or were the modes improved to meet population growth?

4. APPRAISAL

I. Are there failings of cost-benefit analysis?

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 *Grand Boulevards* was the departure point of a development in urbanization 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 the taste for the environment) or to technological change that could modify the transport-communications trade-off as with teleconferencing flexible working hours and working from the home. But relative prices might also change due to 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 the likes of: the value of time, of early or late departure, or of 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 to-day.

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, induced by a major infrastructure, the installation in Paris of an unemployed individual from Central France? And what is the answer if this unemployed individual come from abroad¹⁴? 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 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 neighborhoods. 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 center of gravity of appraisal from normative towards positive economics, no less demanding a practice for economists.

J. How many sides to stations?

The special role played by stations in projects may in certain case become entirely central. They of course generate peaks in land values and might attract major developments, as observed for High Speed Rail stations, and also generate considerable added value. Attempts are made to capture this value added in order to finance the project and rumor 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, and 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 organization of stations also exist, for instance the Orly-Val system serving Orly airport where the defects of the station organization imperils 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 travelers and retail stores passed by), adding to the reasons for studies of the economics of stations.

K. 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.

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

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 (Bezanson 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 components parts. But this question can in principle be answered by modeling studies that will determine if the effects are additive over time or whether some economies of scale arise. In the absence of modeling possibilities, the analysis of past experience can be a welcomed guide to the answer.

5. CONCLUSION

We have proposed above a list of unresolved problems and identified loci of missing knowledge or of hoped for progresses in the context of an enlargement of current partial equilibrium cost-benefit practice to include economy-wide effects for large projects such as the GPE. The points were formulated with the intent of sustaining controversy with respect to demand modeling (A to D), to impacts outside of the transport market, such as urban form and economic development (E to H), and to appraisal technique in general (I to K). The main conclusions are summarized in Table 2.

Table 2. **Main issues and conclusions**

In terms of demand modelling:	
	<ul style="list-style-type: none"> - All trip categories should be accounted for and trip making behavior should also be fully explored. - 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):	
	<ul style="list-style-type: none"> - It is important to take stock of the various LUTI approaches and to explore systematically their operational properties such as uniqueness, reproducibility, <i>etc.</i> - It would be useful to extract useful orders of magnitude from the flowering of recent econometric studies of agglomeration effects and to better understand their components. -- 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:	
	<ul style="list-style-type: none"> - How should indivisibilities and the very long term be incorporated in cost-benefit analysis? - How can the many-sided possibilities of stations be better accounted for? - More attention should be devoted to the definition of the scope of projects.

By aiming at controversy, we have neglected some very hard issues lurking behind some of the K points, and ignored other complexities that could have been raised. In conclusion, it is useful to emphasize a partial list of both dodged issues and ignored complexities.

5.1. Hard problems

We have dodged some very hard problems, not found only in the evaluation of large urban networks, pertaining to:

1. **The existence of non linearity in (D):** the transport component of Spatialized Computable General Equilibrium (SCGE) LUTI models might well use *a priori* non linear utility functions, but it is not clear whether these should be estimated for every application city or have their parameter values specified only on theoretical grounds on the basis of “desirable” values. Indeed, SCGE transport demand system applications do not avoid the issues raised by traditional demand systems, such as (i) in classical systems, should symmetry of the Slutsky matrix be imposed? (ii) in AIDS systems, should minimum consumption levels be constrained positive or at least non-negative¹⁵? (iii) in Logit systems, are the assumptions of additive separability of utility credible among close substitutes such as modes or paths within a network or should specifications of the “Mother Logit” type, broader but little used, be adopted?
2. **Network design in (E):** there does not yet exist a satisfactory or practicable formulation of the problem of network design. Network topology is for those reasons typically assumed exogenous, which introduces a modicum of ill-defined under optimization as one never really knows if another network design would not be preferable, notably when the number of links considered is relatively high and the number of potential alternate designs significant.
3. **The role of institutions in (F):** if urban planning solves some economic coordination problems, it also solves the hard “network design” problem that transportation economics cannot avoid. It has been famously said: “Individual action would never give rise to a system of city parks, or even to any useful system of streets” (Fisher, 1907).
4. **The birth and location of firms in (F):** the birth and location of firms is not yet satisfactorily addressed by existing work on this issue.

