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Forecasting Urban Traffic in France, 1950s to 2000s

The Nation-State, private engineering firms and the globalization of an area of expertise

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La Modélisation des déplacements urbains en France 1950 à nos jours

L'Etat-nation, les bureaux d'études et la mondialisation d'un champ d'expertise

Résumé

En dépit de l'importance de la modélisation des déplacements urbains en matière de politiques de transports, force est de constater la quasi-absence d'intérêt dont les historiens et autres chercheurs en sciences sociales ont fait montre à son égard jusqu'à présent. Ce document propose une première analyse de la modélisation des déplacements urbains en France, des années 1950 au début des années 2010. Pour ce faire, nous avons adopté une perspective particulière, qui envisage la modélisation comme un processus de production : outre le « produit » lui-même (la structure des modèles), nous nous sommes intéressés à la fois aux différents acteurs (individus et institutions) qui ont produit ce type de modélisation, aux « matières premières » (enquêtes sur la mobilité…) et aux « moyens de production » (logiciels et machines informatiques) nécessaires à sa production et sa mise en œuvre. Regardée à travers cette grille d'analyse, la trajectoire de la modélisation des déplacements urbains en France met en évidence deux grandes périodes distinctes, aux caractéristiques contrastées. Après avoir commencé par se familiariser, à partir des années 1950, avec la modélisation américaine, les acteurs français, publics et privés, construisent, sous l'égide de la puissance publique, durant la décennie suivante et le début des années 1970, une expertise nationale que l'Administration centrale va ensuite « normaliser » et diffuser massivement à travers le territoire. Comme pour le cas nord-américain, la période « 1980-présent » est en revanche marquée par la domination progressive de ce champ de modélisation par le secteur privé, représenté souvent par des bureaux d'études étrangers et des entreprises productrices de logiciels originaires de pays autres que la France. Ce sont ces acteurs privés qui deviennent le vecteur principal du changement dans les pratiques en matière de modélisation des déplacements urbains en France après 1980.

Mots clefs : modélisation, déplacements urbains, histoire, France, après-guerre.

Forecasting Urban Traffic in France, 1950s to 2000s

The Nation-State, private engineering firms and the globalization of an area of expertise

Abstract

Despite of its impact on urban transportation policies after the World War II, urban travel demand modeling (UTDM) – an array of mathematical tools and practices geared towards predicting flows in urban transportation networks, such as urban highways and mass transit systems – has received scant attention from humanities and social sciences scholars. This working paper offers a first long-term analysis – from the 1950s to the 2000s – of the trajectory of this kind of modeling in France. To do so, it makes use of an analytical framework which envisages modeling practices as a production process: aside from the "product" itself, i.e. the main characteristics of the model under study, the analysis is interested in the different actors involved in producing the model (individuals and institutions), as well as the "raw materials" (for example, data from surveys of household travel) and the "means of production", such as computer facilities (hardware and software), which are necessary for its production and implementation. Based on this analytical framework, this paper highlights a process characterized by two main developments. From 1950-1980, State French engineers along with private consulting firms, after having familiarized themselves with American modeling practices, succeeded in creating a national expertise in this domain, which the central French state normalized, disseminated, and implemented on a large scale throughout the national territory in the 1970s. The post 1980 period clearly contrasts with what went before. Indeed, evidence shows that the French state progressively withdrew from UTDM, and, therefore, prepared the way for the rise to dominance of private (and more often that not foreign) engineering consulting firms, which became the main repositories of expertise concerning urban traffic forecasting in France.

Keywords : modeling, urban travel demand, history, France, post-World War II.

Sommaire

Introduction

For better or for worse, the automobile is an integral part of our way of life.[1] Its ascendant trajectory within modern societies would likely have been far less spectacular, had engineers and other like-minded practitioners not been devising a series of tools charged with the task of tackling the ever growing demand of automobiles, especially in large cities. Urban Travel Demand Modeling (UTDM) – one can also find the terms of "Four-Step Model" (US) and "Four-Stage Model" (UK), which mirrors the specific modeling approach that has dominated the history of urban travel demand modeling up to now: see Insert –, an array of mathematical tools and practices geared towards predicting flows in urban transportation networks, such as urban highways and mass transit systems, has been one of these tools.

It was the United States – the first country that had to deal with traffic-related problems[2] – that began to experiment with the first urban travel forecasting models in the 1950s.[3] Since its inception as a specific modeling field in the wake of the World War II, urban travel modeling has been being massively utilized by American engineers and planners. Following successive refinements and substantial modifications both in its mathematical structures and uses, it has been proved instrumental in designing new transportation infrastructures, and, in more recent times, in making optimal use of existing capacity, thanks to a series of policy instruments such as urban tolls, public transport fares or real-time information systems. These models rapidly spread beyond the US and were enthusiastically taken up by a number of countries on the Old continent who were just as anxious to enter the "car society".[4] Nearly 60 years after their inception in the United States, this set of models, although subject to refinements and modifications, still remains of key importance in the transportation profession and in urban transport policies throughout the world.

This working paper intends to tell the story of urban travel demand modeling (UTDM) in France. Despite its importance in shaping the French urban landscape after the World War II, this kind of modeling has received scant attention from humanities and social sciences scholars, who usually mention it only as an aside. Indeed, until very recently, the only available research study fully devoted to the history of UTDM in France was the pioneering work, published in 1975 but still worth reading, by Gabriel Dupuy, which focuses on the 1960s and the early 1970s only.[5] However, there are signs of change. The late 1990s and the early 2000s witnessed the publication of a series of works authored by Eric Bay and Gilles Debizet, which tackle the question of urban travel forecasting via an analysis of the

1 This second version of the Working Paper has benefited from close reading by Gilles Debizet. It goes without saying that the usual disclaimers concerning ultimate attribution of fault apply.

2 In 1927, there was one car for every 44 inhabitants in both France and Great Britain, one for every 196 in Germany and one car for every 5.3 inhabitants in the United States (Paul Yonnet, *Jeux, modes et masses, 1945-1985*, Paris: Gallimard, 1985, p. 254).

3 The history of this field of modeling in the United States in the long run has been dealt with extensively in Konstantinos Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours). Administrations, universités et bureaux d'études", unpublished "HDR" Thesis, vol. 2, Université de Paris-Est Marne-la-Vallée (UPEM), December 2013. For people who are not familiar with the French Academic System, let us note that "HDR" ("Habilitation à Diriger des Recherches") is the highest academic qualification a professional scholar with a Ph.D. can achieve in France. In the Humanities, the "Habilitation" process requires three kinds of documents: an intellectual autobiography of the candidate; the project of a book based on original research; a collection of already published articles and contributions to edited books).

4 Concerning the expression "car society", and the construction of such a society in Sweden with the help of traffic models, see, for example: Pär Blomkvist, "Transferring Technology – Shaping Ideology. American Traffic Engineering and Commercial Interests in the Establishment of a Swedish Car Society, 1945-1965", *Comparative Technology Transfer and Society*, vol. 2, n° 3, 2004, p. 273-302; Per Lundin, "American Numbers Copied! Shaping the Swedish Postwar Car Society", in ibid., p. 303-334. Concerning the place of the automobile in contemporary societies and cultures, see *inter alia* the following works, all of which contain comprehensive bibliographies: Yonnet, *Jeux, modes et masses*; Peter Woolen and Joe Kerr (eds.), *Autopia: Cars and Culture*, London: Reaktion Books, 2002; Gabriel Dupuy, *La Dépendance à l'égard de l'automobile*, Paris: La Documentation française, 2006; Gijs Mom and Laurent Tissot (eds.), *Road History. Planning, Building and Use*, Neuchâtel: Editions Alphil, 2007; Mathieu Flonneau and Vincent Guigueno (eds.), *De l'histoire des transports à l'histoire de la mobilité?,* Rennes: PUR, 2009. Concerning the American case, the reader can now refer to the monumental work accomplished by Michael L. Berger, *The Automobile in American History and Culture. A Reference Guide*, Westport (Connecticut): Grenwood Press, 2001.

5 Gabriel Dupuy, *Une Technique de planification au service de l'automobile: les modèles de trafic urbain,* Paris: Copedith, 1975.

consulting engineering firms and government agencies then working in the field of transportation.[6] More recently, in 2011 the journal *Flux* featured two articles, written by Gilles Debizet and the author of this working paper (WP) respectively,[7] both of them seeking to account for the development of urban travel demand modeling in France from the 1960s up to the present.[8] In doing so, it makes use of an analytical framework which envisages modeling practices as a *production process*: aside from the "product" itself, i.e. the main characteristics of the model under study, the analysis is interested in the different actors involved in producing the model, as well as the "means of production" and the "raw materials" necessary for its production and implementation.[9] Indeed, more often than not, such modeling requires a wide range of actors – individuals and institutions (research bodies and training institutions, private engineering consulting firms, government departments, etc.) –, occupying different places within the "production process". It also requires "raw materials" (for example, data from surveys of household travel) as well as "means of production" such as computer facilities (hardware and software).

Based on this analytical framework,[10] this paper highlights a process characterized by two main developments. From 1950-1980, State French engineers along with private consulting firms, after having familiarized themselves with American modeling practices, succeeded in creating a national expertise in this domain, which the central French state normalized, disseminated, and implemented on a large scale throughout the national territory in the 1970s. The post 1980 period clearly contrasts with what went before. Indeed, evidence shows that the French state progressively withdrew from UTDM, and, therefore, prepared the way for the rise to dominance of private (and more often that not foreign) engineering consulting firms, which became the main repositories of expertise concerning urban traffic forecasting in France.

6 Eric Baye (en collaboration avec Jean-Michel Cusset), "L'Ingénierie-conseil de prévision et de régulation du trafic en France", Rapport pour le compte de la DRAST, Lyon, March 1995; Eric Baye and Gilles Debizet, "Des Nouvelles problématiques urbaines à l'innovation de l'expertise transport/déplacement. Mise en parallèle et convergence: Allemagne – France – Royaume Uni", Rapport pour le compte de la DRAST, Lyon, April 2001; Eric Bay and Gilles Debizet, "Innovation et bureaux d'études dans la planification des transports urbains", *Metropolis,* n° 108/109, 2002, p. 52-57; Gilles Debizet, "Déplacements urbains de personnes: de la planification des transports à la gestion durable de la mobilité. Mutations d'une expertise", Ph.D. dissertation, Université de Paris I Panthéon-Sorbonne, 2004 (https://tel.archives-ouvertes.fr/tel-00006468: last accesed December 7, 2014); Gilles Debizet, "Crise ou mutations de l'expertise", in H. Maksim, S. Vincent, C. Gallez and V. Kaufmann (eds.), *L'Action publique face à la mobilité,* Paris: L'Harmattan, 2010, p. 139-162.

7 Gilles Debizet, "L'Evolution de la modélisation des déplacements urbains en France, 1960-2005. Le poids de l'organisation institutionnelle des transports", *Flux,* n° 85/86, July-December 2011, p. 8-21; Konstantinos Chatzis, "La Modélisation des déplacements urbains en France depuis les années 1980, ou la domination progressive du champ par le secteur privé", *Flux*, n° 85/86, July-December 2011, p. 22-40.