5.2. Neglected problems

The most important problems ignored in the above discussions are:

5. **The need for a CGE model:** when is a spatialized CGE model required? Can the conditions for the profitable use of SCGE-LUTI models be defined? It could be thought that taking into account the consequences of a project on the value of factor inputs, such as land, can justify use of a SCGE model, but this is not the case: it is well known that the traditional partial equilibrium calculation of surplus on the network summarizes all of the social surplus

¹⁵ Some 40 years ago, Solari (1971) found that minimum consumption levels estimated from unconstrained maximization were negative. Similarly, in mode choice models containing Dogit captivity parameters for each mode, many experiments involving four intercity modes in Canada (Dagenais *et al.*, 1982) suggested that better fits were obtained when the captivity parameters were not constrained to be positive.

effects under competitive conditions and the absence of externalities. A first motivation is therefore provided by the existence of externalities in urban areas.

It could perhaps be argued instead that the desire to determine the real final incidence of the price and time redistribution caused by the project provides better grounds for SCGE-LUTI model use even if, as a rule, projects should not primarily be used as redistributive instruments of either time or money. Even first best conditions fail to provide redistribution effects.

One might finally have a feeling that SCGE analysis was required if the project was "large and transformational", but an analytical definition of this intuition is not readily forthcoming. At first come to mind examples of "transformational" transport projects and innovations implying a change of an order of magnitude or more in the generalized cost of transport: the development of the British canal system between 1750 and 1790, the development of the railways, the use of steamships in the 19th Century and the progress of air travel in the 20th Century. But a precise and convincing definition of the border between "small" and "large" projects remains to be formulated.

6. **The role of "accompanying measures"**: insufficient attention is generally paid to measures which ease the insertion of a project in the real urban context. Those measures raise the issue of the definition of the project, a matter touched upon in point K.
7. **Political biases**: we have made no appeal to the general view that the political system generates decisions that underrate the importance of maintenance and demand management to the advantage of new projects. In a wider context, this concern could be addressed and something made of voting behavior models (median voter, etc.), a traditional topic of political economy.
8. **The possibility of high PT cost benefit ratios**: consider for a moment the **Big Split Conjecture** that the transport costs that have fallen much over the last 50 years are air and maritime door-to-door general cargo (replaced by the container mode) costs and that land costs (road, rail, water) have hardly budged: long Dutch series suggest that the latter have on average decreased by only 10% during the last 50 years (Ministerie van Verkeer en Waterstaat, 2002). In such a context, is there any possibility of ever achieving high cost benefit ratios in a transit industry where costs are not falling? Possibly, benefits generated by a public transport project that reduces travel times by half among large numbers of origin-destination pairs should be the best one could ever expect in urban markets where order of magnitude improvements in LOS are out of reach.
9. **Risk and uncertainty, including macroeconomic risk**: accepting for a moment the distinction between risk and uncertainty proposed by Knight (1921), both dimensions need to be incorporated into analyses but it is not clear how this should be done, notably for macroeconomic risk put in evidence in the aftermath of the 2008 financial crisis which impacted transport markets and financing conditions.

6. APPENDIX. SHOULD MODAL PT PATHS BE SPLIT BETWEEN BRANCHES?

What should one think of the innovation, illustrated in Figure 2, 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:

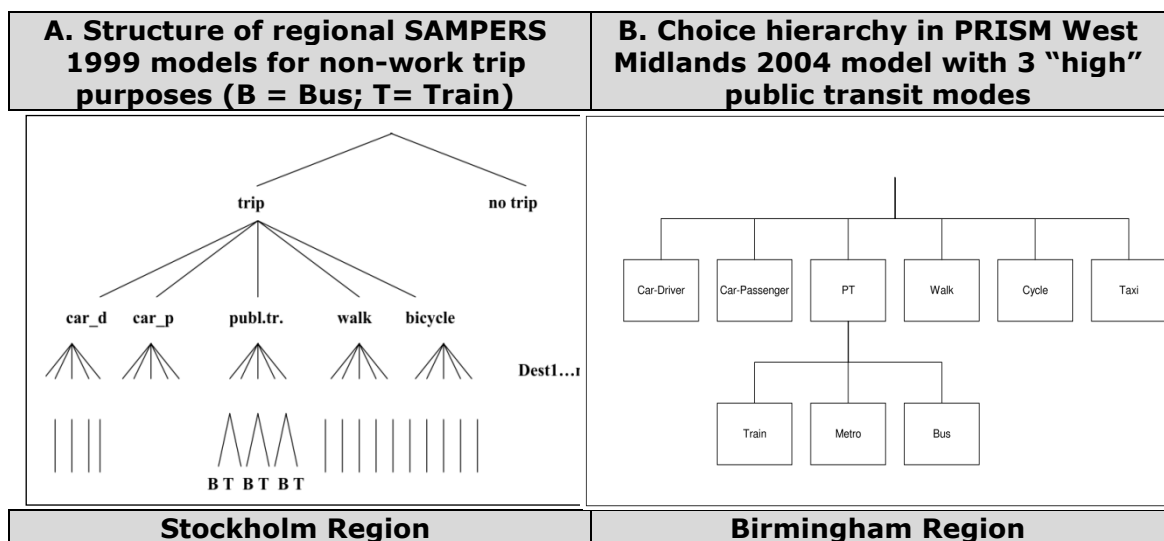
- i) **Access merely displaced:** the new layer simply kicks the multiple path access problem downhill: for instance, SAMPERS 1999 was using an a deterministic access algorithm (the optimal strategy implemented in EMME/2)¹⁶, with the result that access to Train and Bus were “unstable”: the 2003 model revision suppressed this transit layer (Transek, 2003, 2004);
- ii) **A baker’s evening dozen:** which are “high” and which are “low” access modes in a place like Grand Paris with 4 different types of buses¹⁷ (Ordinary, Bus Rapid Transit (BRT), T-Zen¹⁸, Local mayors’ minibuses), 2 kinds of tramways (large ones on rails, with high windows; smaller ones on tires) 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?

¹⁶ The idea is that transit users always walk to the stop or station that generates the lowest generalized path cost for them.

¹⁷ 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.

¹⁸ 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?

Figure 2. **Recent urban transit hierarchies**



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 functions¹⁹. 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.

¹⁹ For instance, in a probit model for the region of Paris, Palma & Picard (1995) use cubic forms on Time in a model.

7. REFERENCES

- Abraham, C. (1961). La répartition du trafic entre itinéraires concurrents: réflexions sur le comportement des usagers, application au calcul des péages. *Revue générale des routes et aérodromes* 357, pages 57-60, 65-72, 75-76.
- Bar-Gera, H (2006). Primal Method for Determining the Most Likely Route Flows in Large Networks. *Transportation Science* 40, 3, 269-286.
- Bezançon, X. (2004). 2000 ans d'histoire du partenariat public-privé pour la réalisation des équipements et services collectifs, Presses de l'École Nationale des Ponts et Chaussées, Paris.
- Bröcker J. and Mercenier J (2011). General Equilibrium models for transportation economics. In de Palma, A., Lindsey, R., Quinet, E. and Vickerman, R. (2011) *A Handbook of Transport Economics*, Edward Elgar.
- CATS (1959-1962). Chicago Area Transportation Study. *Final report in three parts*. Study conducted under the sponsorship of [the] State of Illinois, Department of Public Works and Buildings, County of Cook, Board of Commissioners of Cook County. CONTENTS: v. 1, *Survey findings*, December, 1959; v. 2, *Data projections*, July, 1960; *Transportation plan*, April, 1962. Chicago.
- Citilabs (2008). *Cube Voyager Reference Guide Version 5.0*. Document revision 50-006-1, 1000 pages, Citilabs, 12 December.
- Combes, P.P., G Duranton, G., Gobillon, L., Puga, D. and S. Roux (2009). The productivity advantages of large cities: Distinguishing agglomeration from firm selection. Discussion Paper 7191, Centre for Economic Policy Research.
- Crafts, N. (2009). Transport Infrastructure Investments : Implications for growth and productivity *Oxford Review of Economic Policy* 25, 3, 327-343.
- Dafermos, S. (1983). A Multicriteria Route-Mode Choice Traffic Equilibrium Model. *Bulletin of the Greek Mathematical Society* 24, 13-32.
- Dagenais, M. G., Gaudry, M. J. I. and T. C. Liem (1982), Testing the Generalized Dogit Mode Choice Model. Abstract. *Atlantic Economic Journal*, 60, September.
- Daly, A. (1999). The use of schedule-based assignments in public transport modeling. *Proceedings of 27th European Transportation Forum*, Seminar F, Cambridge, England, 149-157.
- DfT (2008). Department for Transport: Economic Benefits in Transport appraisal. Published April 1. <http://www.dft.gov.uk/pgr/economics/rdg/webia/webtheory/>.