8 Dealing with the same subject matter, Debizet's work and mine often draw upon the same primary sources and share several observations and assessments on the trajectory of UTDM in France from 1960-2010. Be that as it may, our respective works, as far as I can judge, place the emphasis on different aspects of the (common) phenomenon under study. As a researcher interested in transportation and regional planning policies (and their shifts over time) in contemporary France, Debizet studies modeling as a body of engineering knowledge and know-how involved in various and evolving ways in these policies. I mainly read the development of the UTDM in France (and the US) from the perspective of an historian of science and technology, more interested in the production process and the specific characteristics of this kind of modeling.

9 Both models and modeling have been the subject of considerable attention of late from an epistemological perspective (the relationship between the model and the reality depicted; the role of models and modeling in the production of scientific knowledge both in the past and in the present, etc). But, as far as we are aware, research that analyses modeling as an activity in "society" is far thinner on the ground (conditions for producing models, social uses of modeling, etc.). See, for exemple, the survey article by Michel Armatte and Amy Dahan-Dalmedico, "Modèles et modélisations, 1950-2000: Nouvelles pratiques, nouveaux enjeux", *Revue d'Histoire des Sciences*, vol. 57, n° 2, 2004, p. 245-305, and the more recent book by Angela N. H. Creager, Elisabeth Lunbeck and M. Norton Wise (eds.), *Science without Laws. Model Systems, Cases, Exemplary Narratives*, Durham and London: Duke University Press, 2007.

10 To use Neil J. Smelser's terms (*Social Change in the Industrial Revolution. An Application of Theory to the British Cotton Industry*, Abingdon: Routledge, 2006 (1st ed. 1959), ch. 2), our analytical framework consists in "empty theoretical boxes" which have to be filled with empirical evidence. Their only function is to provide useful guidelines for a systematic description of the evolution of urban travel demand modeling practices while indicating the empirical points of investigation. It is evident that, as an analytical tool, the framework allows neither empirical conclusions nor predictions to be drawn as to the contents of these practices and their precise temporal trajectory.

For this attempt at reconstituting the timeline of urban travel demand modeling in France over the long term, I have opted for a panoramic perspective. Because of space constraints, the analysis of the mathematical structure of the traffic forecasting models used will be kept to a strict minimum: I will only refer to the major conceptual developments that characterized this type of modeling. For the same reasons, I won't go into any detailed analysis of the *modus operandi* of the institutions involved in the modeling (headcount, careers, "division of labour", etc.). It is also obvious (to me at any rate) that the perspective adopted here must be combined by other approaches to complete the story of urban travel modeling in France. In fact, two entire swathes of this history have been omitted (for the moment). Firstly, the manner in which the car and "car culture" was taken up in France after the Second World War.[11] Moreover, the account given here also lacks any detailed study dealing with the following questions: what were the everyday practices of practitioners (in terms of calibrating the model and validating its outputs, for example)? What was/were the exact role(s) of this kind of modeling in the political decision-making process, or, put another way, how did politicians use the results provided by modelers in their transport policymaking ptocess?

General principles of 'four-step' urban travel demand modeling

This type of modeling seeks to forecast the traffic within an urban network in a given urban area. As the name indicates, the "four step" modeling approach is based on a combination of four stages or steps: trip generation, trip distribution, mode split and assignment. Each stage addresses a specific question.

1) How many trips will be made? The aim of trip generation (first step) is to predict the number of trips to and from the different zones making up the urban area under study.

2) Where will they go? Once the total number of trips originating and ending in each zone is deemed to be known, the objective of trip distribution (or destination choice, or zonal interchange analysis) (second step) is to allocate the pattern of movement between the different zones. This stage makes it possible to determine the trips corresponding to various possible origin-destination pairings.

3) What mode (private car, public transport modes, etc.) will be used for the trip? Mode split (or mode choice) (third step) computes the relative proportions of these movements by alternative modes.

4) and, finally, what route will be taken ? Trip assignment (or route or traffic assignment) breaks down movements over the transport network studied.

Nota bene: We should stress that the "four-step" model is not a *model stricto sensu*, but a general modeling *approach* (this is why we prefer to refer to "four-step" *modeling*). Indeed, *several* different models have been produced within each of the four steps.

11 As a starting point here, one may use the works by Dupuy, *Une technique de planification au service de l'automobile,* and Mathieu Flonneau, *Paris et l'automobile: un siècle de passions*, Paris: Hachette Littératures, 2005.

1. From the 1950s to the mid-1970s: from importing American know-how to the development of national expertise[12]

1.1. 1950s/early 1960s: the search for and importing of information

In 1953, only 20% of French households had one car or more, increasing to 30% in 1960. However, over the 1960s the trend accelerated: 40% of households had a car in 1964 and 50% by 1967. In January 1973, the figure had risen to 62%, while 9% of households already owned two cars. Staying in 1973, trips made in private cars amounted to 330 billion traveler-kilometers, not including the distances traveled by foreign cars, i.e., four times more than the number of kilometers covered by public transport.[13] This explosion in the number of privately-owned cars called for an infrastructure that would have to be designed according to new rules. Thus, French urban travel demand modeling was born right here in the 1960s. However, the first event of significance in the history of French modeling took place in the US.

For about ten years, beginning in the late 1940s, some 4,500 "missionaries", including officials and servants of the French State as well as members of "civil society", set off on a "pilgrimage" to the US to discover the secrets of American economic success and try to bring these back to France.[14] They included roads engineers just like those who travelled to the US in 1951 to study the American transport experience as part of a mission organized by the *Association Française pour l'Accroissement de la Productivité* (French association tasked with boosting national productivity) and the Roads Department of the French Ministry for Public Works (*Ministère des Travaux Publics*).[15] The latter continued to send engineers across the Atlantic from the *Corps des Ponts et Chaussées* (IPC or X-ponts: Bridge and Roads Corps)[16] and the (less prestigious) *Corps des Ingénieurs des Travaux Publics de l'Etat* (ITPE: State Public Works Engineering Corps) throughout the 1950s and 1960s.[17] It is worth noting that some of these engineers stayed considerably longer and completed courses in transportation planning in US universities (including urban travel demand modeling).[18]

12 This part builds on a previous article of mine published in French: Konstantinos Chatzis, "De l'importation de savoirs américains à la création d'une expertise nationale. La modélisation des déplacements urbains en France, 1950-1975", in Flonneau and Guigueno (eds.), *De l'histoire des transports à l'histoire de la mobilité?*, p. 159-169.

13 Fernard Braudel and Ernest Labrousse (eds.), *Histoire économique et sociale de la France*, t. IV, vol. 3: "Années 1950-1980", Paris: PUF, 1993 (1st edition: 1982), p. 1289 and p. 1239.

14 Concerning study trips to the US in the 1940s and the 1950s, see, for example: Dominique Barjot (ed.), *Catching up with America. Productivity Missions and the Diffusion of American Economic and Technological Influence after the Second World War*, Paris: Presses de l'Université de Paris-Sorbonne, 2002; Richard F. Kuisel, *Seducing the French: The Dilemma of Americanization,* Berkeley: University of California Press, 1993. Concerning the part played by the US in the reconstruction of Postwar European Science, see John Krige, *American Hegemony and the Postwar Reconstruction of Science in Europe*, Cambridge (Mass.): The MIT Press, 2006. Concerning France, the reader will benefit from reading the more monographic study by J.-P. Gaudillière, *Inventer la biomédecine. La France, l'Amérique et la production des savoirs du vivant (1945-1965)*, Paris: Editions La Découverte, 2002.

15 See: "Mission française d'ingénieurs routiers aux Etats-Unis, octobre-novembre 1951 ", *Revue Générale des Routes et des Aérodromes* (*RGRA*), n° 252, January 1953, p. 21-26.

16 The *Ponts et Chaussées* corps was among the most important group of high-ranking civil servants in France from the early 19th century on. The most prestigious route to becoming a member of this *corps* is by studying at two elite institutions: *Ecole Polytechnique* (which is also referred to as 'X'), which dispenses general scientific training, and *Ecole des Ponts et Chaussées*, specialized in civil engineering. Thence, the denomination "X-ponts" to denote members of the *Corps des Ponts et Chaussées* who have studied at both institutions. Concerning the origins of the *Corps des Ponts et Chaussées*, see Bruno Belhoste and Konstantinos Chatzis, "From Technical Corps to Technocratic Power: French State Engineers and Their Professional and Cultural Universe in the First Half of the 19th Century", *History and Technology*, vol. 23, n° 3, 2007, p. 209-225.

17 Concerning the history of IPC and ITPE over the long term, see Konstantinos Chatzis and Georges Ribeill, "L'Espace des carrières des ingénieurs de l'Equipement dans le public et le privé (1800-2000)", *Revue Française d'Administration Publique,* n° 116, 2005, p. 651-670. The 1960s have been covered by Jean-Claude Thoenig, *L'Ere des technocrates. Le cas des ponts et chaussées*, Paris, L'Harmattan, 1987 (1st ed.: 1973). Concerning the actors involved in urban planning, see Viviane Claude, *Faire la ville. Les métiers de l'urbanisme au XXe siècle*, Marseille: Editions Parenthèses, 2006, chapters 3 and 4 for the period of interest to us here.

18 Concerning such missions and trips, as well as the context in which they took place (preparation of successive economic plans by the French government, French auto industry policy, etc.), see, Dupuy, *Une technique de planification au service de l'automobile,* ch. 2 and ch. 3. The author refers to the cases of Joseph Elkouby (IPC, X-1944, who studied at

These French State engineers published a great deal of the various technical literature – articles,[19] books,[20] reports,[21] and even (sometimes confidential) translations[22] – on urban travel demand modeling (UTDM) produced in France in the 1950s and early 1960s. And while these engineers provided a key channel for importing these modeling practices into France, they were by no means the only such vector for transmitting this – primarily American, but increasingly international – field of expertise. Indeed, as it was mentioned in the introduction, while it was originated in the US, urban travel demand modeling (UTDM) would rapidly become a "transnational" object circulating all over the world.[23]

In the early 1950s, a number of forums began to emerge in which transport techniques in general, and among them urban travel demand modeling, were fiercely debated. The *Organisation Mondiale du Tourisme et de l'Automobile* (World Touring and Automobile Organisation) organized an International Symposium on Modern Traffic Management Techniques in The Hague from June 16-21, 1953. The experience was repeated the following year and then once every two years through to at least the late 1960s.[24] Other forums in which urban travel demand modeling techniques were eagerly discussed also emerged, including the European Conference of Ministers of Transport (ECMT), which was also established in 1953,[25] and

Yale University in 1952-53), Serge Goldberg (IPC, X-1948, studied at Yale University in 1955-56), Marc Halpern-Herla (IPC, X-1949, studied at Yale in 1955-57) (in ibid., p. 95). See also the transcription of interviews given by Christian Gérondeau (IPC, X-1957) and Serge Goldberg to Benoît Facq, "Les Fondements statistiques de la science française des déplacements urbains. L'histoire des enquêtes ménages déplacements", unpublished MSc Thesis, Université Lumière Lyon 2 and Institut d'Etudes Politiques de Lyon, 2005/2006, interviews n° 7 and n° 12 respectively (according to Facq, Serge Golderg studied in the US between 1956-58). Additional information concerning these trips may be found in different issues of *Revue Générale des Routes et des Aérodromes* (*RGRA*) (see, for example, *RGRA*, n° 285, October 1955, p. 37-69, which describes the mission of *Services Techniques des Grandes villes de France* (technical departments of large French cities) that took place in October/November 1954).