- DRIEA IF (2010). *MODUS, modèle de déplacements en Île-de-France de la DRIEA IF*. 23 pages, Présentation au Comité technique du comité scientifique d'Éole, 16 novembre 2010.
- Fellendorf, M. and Vortisch, P. (2010). Microscopic Traffic Flow Simulator VISSIM. Ch. 2 in Barceló, J. (ed.), *Fundamentals of Traffic Simulation*. International Series in Operations Research & Management Science 145, pages 63-93. Springer Verlag.
- Fisher, I. (1907). Why has the doctrine of laissez faire been abandoned? *Science* 45, 627, 18-27.
- Florian, M. and I. Constantin (2011). *Emme strategy transit assignments with variants*. INRO, Montréal, 87 pages, 5th May. www.inro.ca/en/index.php.
- Gaudry, M. (1985). Modèles agrégés et désagrégés à forme variable: résultats sur Montréal et Paris. *Transports* 304, 288-293.
- Gaudry, M. (1994). *Tópicos avanzados en analisis de demanda de transporte: rol de la forma funcional*. Paper presented at the Seminar organized by the Secretaría Ejecutiva de la Comisión de Planificación de Inversiones en Infraestructura de Transporte (SECTRA), 16 pages, Santiago de Chile, 7th January.
- Gaudry, M. (2011). Quebec-Windsor Corridor High Speed Rail Market Forecast Profiles in Context: Level-of-Service Response Curvature Sensitivity and Attitude to Risk or to Distance in Forty Logit Core Model Applications of the Law of Demand. 100 pages, February. www.e-ajd.net.
- Gaudry, M. and E. Quinet (2011). *Shannon's measure on information and the utility of multiple network paths in transport demand estimation and project appraisal*. Publication AJD-142, Agora Jules Dupuit, Université de Montréal, Version of 4th November, 24 pages.
- Gaudry, M. and Tran, C.-L. (2011). *Identifying all alternative-specific constants in Multinomial Logit models by Inverse Power Transformation Capture*. Publication AJD-141, Agora Jules Dupuit, Université de Montréal, 23 pages, July.
- Gaudry, M., Jara-Diaz, S. R. and J. de D. Ortuzar (1989). Value of Time Sensitivity to Model Specification. *Transportation Research B* 23, 2, 151-158.
- Hensher, D. A. and L. W. Johnson (1979). External structure of variables in individual choice models of travel demand. *International Journal of Transport Economics* 6, 51-62.
- Hensher, D. A. and L. W. Johnson (1981). Behavioural response and form of the representative component of the indirect utility function in travel choice models. *Regional Science and Urban Economics* 11, 559-572.
- Hivert, L., Orfeuill, J.-P. and P. Troulay (1988). *Modèles désagrégés de choix modal: réflexions méthodologiques autour d'une prévision de trafic*. Rapport INRETS n° 67, Institut National de Recherche sur les Transports et leur Sécurité, Arcueil, 72 pages, juin.
- Jara-Diaz, S. (2007). *Transport Economic Theory*. Emerald.