19 See, for example: J. Elkouby, "L'Evolution des conceptions en matière de circulation routière", *RGRA,* n° 279, April 1955, p. 37-48; R. Malcor and F. Ramel, "Circulation et autoroutes urbaines aux Etats-Unis", *RGRA*, n° 285, October 1955, p. 37-56; C. Abraham (avant-propos par R. Coquand), "La Répartition du trafic entre itinéraires concurrents: réflexions sur le comportement des usagers – application au calcul des péages", *RGRA*, n° 357, 1961, p. 57-76.

20 Fédération Routière Internationale, *Circulation et transports dans les zones urbaines,* Levallois-Perret (Seine): Imprimerie Schneider Frères&Mary, March 1964 (the introduction to this collective work is written by Elkouby and Goldberg, and the work includes another "missionary", Halpern-Herla). See also Christian Gérondeau, *Les Transports Urbains*, Paris, PUF, 1969.

21 Service d'Etudes et de Recherches de la Circulation Routière (SERC), *Modèles de trafic. Analyse bibliographique (texte établi par Barbier, Goldberg, Henry et Marais),* note d'information n° 3; SERC, *Etudes de Transports Urbains. Analyse des méthodes américaines* (written up based on a report by Mr. Michel Vergé, state public works engineer), note d'information n° 4; SERC, *Répartition des déplacements urbains par mode de transport* (written by Serge Golderg), note d'information n° 8 (all of these memoranda date from the first half of the 1960s).

22 First and foremost, we should mention the seminal report by Colin Buchanan, translated into French two years after it was first published in English (Colin Buchanan et al., *Traffic in Towns. A Study of the Long Term Problems of Traffic in Urban Areas,* London: HMSO, 1963; French translation: *L'Automobile dans la ville, étude des problèmes à long terme que pose la circulation dans les zones urbaines…*, Paris: Imprimerie Nationale, 1965 (translated by the services of the French Ministry of Public Works). See also: SERC (section Documentation), "Modèle d'opportunité pour l'analyse de la circulation", July 1965 (tapescript available from the SETRA Library: this is a translation of a classic article by C. Clark and G. H. Peters, "The 'Intervening Opportunities' Method of Traffic Analysis", *Traffic Quarterly*, vol. 19, n° 1, January 1965, p. 101-119) ; SERC, "La Capacité des routes", 1968 (translation of the classic manual: Highway Research Board, *Highway Capacity Manual*, Washington, D.C. The translation was apparently based on the second edition of the Manual published in 1965); SERC, "Comparaison des avantages des autobus et des voitures particulières pour la circulation dans les villes", 1966 (translation of R. J. Smeed and J. G. Wardrop, "An Exploratory Comparison of the Advantages of Cars and Buses for Travel in Urban Areas", *Institute of Transport Journal*, vol. 30, n° 9, March 1964, p. 301-315). The two latter translations appear in the bibliography of the following report: Ministère de l'Equipement et du Logement, Ministère des Transports, Commission d'étude des coûts d'infrastructure de Transport, Groupe des Transports urbains*, Sur les coûts et la tarification des transports urbains,* Paris, February 1969 (n° 38 and n° 39).

23 This working paper may also be seen as a first contribution to a (future) "transnational" history of the urban travel demand modeling. Concerning the transnational history of technology, see the article by Erik van der Vleuten, "Toward a Transnational History of Technology: Meanings, Promises, Pitfalls", *Technology and Culture*, vol. 49, 2008, p. 974-994.

24 Years 1953, 1954, 1956, 1958, 1960, 1962, 1964, 1966, 1968. See the detailed minutes of these meetings, in which a number of *Ponts et Chaussées* engineers took part, in the various issues of *RGRA* (n° 260, September 1953, p. 31-34, and n° 261, October 1953, p. 58-72 for the first meeting; n° 440, February 1969, p. 45-107 for the 9th meeting in 1968, etc.).

25 See, for example: Michel Barbier and François Mellet, "Determination of Elasticities of Demand for the Various Means of Urban Passenger Transport", Report of the Thirteenth Round Table on Transport Economics, European Conference of Ministers of Transport, n.d.; Georges Mercadal, "Contribution à une psycho-sociologie des comportements urbains. Choix du moyen de transport" (introductory report to a round table on transport economics organised by the European Conference of Ministers of Transport (November 1968)), Paris: Publications de Recherches Urbaines, Ministère

various ad hoc working groups set up within international bodies such as the OCDE.[26] We should also mention two other institutions whose publications and the international events they continue to organize on a regular basis (notably annual meetings) have played a key role in the dissemination of urban travel demand modeling techniques throughout the world, namely the (American) Transportation Research Board (TRB) (ex-Highway Research Board (HRB), established as early as 1920,[27] and the (European) organization Planning and Transport Research and Computation (PTRC). Founded in 1966, PTRC immediately began organizing its highly popular PTRC Summer Annual meeting,[28] renamed the European Transport Conference (ETC) in the 1990s, and now organized by the Association for European Transport (AET), founded in 1998.[29] Urban travel demand modelers can also exchange and express views in a number of transport and planning journals set up in the 1960s and which devote a lot of column inches to urban travel demand modeling, such as *Transportation Research* and *Transportation Science* (both set up in 1967), *Environment and Planning* (created in 1969) or *Transportation* (1972).[30]

1.2. Early 1960s up to the early 1970s: forging of national expertise

As well as sending engineers to the United States[31] and representatives to various transnational forums for exchanging and disseminating knowledge and know-how related to transportation issues, the French authorities also set up a number of structures at this time tasked with urban transport planning and the related modeling techniques. This was the period in which the French State abandoned its *laissez-faire* dogma in favor of extensive state planning.[32]

It was the *Service d'Etudes et de Recherches de la Circulation Routières* (SERC: Traffic Studies and Research Office), set up in 1955 within the French Ministry for Public Works, that played the dominant role in developing French expertise in urban travel demand modeling in the 1960s. This is also the structure that housed a large number of the "missionary" engineers of the 1950s and 1960s.[33] At the end of the 1960s, this institution made way for two structures

de l'Equipement et du Logement, 1970; A. Bonnafous and B. Gerardin, "La Demande de transports de voyageurs en milieu urbain. Méthodologie de l'analyse et de la prevision" (Rapport de la 32e table ronde d'Economie des transports, tenue à Paris, les 4 et 5 décembre 1975), Conférence Européenne des Ministres des Transports, 1976. Concerning the creation of ECMT (European Conference of Ministers of Transport), see Christian Henrich-Franke, "Mobility and European Integration. Politicians, Professionals and the Foundation of the ECMT", *The Journal of Transport History*, vol. 29, n° 1, 2007, p. 64-82.

26 See, for example: OCDE, *Modèles de circulation urbaine: possibilités de simplification* (report prepared by a group of OECD researchers specialised in road transport), Paris: OCDE, August 1974. This group was created in June 1972 and lasted two years. The joint head of its Technical Secretariat was the *Ponts et Chaussées* engineer Jean-Gérard Koenig (X-1964).

27 On TRB (and HRB), see Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours)", ch. 1 and passim.

28 Today PTRC is an independent, international organisation based in London, which specializes in the training of transport, highways and planning professionals. It designs and delivers training courses, seminars, workshops and conferences on a wide variety of transport and related topics (http://www.ptrc-training.co.uk/: last accessed July 14, 2014).

29 Concerning the AET, a non profit organisation, owned and supported by its corporate members, see http://aetransport.org/: last accessed July 14, 2014. On the European Transport Conference, see: http://aetransport.org/page/open/title/History+of+the+European+Transport+Conference: last accessed July 14, 2014.

30 Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours), p. 138-140**.**

31 We can find traces of this tradition of using stays in the US to keep abreast of developments in urban travel travel modeling right through to the end of the 1970s. For example, Michèle Cyna, a *Ponts et Chaussées* engineer (X-76), completed a masters at MIT in the late 1970s/early 80s (see Michèle Cyna, "Congestion and Schedule Delay", unpublished MSc Thesis, Massachussets Institute of Technology, June 1981), and his supervisor was none other than Moshe Ben-Akiva (see below) with whom M. Cyna co-signed an article: Moshe Ben-Akiva, Michèle Cyna and André de Palma, "Dynamic Model of Peak Period Congestion", *Transportation Research Part B*, vol. 18, n° 4/5, 1984, p. 339-355.

32 Richard F. Kuisel, *Capitalism and the State in Modern France. Renovation and Economic Management in the Twentieth Century*, Cambridge: Cambridge University Press, 1981; concerning the French State's role as a regional "planner", see also Dominique Massardier*, Expertise et aménagement du térritoire: l'Etat savant,* Paris: L'Harmattan, 1996.

33 In 1964, SERC comprised three divisions: *Division d'Etudes Urbaines* (DEU: Urban Studies Division), *Division du Trafic Interurbain et des Mathématiques Appliquées* (Inter-urban Traffic and Applied Mathematics Division) and *Division des Statistiques Générales et des Rélations Exterieures* (General Statistics and External Relations Division) (see Ministère des Travaux Publics et des Transports, SERC, DRCR, "Le Service d'Etudes et de Recherches de la Circulation Routière"*,* Paris, April, 1964). In 1964-65, SERC was being run by the *Ponts et Chaussées* engineer Michel Frybourg (X-46) and comprised a total

intended to be complementary and based on a "division of labor" between basic research work on transportation issues on the one hand, and surveys and applications on the other.

Regarding surveys and traffic studies *Service d'Etudes Techniques des Routes et Autoroutes* (SETRA: Roads and Highways Technical Survey and Studies Bureau), set up in January 1968, included an "Urban Section" tasked with urban transport planning and related modeling techniques.[34] SETRA, a Paris-based structure within the *Ministère de l'Equipement*[35] (Ministry for Infrastructure) was rapidly supported by several local public agencies known as *Centres d'Etudes Techniques de l'Equipement* (CETEs: Infrastructure Technical Survey Bureaus), set up between 1968 an 1973, which replaced other pre-existing local structures.[36] Transport modeling in the *Ile-de-France* (Paris region) was not the responsibility of a body affiliated to the SETRA as was the case in other regions (indeed, a CETE never existed for the *Ile-de-France*). Instead, urban travel demand modeling was developed within another structure, the *Service Regional de l'Equipement de la Région Parisienne* [later renamed *Direction Régionale de l'Equipement d'Ile-de-France* (DREIF: Regional Infrastructure Department for the Ile-de-France)],[37] a regional structure under the auspices the Ministry for Infrastructure which developed its own "four-step" model in the early 1970s and still existed in the 2000s in a modified form under the name MODUS.[38]

Basic research into transportation issues (including modeling) was transferred to the *Institut de Recherche des Transports* (IRT*:* Transport Research Institute),[39] which became the *Institut National de Recherche sur les Transports et leur Sécurité* in 1985 (INRETS: National Institute for Transport and Safety Research).[40]

A number of *Ponts et Chaussées* engineers were actively involved in urban travel demand modeling in the above mentioned structures, especially, SETRA and IRT. A non-exhaustive list would include Mikhaël Sakarovitch (X-1957), specialized in Operations Research techniques with a doctorate obtained in the US,[41] François-Léon Barbier de Saint-Hilaire (X-1962), who created what was to become the classic DAVIS model[42] in the late 1960s/early 70s (see below), Jean-Gérard Koenig (X-1964) and Jean-Henri Poulit (X-1957), whose works around

of sixteen people, including five *Ponts et Chaussées* engineers (of which, Goldberg) and four state public works engineers. See *Annuaire du Ministère des Travaux publics et des Transports*, année 1964-65, p. 420.

34 This division became autonomous in 1976 as the *Centre d'Etudes des Transports Urbains* (CETUR) and was renamed the *Centre d'Etudes sur les Réseaux, les Transports, l'Urbanisme et les Constructions Publiques* (CERTU) in 1994. In January 2014, the CETEs, CERTU and SETRA merged to give birth to *Centre d'Etudes et d'Expertise sur les Risques, l'Environnement, la Mobilité et l'Aménagement* (CEREMA) (http://www.cerema.fr/: last accessed July 14, 2014).

35 The *Ministère de l'Equipement* (French Ministry for Infrastructure) was created in 1966 out of the merger of the Ministries of Public Works and Construction. It has gone through a number of name changes and is currently knows as *Ministère de l'Ecologie, du Développement Durable et de l'Energie* (Ministry of Ecology, Sustainable Development and Energy) (http://www.developpement-durable.gouv.fr/: last accessed July 14, 2014). In the rest of this paper, it will be referred to by its original name i.e., Ministry for Infrastructure.

36 There were seven different CETEs: CETE Méditerranée (located in Aix-en-Provence, set up in 1968), CETE Nord (Lille, 1970), CETE Sud Ouest (Bordeaux, 1971), CETE Normandie (Rouen, 1971), CETE de l'Ouest (Nantes, 1972), CETE de l'Est (Metz, 1973).

37 Now known as *Direction Régionale et Interdépartementale de l'Equipement et de l'Aménagement d'Ile-de-France* (http://www.driea.ile-de-france.developpement-durable.gouv.fr/: last accessed July 14, 2014).

38 See Vincent Lichère, "MODUS. Modèle de déplacements urbains et suburbains. Présentation générale de la version 1", Note interne, Paris, DREIF, November 1995 (document available at the DREIF Library).

39 IRT dates officially from 1970 although it appears to have been actually set up as early as 1968. See, for example*,* "Bilan des activités du Département 'Recherche opérationnelle et informatique' pour l'année 1968" (document which can be consulted in the SETRA Library).

40 In January 2011, INRETS merged with the *Laboratoire Central des Ponts et Chaussées* (LCPC) to give birth to *Institut Français des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux* (IFSTTAR: French Institute of Science and Technology for Transport, Spatial Planning, Development and Networks).

41 M. Sakarovitch, "The Multicommodity Maximum Flow Problem", Ph.D. dissertation, University of California at Berkeley, 1966. See also: P. H. Fargier, M. Sakarovitch and J. P. Uhry, "Introduction à la recherche opérationnelle"*,* IRT, November 1971.

42 See, for example, CETUR, "Système DAVIS, programme d'affectation de trafic sur voirie (version IBM et CII)", Bagneux, October 1976.

the notion of accessibility in the early 1970s are still cited in international research[43] (see below). These state engineers were supported by other key people and, again without in any way providing an exhaustive list, we could mention Jean-Pierre Uhry, a graduate of *Ecole des Ponts et Chaussées* who created the EVARAU model (assignment phase) during his time at IRT,[44] as well as an assignment model for public transportation systems, known as TERESE, which became a staple of French transport modeling after its development in the mid-1970s (see below)[45]; or M. Bruynooghe, also an engineering graduate of *Ecole des Ponts et Chaussées*.[46]

Although the Ministry for Public Works and its successor in the 1960s, the Ministry for Infrastructure, played a key role in "acclimatizing" and developing models for forecasting urban traffic, other actors, mostly located in the Paris region, were also actively involved in urban travel demand modeling from the end of the 1950s on.

One of these was the *Institut d'Aménagement et d'Urbanisme de la Région Parisienne* (IAURP: City Planning Institute for the Paris region), which was set up in 1960 – it subsequently became the IAURIF in 1976 and IAU-îdF in 2008. At the beginning of the 1960s thanks to the contributions of Pierre Merlin, a geographer and graduate of *Ecole Polytechnique* (X-1957), and Michel Barbier, a graduate from the *Ecole des Ponts et Chaussées* in 1959, who also held a Masters degree in Operations Research from the Case Institute of Technology of Cleveland, IAURP pioneered research dealing with the issue of the so-called "generalized cost" of transport – taking account of factors such as monetary cost, time spent, various types of inconvenience, etc. –, which was subsequently used to study transport mode split between privately-owned cars and public transport (i.e., the third step in 'four-step' modeling).[47]

Other actors were also actively involved in urban travel demand modeling in the 1960s. These included a number of public and private engineering consulting firms. We should mention in particular: 1) the *Société pour l'Avancement et l'Utilisation de la Recherche Opérationnelle Civile* (AUROC), set up by two graduates of *Ecole Polytechnique*, Jacques Mélèse (X-1947) and Jacques Barache (X-1947), at the end of the 1950s, and which employed about twenty people when it merged with CEGOS in 1965[48]; 2) the private engineering consulting firm known as *Société d'Economie et de Mathématique Appliquées* (SEMA: Economics and Applied Mathematics Bureau) set up in 1960,[49] which produced several models corresponding to the different phases in four step-modeling (SEMA's team of modelers was organized around the *polytechnicien* H. Le Boulanger (X-1956))[50]; 3) the private engineering consulting firm known as *Société d'Etudes*

43 G. Koenig, "La Théorie de l'accessibilité urbaine, un nouvel outil au service de l'aménageur", *RGRA*, n° 499, June 1974, p. 67-78; G. Koenig, "Théorie économique de l'accessibilité urbaine", *Revue Economique*, vol. 25, n° 2, 1974, p. 275-297; J. Poulit, "Approche économique de l'accessibilité", January and November 1973.

44 J. P. Uhry, "Le Modèle EVARAU. Un programme interactif pour la recherche d'un meilleur tracé d'un réseau d'autobus", IRT, October 1969.

45 While he was developing TERESE, which "draws largely on the principles underpinning the EVARAU model," Uhry was a university researcher at *Institut de Recherches en Mathématiques Avancées de Grenoble* (IRMA). See, for example CETE-Lyon, SEMALY and IRMA-Grenoble, "TERESE, affectation d'une demande TC", undated (mid-1970s), p. 2 (document available from the SETRA Library). During the period 1975-1995, TERESE was used for a number of cities, including Lyon, Grenoble, Nantes, Bordeaux, Strasbourg, Montpellier, Rouen, Toulon, Valenciennes or Orléans. See, Carole Berenguer, "Evaluation de la modélisation des trafics sur la ligne D du métro de Lyon", Rapport pour le compte de la DRAST, Lyon, March 1996, p. 10.

46 M. Bruynooghe is the author of "Un Modèle intégré de distribution et d'affectation du trafic sur un réseau", April 1969 (document kept at the *Ecole des Ponts et Chaussées* Library).

47 Concerning the "output" of IAURP, see in particular Michel Barbier and Pierre Merlin, "Choix du moyen de transport par les usagers", *Cahiers de l'IAURP,* vol. 4-5, April 1966, p. 5-56; François Mellet, "Analyse du choix du mode de transport par les usagers en région parisienne", *Cahiers de l'IAURP,* vol. 17-18, cahier 2, October 1969, p. 5-42; the studies published in the "Choix entre transports publics et transports individuels en région parisienne" *Cahiers de l'IAURP,* vol. 26, February 1972. See also Marc Gaudry and Emile Quinet, "Shannon's Measure of Information, Path Averages and the Origins of Random Utility Models in Transport Itinerary or Mode Choice Analysis", Working Paper n° 2012-31, Paris School of Economics/Ecole d'Economie de Paris, June 2012, p. 17-18 and *passim*.

48 On AUROC, see "Systémique: mode d'emploi (entretien avec Jacques Mélèse", *Gérer et Comprendre*, June 1993, p. 17-27.

49 Concerning SEMA, see Jacques Lesourne, *Un Homme de notre siècle,* Paris, Odile Jacob, 2000, Part III.

50 See, for example, A. Brachon, H. Le Boulanger and P. Lissarrague, "Recherche sur les comportements en matière de déplacements. Synthèse sur les modèles de trafic de personnes en zone urbaine", SEMA (Metra International), Division Recherche et Développement (Synthèse et Formation n° 52), February 1969.

Techniques et Economiques (SETEC: Technical and Economic Survey Office) created in 1957 by two *Ponts et Chaussées* engineers who had come over from the public sector: Henri Grimond (X-ponts 1946) and Guy Saias (X-ponts 1944). SETEC's involvement in modeling techniques was bound up with the *polytechnicien* Roger Marche (X-1949) and Alain Bieber, a graduate of the *Ecole des Ponts et Chaussées* and who held a Ph.D. from the University of California at Berkeley in 1966[51]; 4) the *Centre d'Etudes et de Recherches sur l'Aménagement Urbain* (CERAU: Center for Urban Planning Surveys and Research), a consulting firm founded in 1966 as part of *Caisse des Dépôts et Consignations* (Deposits and Consignments Office) and headed by Georges Mercadal, a *Ponts et Chaussées* engineer (X-1956)[52]; 5) the *Bureau Central d'Etudes pour les Equipements d'Outre-Mer* (BCEOM: Central Bureau for Overseas Infrastructure Studies) created in 1949.[53] Finally, though some foreign firms – such as Freeman, Fox, Wilbur Smith and Associates, which produced several travel demand models in the 1960s – were involved in urban travel demand modeling in France during this period, we should note that they were not nearly as prevalent as in the post 1980 period (see below).[54]

To complete the list of actors involved in French urban travel demand modeling at this time we need to add in a number of engineering schools and primarily *Ecole des Ponts et Chaussées* (ENPC, now *Ecole des Ponts ParisTech*).[55] The latter acquired a large number of American publications on urban travel demand modeling,[56] and in the mid-1960s started offering comprehensive courses on the subject taught by modeling practitioners of the time.[57] *Ecole des Ponts et Chaussées* also participated in the modeling adventure in the 1960s through several studies of the topic undertaken by undergraduate students.[58] In the late 1960s, IAURP resorted to the skills of researchers at the *Ecole des Mines* Scientific Management Department (*Centre de Gestion Scientifique*) to render models developed by its own modelers operational.[59]

Most of these actors belonged to the same networks of sociabilities – as we have already seen, the French modelers' community at this time included many *polytechniciens* and several graduates of *Ecole des Ponts et Chaussées* –, and often worked in symbiosis, with one or several engineering consulting firms in collaboration frequently working on behalf of public authorities. They also shared a number of "common resources". These included the large computers of that time, the "means of production" for the modeling process in our "parlance", or the

51 A. Bieber, "Modal Evolution of Intercity Traval Demand. A Markovian Analysis", Ph.D. dissertation, University of California at Berkeley, 1966.