- Johnston, J. (1984). *Econometric Methods*, Third Edition, McGraw-Hill Book Company.
- Kazarda, J. D. and G. Lindsay (2011). *Aerotropolis: The Way We'll Live Next*. Allan Lane, 466 pages.
- Kim, T. J. (1978). Effects of subways on urban form and structure. *Transportation Research* 12, 231-239.
- Klein, D., Binyam, R. and A. T. Moore (1997). *Curb Rights*, The Brookings Institution, June.
- Knight, F. H. (1921). *Risk, Uncertainty and Profit*. Houghton, Mifflin.
- Koppelman, F.S. (1981). Non-linear utility functions in models of travel choice behavior. *Transportation* 10, 127-146.
- Lapparent, M. de (2003). *Individual Demand for Travel Modes and Valuation of Time Attributes within the Regular Journey-to-Work Framework*. Publication AJD-70, Agora Jules Dupuit, Université de Montréal, 28 p, January. www.e-ajd.net.
- Lapparent, M. de (2004). *La valeur du temps dans les déplacements réguliers professionnels*. Thèse d'économie, Université Paris I –Panthéon-Sorbonne. Publication AJD-81, Agora Jules Dupuit, Université de Montréal, 180 p., juin. www.e-ajd.net.
- Lapparent, M. de (2010). Latent Class and Mixed Logit Models with Endogenous Choice Set Formation Based on Compensatory Screening Rules. Ch 17 in Hess, S., and Daly, A. (eds), *Choice Modelling: the state-of-the-art and the state-of-practice; Proceedings from the Inaugural International Choice Modelling Conference*, 371-396, Emerald Publishing.
- Lapparent, M. de, Palma, A. de and C. Fontan (2002). *Nonlinearities in the Valuation of Travel Attributes*. Publication AJD-69, Agora Jules Dupuit, Université de Montréal, 22 p., October. www.e-ajd.net.
- Lewis E. G. (2010). The Economics of Immigration: Theory and Policy. *Journal of Economic Literature* 48, 4, 1028-1030, Dec.
- Mackie P., Graham D. and Laird J. (2011). The direct and wider impact of transport projects: a review in de Palma, A., Lindsey, R., Quinet, E. and Vickerman, R. (2011) *A Handbook of Transport Economics*, Edward Elgar.
- McCarthy, P. S. (1982). Further evidence on the temporal stability of disaggregate travel demand models. *Transportation Research B* 16, 4, 263-278.
- Mills, E. S. (1972). Markets and efficient resource allocation in urban areas. *Swedish Journal of Economics* 74, p. 100-113.
- Mills, E. S. (1974). Mathematical models for urban planning. In Brown, A. (ed.). *Urban and Social Economics and Market and Planned Economies* 40, 2, 113-129, Praeger, New York.