52 Concerning CERAU, see for example the brochure: *CERAU*, 1969, published by the firm (in 1969, CERAU had five offices outside Paris, in Lyon, Rennes, Orléans, Nice and Marseille (ibid., p. 5)).

53 BCEOM, "Etude sur les Pénétrantes Urbaines", April 1967.

54 In the 1970s, this firm developed the AMERTUM program on behalf of CETE Aix-en-Provence. Concerning the service offered by this firm in France, see: Marc Doizon, "Développement, programmation, et application d'un module de répartition modale en milieu urbain", Ph.D. dissertation (doctorat de spécialité (3e cycle)), Université d'Aix-Marseille, Institut d'Aménagement régional d'Aix-en-Provence, 1974, p. 100 and *passim*; SETRA, Société civile Freeman Fox (Paris) et "Le Mas" de Verte Colline, "Note technique 1. Analyse de fonctions de conductance à deux paramètres: distribution de déplacements (modes motorisés) en fonction de la distance", April 1975 (available at the SETRA Library).

55 Concerning *Ecole des Ponts et Chaussées* (ENPC), see Konstantinos Chatzis, "Die älteste Bauingenieurschule der Welt – die Ecole des ponts et chaussées, 1747-1997", *Bautechnik Spezial*, 1998, p. 26-42.

56 For example, the catalogues of the ENPC Library contain: a collection of Highway Research Board Proceedings for the period 1941-1961 (P 0726); Highway Research Board –Yearbook for 1963-1967 (P 0723); Highway Research Circular (1945-1960) (P 0587); the seminal work by Robert E. Schmidt and M. Earl Campbell, *Highway Traffic Estimation*, Saugatuck (Connecticut): The ENO Foundation for Highway Traffic Control, 1956 (8° 36867).

57 See, for example: MM. Lagneau and Pebereau, Professeurs (MM. Biass, Coignet, Coquery, Cornet-Vernet, Mme Dottelonde, Gerondeau, Mercadal, Nardin, Ralite: Maîtres de conférence), "Cours d'Aménagement urbain, 1965-66"; A. Bieber, O. Dubois-Taine, J. Orselli and J. Ville, "Circulation et transports urbains (Enseignement spécialisé n° 29)", année 1972-73 (these documents may be consulted at the ENPC Library).

58 See, for example, J. Ichbiah, "L'Affectation du trafic sur un réseau (analyse bibliographique d'une documentation allemande et américaine. Etude particulière de certains points", January 1966; Yves Cousquer and Pierre Richard, "La valeur du temps dans les déplacements domicile-travail. Cas d'un grand ensemble de Lyon", 1966 (these documents may be consulted at the ENPC Library).

59 Michel Barbier et al., "Investissement et tarification des transports urbains (Un essai d'approche systématique)", *Cahiers de l'IAURP,* vol. 17-18, cahier 4, October 1969, p. 5-44.

household travel surveys, the "raw materials" that would feed the models themselves. We should stress the scarcity of such resources at this time.

It was not until 1969/70 that the French Ministry for Infrastructure gradually began to be equipped with its own computers: an IBM 360/50 (located at SETRA), a CII 10 070, leased by *Compagnie Internationale d'Informatique* (located in IRT), and an IBM 360/50 series (managed by CETE Aix-en-Provence).[60] As late as 1976, CETE de l'Est, which was created in 1973, did not have its own hardware – its own network of five terminals was actually hooked up to the CII-IRIS 80 computer belonging to CETE de Lyon.[61] In the 1960s, *Ponts et Chaussées* and other government engineers involved in modeling frequently resorted to the services of computer companies such as IBM-France, which provided its customers with turnkey models in the form of programs that ran on their machines.[62] In addition to IBM, we should mention *Société d'Etude et de Recherche pour le Traitement de l'Information* (SERTI), which possessed an UNIVAC 1108,[63] and *Société d'Informatique Appliquée* (SIA), a subsidiary of SEMA, which got its hand on the most powerful machine of the time, a CDC 3600 calculator made by Control Data Corporation, and a little later on a CDC 6600 model built by the same firm.[64]

In addition to computer hardware, contemporary modelers also shared "raw materials", i.e., the household travel surveys that were fed into the models[65]. Whilst most of these were carried out under the auspices of SERC (and subsequently SETRA and the various different CETEs), other actors such as Régie Autonome des Transports Parisiens (RATP: body responsible for the Parisian metro and bus network), or the City of Paris also conducted similar surveys in tandem with private consulting engineerig offices. A number of large French cities were also surveyed: Lyon, Lille and Nancy in 1965, Marseille, Aix-en Provence, Nice and Grenoble in 1966, Bordeaux in 1967, etc.[66]

Here is a brief overview of how the city of Nancy was surveyed. Between February 15 and April 8, 1965, thirty-seven students from the University of Nancy shared the tasks of surveying, verifying and counting. The survey sample, questionnaire format and table of findings were defined during preliminary work lasting several months. Approximately 7,500 of the city's inhabitants, chosen at random from the list of electricity company (EDF) subscribers, replied to the questionnaire. The survey required 2,200 hours of work from 28 survey assistants. The table of findings was processed by mechanical tabulation on an IBM 1401. All card

60 Jean-Louis Deligny, "Le Centre de calcul de l'Administration centrale du Ministère de l'Equipement et du Logement", *RGRA*, n° 456, July-August 1970, p. 65-75. The Ministry for Infrastructure has possessed an IBM 1130 8K since March 1968. See "Bilan des activités du Département 'Recherche opérationnelle et informatique' pour l'année 1968", p. 1. (document available at the SETRA Library)

61 Brochure published by CETE de l'Est (undated) concerning year 1976, p. 17 (available from the CETE de l'Est Library).

62 Information taken from the following documents: Ministère des Travaux Publics et des Transports, Direction des Routes et de la Circulation Routière, Ecole Nationale des Ponts et Chaussées, "Titre IV: Etudes de Transport", April 1965; *Cahiers de l'IAURP,* vol. 28, September 1972 (cahier 2); Ponts et Chaussées, SERC, Agence de l'Est, "Affectation de trafic avec contraintes de capacité, Programme IBM-CAPRE", May 1967 (document available from the SETRA Library); MM. Koenig, Seigner et Boussuge, "Génération, distribution, affectation de trafic sur les voies nouvelles", *RGRA* (Recyclage : formation permanente, année 1974), fascicule n° 1, January 1974, p. 1-16.

63 See Ministère de l'Equipement et du Logement et al., "Sur les coûts et la tarification des transports urbains", Appendix n° 1, p. 1 et p. 3.

64 Information taken from the following documents: J. Letellier, "ATTRAVAR", OTR de Normandie, April 1965, p. 19-20; Amy Dahan Dalmedico, *Jacques-Louis Lions, un mathématicien d'exception*, Paris: La Découverte, 2005, p. 48-49. Concerning the mainframes of the 1960s, see: Paul E. Ceruzzi, *A History of Modern Computing*, Cambridge (Mass.): The MIT Press, 2003 (2nd ed.). For the American setting, see Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours)."

65 On the history of household travel surveys in the United States, originated in the 1940s and massively "exported" to other countries, among them France, see Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours)."

66 For a list and analysis of survey findings, see: SETRA, "Caractéristiques des déplacements en milieu urbain", dossier 1 (Rapport): "Caractéristiques socio-économiques des villes", Bagneux, undated; CETUR, "Caractéristiques des déplacements en milieu urbain", dossier 4 (Rapport et Annexe): "Répartition entre modes de transports", Bagneux, n.d.; CETUR, "Evolution des caractéristiques des déplacements en milieu urbain entre 1966 et 1973. Analyse d'après les enquêtes ménages réalisées à Grenoble, Nice, Rouen", Bagneux, 1977. Concerning these surveys, see also the analyses of Facq, "Les Fondements statistiques de la science française des déplacements urbains."

punching, programming and data processing took place over a six-week period after the end of the survey.[67]

Among the many surveys carried during this time, the "first global transport survey in the Greater Paris Region" (*Etude Globale de Transport de la Région Parisienne*), which included projections of traffic patterns through 1975, 1985 and 2000, deserves a special mention. In 1966, a transport study group that had been put together by the General Delegation of the Greater Paris Region (*Délégué Général au District de la Région de Paris*) suggested carrying out a "global transport survey". This would involve a certain number of regularly updated and processed measurements and indicators to provide checks on the coherence of transport decisions in the Paris region. A "global study group" was set up once proposals had been vetted and approved by the Board of the Districts and by the Ministry for Infrastructure and Housing.[68] This group was then organized into three units – "information processing", "scientific analysis" and "survey preparation and control" –, and the survey was organized on an "industrial" scale by breaking down the various tasks into a number of meticulously prepared operations. The group spent more than a year, from late 1967 to early 1969, designing the survey procedure and planning its implementation (deciding upon the models to be used, the nature and volume of statistical data to be gathered, etc.). The survey itself took place between 15 March and 1 July 1969 and involved 21,000 households. After systematically verifying and cross-checking all data gathered (July-December 1969), the survey group had to correct the various errors related to the sampling techniques or due to the refusal of some people to answer certain questions (January-March 1970), write the data processing programs, and analyze and format the initial findings (April-July 1970). These were announced in September 1970 during a press conference given by the Prefect of the Paris Region. The global transport survey cost a total of 11.3 million francs (in 1971) – in 1966, the estimated cost was 14 million francs –, and it mobilized a plethora of public and private actors most of which have already been mentioned: SETEC, SERTI, BCEOM, SIA and CERAU, all appeared on the list of participants of this venture which was organized by the *Service Régional de l'Equipement de la region Parisienne* with the help of IAURP.[69]

It is obvious from what we have just seen that the French urban travel modeling landscape of the 1960s involved a great number of different actors. This in turn gave rise to a wide range of models for each of the "four-steps" involved in the urban travel demand modeling techniques (apart from the third step, that of mode choice, which generated little research outside of that carried out by IAURT).[70] By the late 1960s/early 70s, one can use the expression of "national science" to characterize the French production in this field, since several models designend by French actors and run on computers based inside the country were available at that time.[71] We should also stress that this national scientific production attracted attention

67 SERC. Agence de l'Est, *Nancy, enquête de circulation 1965,* Metz: Imprimerie Louis Hellenbrand, 1966*,* particularly p. 2.

68 These proposals are contained in *Cahiers de l'IAURP*, vol. 28 ("L'Etude Globale de Transport de la Région Parisienne"), 1972, fascicule: "Avant-propos; 1. Le cadre de l'étude", p. 19-25.

69 Ibid., p. VI, p. 4-5, p. 11 in particular. For further information, the reader may refer to *Cahiers de IAURP*, vol. 28, 1972.

70 The reader may read about this production by consulting *inter alia*: SERC, "Modèles de trafic, analyse bibliographique"; *Cahiers de l'IAURP,* vol. 4-5, vol. 26 and vol. 28; Brachon et al., "Recherche sur les comportements en matière de déplacement"; J. Letellier, "ATTRAVAR"; A. Gaudefroy-Demombynes, "Le Simulateur de déplacements en milieu urbain", *RGRA,* n° 487, May 1973, p. 101-104; E. Balavoine, "La Prévision de la demande de transports urbains", Ph.D. dissertation, Université de Bordeaux I, 1981; Pierre Merlin, *La Planification des transports urbains, enjeux et méthodes,* Paris: Masson, 1984; P. Merlin, *Bibliographie sur la planification des transports urbains/Bibliography on Urban Transport Planning,* Arcueil and Saint-Denis: IRT and Presses Universitaires de Vincennes, 1984.

71 On the "national science" issue, see David Edgerton, "Science in the United Kingdom. A Study in the Nationalization of Science", in John Krige and Dominique Pestre (eds.), *Science in the Twentieth Century*, Amsterdam: Harwood Academic Publishers, 1997, p. 759-776.

from abroad. Several French modelers published English-language research articles,[72] and some of this work is still being quoted by colleagues from various different countries.[73]

1.3. Early-mid 1970s: from the proliferation to the standardization

The burgeoning activity of the 1960s that had generated a number of home-produced models for each of the four steps in urban travel demand modeling in France was brought to a halt at the beginning of the next decade with the creation of a *normalized French science* in this modeling field. What exactly do we mean by this expression?

In 1972 and 1973, several circulars were issued setting out the institutional framework, objectives, methodology and funding for studies concerning the design, location and programming of urban road and transport infrastructure.[74] Along with the drafting of these methodological circulars, as a group of State engineers put it, "Paris-based departments of the Infrastructure Ministry, especially the urban section of SETRA, undertook to provide local users with traffic forecasting methods and models adapted to the new types of problems. In particular, it appeared essential – in light of experiences outside France – to spare each city the task of having to reinvent its own specific forecasting method requiring extremely costly and time consuming new household mobility surveys (approximately two years' work was required) with no ultimate guarantee of any benefit. Therefore, it was sought to introduce models that were as universal as possible, that could be calibrated for each city on the basis of a restricted number of "core" parameters and could usually be obtained from simple surveys (tallying). The raw data used in the standard models introduced was gleaned from sixteen household surveys conducted in French cities between 1966 and 1971."[75]

Methodological circulars, guides, pilot schemes, summary reports published by the central services of the Ministry for Infrastructure, particularly SETRA,[76] articles summarizing urban travel demand modeling "doctrine" published in technical journals and widely read by

72 For a non-exclusive list of such publications, see: M. Bruynooghe, A. Gibert and M. Sakarovitch, "Une Méthode d'affectation du trafic", in W. Leutzbach and P. Baron (eds.), *Beiträge zur Theorie des Verkehrsflusses Strassenbau und Strassenverkehrstechnik* (Proceedings of the Fourth International Symposium on the Theory of Road Traffic Flow, Karlsruhe, June 1968), Heft 86, Herausgegeben von Bundesminister für Verkehr, Abteilung Strassenbau: Bonn, 1969, p. 198-204; C. Ferragu and M. Sakarovitch, "A Class of 'Structural' Models for Ttrip Distribution", *Transportation Research*, vol. 4, 1970, p. 87-92; H. Le Boulanger, "Research into the Urban Traveller's Behaviour", *Transportation Research*, vol. 5, 1971, p. 113-125; P. Rochefort, "The Demand for Inter-Urban Transport Econometric and Psycho-Sociological Approaches", in *Models of Traffic Outside Towns* (PTRC Symposium Proceedings, 12-15 May 1970), Amsterdam: Bournemouth, 1971, p. 47-50; J. G. Koenig, " Indicators of Urban Accessibility: Theory and Application ", *Transportation*, vol. 9, 1980, p. 145-172.

73 Concerning works referring to the French production of the time, see: F. Tagliacozzo and F. Pirzio, "Assignment Models and Urban Path Selection Criteria: Results of a Survey of the Behaviour of Road Users", *Transportation Research*, vol. 7, 1973, p. 313-329 (the authors refer to work carried out by SEMA modelers); W. J. Jewell, "Models for Traffic Assignment", *Transportation Research*, vol. 1, 1967, p. 31-46 (the author spent from September 1965 to February 1966 in Paris as a Fulbright Research Scholar where he worked with H. Le Boulanger and his team at SEMA. He refers to Sakarovitch's work at Berkeley); J. M. Morris, P. L. Dumble and M. R Wigan, "Accessibility Indicators for Transport Planning", *Transportation Research Part A*, vol. 13A, 1979, p. 91-109 (there are several references to Koenig who was also referred to recently in Donald G. Janelle and D. C. Hodge, *Information, Place and Cyberspace. Issues in Accessibility*, New York: Springer, 2000); Peter A. Steenbrink, "Transport Network Optimization in the Dutch Integral Transportation Study", *Transportation Research*, vol. 8, 1974, p. 11-27 (he refers to Barbier's research at IAURP and the article co-signed by the trio of Bruynooghe, Gibert and Sakarovitch, which was cited even more recently by Hai Yang and Hai-Jun Huang, *Mathematical and Economic Theory of Road Pricing*, Oxford: Elsevier, 2005, and by A. Nagurney and D. Boyce, "Preface to 'On a Paradox of Traffic Planning'", *Transportation Science*, vol. 39, n° 4, November 2005, p. 443-445).

74 Concerning these circulars, see for example: Jean Poulit, "Le Problème urbain: ses dimensions, ses méthodes", *RGRA* (Recyclage: formation permanente, année 1973, fascicule n° 1), January 1973, p. 1-15; G. Koenig, "Conception générale et programmation des réseaux urbains de voirie et de transport collectif", *RGRA* (Recyclage: formation permanente, année 1974, fascicule n° 4), supplément au numéro 497, April 1974, p. 1-16.

75 Koenig et al., "Génération, distribution, affectation de trafic sur les voies nouvelles", p. 1-2.

76 See SETRA (Division urbaine) – IRT, "Etudes préliminaires d'infrastructures de Transport. Note de synthèse", Bagneux, undated (this contains the Ministries different operational models); SETRA (Division urbaine), "Dossier pilote concernant la réalisation des enquêtes ménages déplacements", Bagneux, 1975; SETRA (Division urbaine), "Caractéristiques des déplacements en milieu urbain", dossier n° 1 (Rapport): "Caractéristiques socio-économiques des villes", Bagneux, undated; CETUR, "Caractéristiques des déplacements en milieu urbain", dossier n° 2 (Rapport): "Génération des déplacements de personnes"; dossier n° 3 (Rapport): "Distribution des déplacements"; dossier n° 4 (Rapport et Annexe): "Répartition entre modes de transports"; dossier n° 5 (Rapport et Annexe): "Coefficients de pointe"; dossier n° 6

public works engineers (such as the *Revue Générale des Routes et des Aérodromes* (Journal of Highways and Airports): all of these various publications helped standardize the procedures and methods used in urban travel demand modeling studies, including those employed in household travel surveys.[77] This trend towards increasing standardization, which was already well underway in the United States,[78] also affected the models used. Central government selected a number of urban travel demand models available on the market at the beginning of the 1970s. The models chosen were standardized in computer programs run on the computers of the Ministry's technical services and disseminated and implemented on a large scale throughout the national territory during the 1970s via local public agencies (especially the CETEs).[79] It is also worth noting that the various private engineering consulting firms could also use the standardized models available on the Ministry's computers at a lower rate than that charged by private computer service companies such as IBM.[80]

Although it was not the only factor in the equation, we may well wonder whether there was a link between this growing involvement of the different CETEs – which were now equipped with standard models and the technical resources for implementing these on a massive scale – in the urban travel demand modeling "market" on the one hand, and the difficulties encountered by French consulting firms specialized in this field from the mid-1970s on the other, difficulties that were to culminate in the disappearance of a number of them. Quantitative data unearthed in a 1981 report of the National Federation of Planning Agencies (*Fédération Nationale des Agences d'Urbanisme*) provide a good illustration of the "power relationships" between government technical deparments and the private sector in transportation planning and modeling in the 1970s: of the 57 traffic plans identified in this document, only four were prepared by private consulting firms. The others were produced by central and local government structures.[81]

(Rapport): "Stationnement dans les zones centrale"; dossier n° 7 (Rapport et Annexe): "Conditions de déplacement (Temps, distances, vitesses)", Bagneux, n.d.; SETRA (Division urbaine), Annexe Générale : "Tableaux comparatifs sur 16 villes pour les principaux paramètres", n.d. (all of these reports date from the mid- and late 1970s).

77 Facq, "Les fondements statistiques de la science française des déplacements urbains"; Hadrien Commenges, « Socio-économie des transports : une lecture conjointe des instruments et des concepts », *European Journal of Geography*, 2013 (en ligne), document 633 : http://cybergeo.revues.org/25750 (last accessed on July 13, 2014).

78 See Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours", ch. 2.

79 The different SETRA and CETE Libraries contain a host of studies produced in the 1970s using these standardised models. We conducted detailed research at the library of CETE de l'Est (Metz). The model most commonly used in the various studies carried out in the 1970s was the DAVIS model (for the assignment step), while there was greater latitude in the models used for the other steps (FABER for the distribution step, etc.). It should be noted that prior to this period of standardization, local agencies appear to have developed several in-house models. See, for example: T. Lecuve (SETA-Agence de l'Est), "Programme CROIS: modèle de facteur de croissance (Fortran IV sur 1130-8 K)", September 1969; B. Pignon (SETRA-Agence de l'Est), "Le programme SDAGEST: prévisions de trafic dans une agglomeration moyenne", September 1969 (these documents are available at the CETE de l'Est Library). The same results emerged following an analysis of the documentation compiled by Charles Foucard, an undergraduate student at *Ecole des Ponts et Chaussées*, concerning the city of Strasbourg (see Charles Foucard, "Les Relations entre décideurs et modélisateurs de trafic", Rapport de recherche, ENPC, 2003).

80 Thus, the fee for using the FABER model (distribution step), run on the IBM mainframe at SETRA, was 500 francs; DAVIS (assignement step), run on the IBM mainframe at SETRA and on the CII computer at IRT, cost 800 francs, plus 200 francs per plotter chart; AFTAT (assignement step), run on the CII computer at CETE de Bordeaux, cost 800 francs; however, it cost 3,000 francs to use the SATURNE model (assignement step), available on IBM mainframes from IBM-France. See Koenig et al., "Génération, distribution, affectation de trafic sur les voies nouvelles", p. 15. See also the following document: SETRA-Agence de l'Est (Département informatique), "Barème 73. Prestations informatiques", March 1973 (which may be consulted at CETE de l'Est Library): it contains certain information on the tasks carried out by IT department staff when different travel forecasting models were being run on departmental computers as well as deadlines and rates charged. For example, in respect of the DAVIS, the related task were as follows: punching of data sheets; verification of punched cards from data sheets; collation-verification of data sets; calling up of the required data; use of computer programs; generating outputs on triplicate paper; deleaving; file maintenance (the period requested should be less than six months old). As regards deadlines, "these were ten working days from submission of completed data sheets, not including the time required for deleaving" (ibid., p. 10-11).