- Ministerie van Verkeer en Waterstaat, 2002. *Perspectief op mobiliteit : sneller, goedkoper en verder*, 51 pages, Den Haag, Juni.
- Moore II, J. E. et T. J. Kim (1995). Mills' urban system models : perspective and template for LUTE (Land Use/Transport/Environment) applications. *Computers, Environment and Urban Systems* 19, 4, 207-225.
- Nowotny, K. (2011). *Welfare Magnets, Taxation, and the Location Decisions of Migrants to the EU*. WIFO Working Papers, No. 393/2011, Österreichisches Institut für Wirtschaftsforschung, 27 p., April.
- Orro, A., Novales, M. and F. G. Benitez (2005). *Nonlinearity and Taste Heterogeneity Influence on Discrete Choice Model Forecasts*. 18 p., Association for European Transport and contributors.
- Orro, A., Novales, M. and F. G. Benitez (2010). Box-Cox Mixed Logit model for travel behaviour analysis. Paper presented at the 8th International Conference of Numerical Analysis and Applied Mathematics, Rhodes, 4 pages, September. Forthcoming in *American Institute of Physics (AIP) Conference Proceedings*.
- Palma A. de et Beaudé, O. (2011). Etat de l'art des méthodes d'analyse socio-économiques dans le cadre d'un projet urbain. Document de travail ENS Cachan.
- Palma A. de (2011). *Le Grand Paris : Quels outils, quels enjeux ?* Document de travail pour la table ronde 152 ITF, Paris.
- Palma, A. de and N. Picard (1995). Route choice decisions under uncertainty. *Transportation Research A* 39, 295-324.
- Parra Granifo, R. S. (1995). Modelos de particion modal Logit Box-Cox para Santiago: interpretation microeconomica y valores del tiempo. In Martínez Concha, F. J. (ed). *Actas Septimo Congreso Chileno de Ingeniería de Transporte*, Santiago, pp. 169-186.
- Pong, S. (1991). L'application du modèle probabiliste et de la transformation de Box-Cox au choix du mode de transport au Chili. Thèse de Maîtrise, Département de sciences économiques, Université de Montréal.
- Prager J.-C. et Thisse J.-F. (2008) *Economie et Géographie du développement* Paris, Repères La Découverte.
- PTV AG. PTV Vision: VISUM 11.5 – Bases théoriques, 812 pages.
- Rand Europe (2004). *PRISM West Midlands: Tour based mode destination modelling*, 196 pages, 6th July. <http://www.prism-wm.com/>.
- Setec (1959). *Tunnel sous la Manche – Étude de Trafic et de Rentabilité: Partie B – Annexe*. The Economist Intelligence Unit Ltd (Londres), De Leuw, Cather and C^o (Chicago) and Société d'Études Techniques et Économiques (Paris), pages iii-ix (pages 196-202, Volume 3), novembre.
http://temis.documentation.developpement-durable.gouv.fr/document.xsp?id=Temis-0005494&qid=sdx_q0&n=1&q=.

- Solari, L. (1971). *Théorie des choix et fonctions de consommation semi-agrégées*. Librairie Droz, Genève.
- STIF (2004). *Prévisions de trafic régional sur l'Île de France : Fonctionnalités des modèles Méthodologie, Cas du STIF avec le modèle Antonin*, 16 p.
- Thisse J.-F. (2011). Geographical Economics: A historical perspective. *Recherches Economiques de Louvain* 77, 3.
- Train, K.E. and D. McFadden (1978). The Goods/Leisure Trade-Off and Disaggregate Work Trip Mode Choice Models. *Transportation Research* 12, 5, 349-353.
- Transek (1999). *The SAMPERS System: Overview*. 25 pages, Transek AB, Solna.
- Transek (2003). *Utveckling av Sampers 2.1. Del 1 Estimeringen*. 143 pages, Transek AB, Solna, November.
- Transek (2004) *The SAMPERS System 2.1: Overview*. 29 pages, Transek AB, Solna.
- Turner, M. (2009) The effects of transportation infrastructure on cities: A review of the evidence. Lectures for EAERE Summer school, Venice.
- Vickerman, R. (2007a). Cost-benefit analysis and large-scale infrastructure projects: state of the art and challenges *Environment and Planning B: Planning and Design* volume 34, pages 598-610.
- Vickerman, R. (2007b). MACRO-, MESO- AND MICRO- INFRASTRUCTURE PLANNING AND ASSESSMENT TOOLS Recent Evolution of Research into the Wider Economic Benefits of Transport Infrastructure Investments. Report 2007/9, ECMT.
- Waddell, P., G.F. Ulfarsson, J.P. Franklin and J. Lobb (2007). Incorporating land use in metropolitan transportation planning. *Transportation Research Part A: Policy and Practice*, 41(5), 382-410.
- Warner, S.L. (1962). *Stochastic Choice of Mode in Urban Travel: A Study in Binary Choice*. Northwestern University Press, 90 pages.
- Wegener, M. (2011). Transport in spatial models of economic development. In: de Palma, A., Lindsey, R., Quinet, E. and Vickerman, R. (eds.) (2011) *A Handbook of Transport Economics*, Edward Elgar.
- Worsley, T. (2011), *The evaluation of the London CrossRail Scheme*. Paper for the 152nd ITF Round Table, ITF, Paris.

International Transport Forum

2 rue André Pascal

75775 Paris Cedex 16

itf.contact@oecd.org

www.internationaltransportforum.org