81 Fédération Nationale des Agences d'Urbanisme, "Urbanisme, déplacement, transports" (Actes du colloque des 14 et 15 octobre 1981), thème 4: "Les aspects institutionnels et de gestion. Résultats de l'enquête auprès des agences d'urbanisme", p. 24 (quoted by Baye, "L'Ingénierie-conseil de prévision et de régulation du trafic en France", p. 35-36).

Importation of American know-how, creation of a "national science", standardization and massive deployment of this science: these are the three key periods underpinning the trajectory of French urban travel demand modeling between 1950 and 1975. But what happened after that?

Well, a lot of things, particularly outside France. Great changes in modeling practices occurred, beginning in the mid-1970s, concerning both the mathematical structure of the models themselves and the "means of production" necessary for their production and implementation. The latter became increasingly bound up with desktop computing and international commercial software "toolboxes" that allowed users to build their own made-to-measure models.

These developments were comparatively late in reaching France and began to impact in the 1980s. While the French State had been the central force behind the introduction and development of urban travel demand modeling in the previous period (1960-1975), the main vectors of change from the 1980s on were the private engineering consulting firms. These generally originated outside of France and have been very active there in recent times.

Let's look at all these developments in more detail.

2. Urban travel demand modeling post 1980[82]

2.1. French State and urban traffic forecasting, 1980-2000

If we just focus on the public sector, the period 1980-2000 clearly contrasts with what went before. In fact, although some original developments concerning urban travel demand modeling can be observed during the second half of the 1970s, the bulk of these produced little of significance from an operational point of view.[83] However, we should mention OPERA, a mono-modal model[84] used to forecast traffic for privately-owned cars, initially for the trip generation-distribution steps and subsequently for all four steps. OPERA was developed in the 1980s by CETE Méditerranée and also used by some of the other CETEs as well as by certain large French cities[85] (around the year 2000, a version of this software was developed for Windows known as CartOPERA[86]).

Over thee 1980-2000 period, French government deparments turned out to be little inclined to innovate with new models, and they confined themselves to the task to "tinker" with old ones and adapt these to run on new hardware. Thus, in the late 1980s/early 1990s, CETE Méditerranée, in collaboration with ALMA*,* a Grenoble-based firm,[87] developed a PC version of TERESE, the public transport model developed in the mid-1970s (see above) on behalf of SEMALY[88] and CETUR.[89] The assignement step model DAVIS, another "classic" French model created in the early 1970s by the *Ponts et Chaussées* engineer Barbier Saint-Hilaire (see above), was adapted for use on new hardware between 1983-1985 by its creator in collaboration with applied mathematics researchers from Grenoble University. Barbier Saint-Hilaire subsequently adapted it to run on ATARI and later on PCs (in the early 1990s). However, the

82 This part of the working paper is based on an article of mine that was published in the French journal *Flux*: Konstantinos Chatzis, "La Modélisation des déplacements urbains en France depuis les années 1980, ou la domination progressive du champ par le secteur privé", *Flux*, n° 85/86, July-December 2011, p. 22-40.

83 See, for example: SETRA et al., "Note technique 1. Analyse de fonctions de conductance à deux parameters"; CETUR, "Analyse et prévision du trafic urbain. Recherche d'un modèle d'équilibre prenant en compte l'offre de transport", Bagneux, September 1976; O. Desforges, "Comparaison de trois modèles d'affectation de la circulation urbaine, Davis-Kova 10-Medycis", Rapport de Recherche IRT, n° 29, Arcueil: IRT, February 1978; CETE de l'Est, "Distribution des déplacements urbains: tests d'un modèle d'opportunité", Metz, January 1978; Ministère des Transports – Centre d'Etudes des Transports Urbains – CETE de Rouen, "Modèle de génération et de distribution de la clientèle sur une réseau de Transport Public Urbain", September 1978.

84 The mono-modal approach consists in using separate modeling techniques for each mode of transport to be studied. In order to do so, *diversion curves* were fist established in the 1960s: based on survey data of the use of different modes of transportation in the area under consideration or comparisons with similar cities, engineers defined the percentage use of private vehicles and public transport. Concerning the French case, see for example CETUR, "Les Etudes de prévision de trafic en milieu urbain. Guide technique"*,* Bagneux, 1990, p. 32-33.

85 For example: CETE du Sud-Ouest and CETE de Normandie Centre, the cities of Marseilles, Caen and Toulouse. See Thomas Innocenzi and Romain Papassian, "La Bonne fortune d'outils contestés, pour une histoire de la modélisation dans les transports urbains", Rapport de recherche, ENPC, 2004, p. 36; GESMAD, "Bilan des pratiques et attentes de modélisation des collectivités locales"*,* Rapport de recherché pour le compte de la DRAST et du CERTU, Paris, September 2002, p. 8-9. Concerning OPERA, see the description in CERTU, "Les Logiciels de planification des déplacements urbains"*,* Lyon: Collections du CERTU, 1999. At the end of the 1990s, there were approximately 60 software licenses (ibid.).

86 See CETE Méditéranée and CERTU*,* "CartOpera, Logiciel de prévision et d'affectation de trafic urbain", Manuel de présentation, 2000.

87 Alma was founded in 1979 by applied mathematics researchers from the University of Grenoble including J. P. Uhry (on Uhry, see above) (http://www.alma.fr/Alma-en-bref: last accessed July 10, 2014).

88 SEMALY (*Société d'Economie Mixte du Métropolitain de l'Agglomération Lyonnaise*) was set up in 1968 and became a semi-public company (*Société d'Economie Mixte*) on March 12, 1970. Located in the Lyon region, it was tasked with the Lyon metro project. Its first director was the *polytechnicien* and *Ponts et Chaussées* engineer René Waldmann (X-1950). Concerning the creation of SEMALY and Waldmann, see Harold Mazoyer, "Le Rôle des expériences et méthodes étrangères dans la fabrication d'une expertise locale des transports urbains collectifs: le cas des études du métro de Lyon (1963-1971)", *Métropoles*, n° 6, 2009, p. 171-215. SEMALY acquired the TERESE model (*supra*), which has been used extensively since it was first developed in the mid-1970s to design public transport infrastructures (subways, etc.).

89 CETUR, "Les Etudes de prévision de trafic en milieu urbain. Un outil pour l'aménagement urbain (Fiche d'information n° 17)", Bagneux, 1989.

major innovation in the assignment model itself came in 1993, about 20 years after DAVIS had first been created, with the incorporation of toll-based infrastructures.[90]

We should also note that although there was little innovation from government departments with regard to modeling itself, the central French state and its various public agencies remained active in carrying out (and updating) household travel surveys – about once every ten years in the large cities[91]– as well as research projects regarding trends in mobility.[92]

This "deflationary" policy – in terms of original modeling – pursued by various French government bodies in the 1970s and early 1980s was coupled with increasing criticism of the modeling techniques that had been practiced up to this point. Such criticism included the following: 1) that current models were too conservative and simply extrapolated trends already observed in the past; 2) that models (and the modelers) tended to favor the car; 3) critics also challenged: a) the sequential structure of models (no feedback was provided for between the different steps of the modeling process); b) the *aggregate* nature of the modeling practiced (the unit was the territorial "zone"): for critics, the use of "typical" (average) behavior tended to mask the great divergence in the attitudes of households or individuals regarding mobility; c) the lack of a theoretical basis at "micro" level for individual behavior.[93]

Even though such criticism was common both in France and other developed countries,[94] it only generated alternative urban travel demand modeling techniques outside France (*see* below).[95]

2.2. Private engineering firms and urban traveldemand modeling, 1980-2000

Even though the State was much less present – at least in comparison to the 1960-75 period – in original urban travel demand modeling in France from the mid-1970s on, and was content to implement and "maintain" the standardized models of the previous period and periodically update household travel survey data, this by no means implied a status quo in modeling. In fact, from the 1980s on, France witnessed significant developments in modeling practices inside its national territory. These were a local reflection of broader developments taking place in several countries concerning both the mathematical structure of urban traffic forecasting techniques and computer technology (both hardware and software).

90 Information on the development of DAVIS is taken from Innocenzi and Papassian, "La Bonne fortune d'outils contestés", especially p. 35 and p. 37.

91 On the current state of such surveys, see: CERTU, *L'Enquête ménages déplacements « standard Certu »*, Lyon: Editions de CERTU, June 2008; Joël Meissonnier, "Pour mieux analyser les comportements de déplacement, faut-il ajuster les protocoles d'enquête?", *Les Cahiers Scientifiques du Transport*, n° 62, 2012, p. 3-31. We should bear in mind that from the mid-1970s, the cost of surveys was no longer borne by central government alone, and local partners contributed 50%. Concerning this point as well as the history of this kind of survey in France, see Facq, "Les Fondements statistiques de la science française des déplacements urbains".

92 For a presentation of such research into mobility, see for example, Jean-Pierre Orfeuil, *L'Evolution de la mobilité quotidienne. Comprendre les dynamiques, éclairer les controverses*, Arcueil: INRETS, 2000.

93 For a presentation of such criticism (and a bibliography), see Merlin, *La Planification des transports urbains, enjeux et méthodes,* p. 175-185; Michel Le Nir, "Les Modèles de prévision de déplacements urbains", Ph.D. dissertation, Université Lumière Lyon 2, 1991, second Part, ch. I.

94 For the American case, see Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours)", ch. 3.

95 The following comments regarding this criticism were made by Pierre Merlin, an early practitioner and academic in the field of urban travel demand modeling: "As we have seen, the first 'crude' models and even the basic models of the early 1960s were not preoccupied with their own theoretical basis. At this time, operational issues were the overriding concern. It was only around 1970, when there was a slowdown in new construction programs and in major transport projects that theoretical issues came under scrutiny"; "in France, the wave of criticism that affected [the traditional method of modeling] appeared to have sterilized all genuine research that took place during the 1970s" (Merlin, *La Planification des transports urbains, enjeux et méthodes,* p. 153 and p. 175). Developments in modeling courses at *Ecole Nationale des Ponts et Chaussées* (ENPC) appear to confirm the views of Merlin: students were now encouraged to cast a critical eye on the "positivist totalitarianism" that "represented the dominant discourse within traditional technological circles" (see A. Bieber et al., "Circulation et transports urbains", Collection of copies of documents for 1983-1984, ENPC, Annexe 1, p. 13).

In terms of mathematics, the post 1980 period was characterized by two "opposite" but ultimately complementary trends (complementary because they concerned different application issues): a trend towards more complex modeling practices – illustrated particularly by the so-called *disaggregate modeling* approach that arrived in France in the 1980s – which contrasted with a move towards simpler more straightforward models, the so-called s*trategic* models (which arrived in France in the second-half of the 1990s).[96]

As we have already said, the main vectors of change from the 1980s on were the (predominantly non-French) private engineering consulting firms. During the same period, modeling also entered the PC computing era – signaling the end of the mainframes that constituted a scarce resource – and that of global (international) commercial software products which are "toolboxes" that allowed users to build their own made-to-measure models.

2.2.1 The arrival in France of disaggregate modeling

The so-called disaggregate approach was initially an Anglo-Saxon product,[97] associated with academics that have subsequently become renowned in the field of transportation, such as Moshe E. Ben-Akiva, Professor at MIT, or Daniel McFadden, winner of the 2000 Nobel Prize for Economics. It underwent its early – mostly theoretical – development in the 1960s and the early 1970s, and was ready for wide-scale use in the first-half of the 1980s.[98]

Although references or even comments concerning disaggregate modeling may be found in French documents dating back to the early 1970s,[99] this approach only really emerged in France at the beginning of the 1980s and took hold in the 1990s. Nevertheless, even by the early 2000s the "traditional" aggregate approach had far from disappeared.[100]

96 Let us note here that developments in urban travel demand modeling were not confined to disaggregate and strategic modeling. We can mention the so-called activity-based urban transportation models, which began to be applied for the first time operationally in the 2000s (on the history of the activity-based travel demand modeling, see, Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours)", ch. 7). In what follows, we will focus on disaggregate and strategic urban travel demand modeling as these two types of modeling were the approaches disseminated most widely at operational level in France after the 1980s. However, we should note that activity-based modeling is present today in France via the software package marketed by the German company PTV (see below). Concerning this product, see M. Fellendorf, T. Haupt, U. Heidl and W. Scherr, "PTV Vision: Activity-based Micro-simulation Model for Travel Demand Forecasting", in F. Ettema and H. J. P. Timmermans (eds.), *Activity-based Approaches to Travel Analysis*, Oxford: Pergamon, 1997, p. 55-72. The issue of activity-based transportation modeling was discussed in France in a small number of academic works as early as in the 1980s (see Patrick Bonnel, "Une méthode de révélation des besoins latents", *Les Cahiers Scientifiques du Transport*, n° 11-12, 1985, p. 101-122; Olivier Coutard, "Modèles de la mobilité quotidienne: présentation critique de l'approche basée sur les activités", Mémoire pour l'obtention du D.E.A. Transport (ENPC/Université de Paris XII/Université de Paris I), Arcueil: INRETS, 1988.

97 Disaggregate modeling attempts to describe the behavior of an individual in the course of his/her trip planning by translating behavior into the probability of choosing a given mode of transport in accordance with the individual's characteristics and that of his/her choice "environment". These probabilities are then applied to a class of individuals and aggregated. Concerning this modeling approach, see *inter alia* the two following works: David A. Hensher and Kenneth J. Button (eds.), *Handbook of Transport Modelling*, Oxford: Elsevier Science Ltd, 2000; P. Bonnel, *Prévoir la demande de transport,* Paris: Presses de l'ENPC, 2004.

98 On the history of the disaggregate modeling in the US, see Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours)", ch. 3.

99 See, for example, CETUR, "Analyse et prévision du trafic urbain. Recherche d'un modèle d'équilibre prenant en compte l'offre de transport", p. 10; Bonnafous and Gerardin, "La Demande de transports de voyageurs", p. 50-51; Doizon, "Développement, programmation, et application d'un module de répartition modale en milieu urbain" (the authors cite the very early research of Moshe Ben-Akiva, including his thesis). In the late 1960s and early 1970s we even find French models that draw on early Anglo-Saxon reflections on disaggregate modeling. This is the case with the BIREG model developed by Phillipe Rochefort, a graduate of the *Ecole Centrale de Lyon* in 1967, who worked at CERAU in the 1960s – Rochefort, "The Demand for Inter-Urban Transport Econometric and Psycho-Sociological Approaches"; A. Danet, P. T. Lang, J. M. Netter, "Etude du choix du mode de transport par les habitants de quelques quartiers de Marseille", Arcueil and Paris: IRT-CERAU, 1970. This is also the case with the modeling work carried out by Doizon, "Développement, programmation, et application d'un module de répartition modale en milieu urbain". Both models draw on the pioneering work of Stanley L. Warner, *Stochastic Choice of Mode in Urban Travel: A Study in Binary Choice*, Evanston: Northwestern University Press, 1962. See also Hervé de la Morsanglière, "Analyse et prévision de la demande de transport (transport de personnes). Eléments de cours", ENTPE, January 1978, p. 105-111.

100 According to certain French modelers, in the early 2000s aggregate models were still more common than disaggegate approaches, even for the mode choice step (Patrick Bonnel, "The Estimation of Aggregate Modal Split Models", *Association for European Transport 2003* (http://abstracts.aetransport.org/paper/index/id/1556/confid/9: last accessed July 10, 2014).

There are a number of reasons for continuing French interest in disaggregate (and multi-modal) modeling post 1980. Beginning in the 1980s, aggregate (and mono-modal) modeling, which had been the dominant approach used for sizing and assessing new infrastructure (roads and subways) from a technical/economic perspective, was faced with new challenges. Because major urban infrastructures had now been largely completed, transport planning policy focused increasingly on existing infrastructure and their optimal use. Moreover, during the 1980s, detailed knowledge of travel patterns within French cities became an essential stake for local policymaking in the wake of the 1982 decentralization laws. The transfer of power from central to local government level meant that local authorities now became sole decision makers in the urban planning sphere. Major French cities needed, therefore, flexible instruments suitable for rapid decision-making in a context where new major infrastructure projects were increasingly rare. Disaggregate modeling made it possible to answer questions such as "if we do this (impact the price of public transport/parking /petrol, etc.) how will this impact travel patterns in existing infrastuctures?" Furthermore, the framework transport legislation of December 30, 1982 (LOTI: *Loi d'Orientatation des Transports Intérieurs*) bolstered the decentralization process. This law revived the urban transportation planning process by establishing the so-called *Plans de Déplacements Urbain*s (PDU: Urban Transport Plans),[101] which promoted a *multimodal* vision of urban transport systems. The development of PDU – which, in 1996, became obligatory for cities with populations of more than 100,000[102] – as well as a concerted will to favor other modes of transport over the car, implemented in a series of key legislation throughout the 1990s,[103] gave rise to new modeling needs.[104] This is one of the reasons that underlay the renewed interest in the mode split step (the third one) in France from the 1980s on, a step for which the disaggregate approach offers significant advantages.[105]

Disaggregate modeling was essentially introduced into France at the beginning of the 1980s via two largely separate channels. The first of these was research and academia: a number of researchers carried out academic work into disaggregate modeling techniques (without these automatically leading on to practical applications).[106] The second channel involved a series of

101 "Urban Transport Plans set out general guidelines for organising transport, traffic flows and parking in the area covered by urban transport. They aim for a more rational use of the car and effective integration of pedestrians, two-wheeled vehicles and public transport" (*article n° 28, Journal Officiel du 31 décembre 1982,* quoted in P. Bouyaux, "Modélisation behavioriste de la demande de transport urbain: problèmes théoriques et application empirique à la ville de Rennes", Ph.D. dissertation, Université de Rennes I, 1988, p. 28). Concerning LOTI and developments in urban transport planning generally in France in the 1980s, see: Pierre Lassave and Jean-Marc Offner, "Urban Transport: Changes in Expertise in France in the 1970s and 1980s", *Transport Review*, vol. 9, n° 2, 1989, p. 119-134.

102 Concerning experiences of the early PDUs, see Pierre Lassave, "L'Expérience des plans de déplacements urbains (1983-1986)", Bagneux, CETUR, July 1987. See also the survey work by J. M. Offner, *Les Plans de Déplacements Urbains*, Paris: La Documentation Française, 2006, and Debizet, "L'Evolution de la modélisation des déplacements urbains en France, 1960-2005. Le poids de l'organisation institutionnelle des transports". According to a survey, there were 110 PDU projects under way at the end of 2007, while 40 urban transport authorities had already completed their Urban Transport Plans by 1997 (Ch. Duchène and O. Crépin, "Les Plans de Déplacements Urbains à la recherche d'un second souffle", *TEC*, n° 198, 2008, p. 25-35).

103 For example, the 1996 French law on the air and the rational use of energy (*Loi sur l'Air et l'Utilisation Rationnelle de l'Energie* (LAURE) of December 30, 1996) officially challenged the longstanding predominance of motorized transport. The guiding principles of PDUs set out in Article 14 of LAURE focus on: cutting the volume of road traffic; developing public transport and energy efficient, non-polluting means of transport such as bikes and walking; encouraging businesses and local authorities to develop employee travel plans that spur the use of public transport and car pooling. The same broad guidelines were included in the solidarity and urban renewal law (*Loi Relative à la Solidarité et au Renouvellement Urbains*: SRU) of December 13, 2000.

104 Concerning modeling and the design of PDUs, especially the second post-LAURE (1996) generation, see *inter alia*: *Revue Générale des Routes*, n° 773, May 1999, which contains a number of case studies; GESMAD, "Bilan des pratiques et attentes de modélisation des collectivités locales"; Debizet, "L'Evolution de la modélisation des déplacements urbains en France, 1960-2005. Le poids de l'organisation institutionnelle des transports".

105 The impact of the above-mentioned developments (decentralization laws, LOTI, PDU, etc.) on the modeling landscape in post 1980 France has been dealt with in depth by Gilles Debizet. The author rightly underscores the links between the principles underpinning the disaggregate modeling approach and its potential use as an effective tool for multimodal transportation planning (within the PDU framework, for example) (see : Debizet, "Déplacements urbains de personnes: de la planification des transports à la gestion durable de la mobilité. Mutations d'une expertise"; Debizet, "L'Evolution de la modélisation des déplacements urbains en France, 1960-2005. Le poids de l'organisation institutionnelle des transports").

106 See, in particular: Charles Raux, "Modèles de prévision des comportements de mobilité quotidienne", Ph.D. disserta-

practical applications developed by sector professionals and mainly by a number of foreign engineering consulting firms.

In the early 1980s, the *Régie Autonome des Transports Parisiens* (RATP), the body responsible for the Parisian metro and bus network, which had already developed an internal *aggregate* model called GLOBAL in the 1970s,[107] started using the services of Cambridge Systematics Europe[108] – that is the European subsidiary of Cambridge Systematics, a major US engineering consulting firm set up in 1972 and very close to MIT[109] – to develop a disaggregate model focusing on the mode choice step. This model was known as IMPACT and became operational in 1984.[110]

The second French disaggregate modeling experiment involved the city of Grenoble. The bulk of the work involved in this project was carried out in 1982 and 1983 and it was headed up by a working group consisting of the following: public actors such as CETE Lyon and *Agence d'Urbanisme de la Région Grenobloise* (Grenoble city planning agency), who contributed certain essential traffic data; *Institut d'Informatique et Mathématiques appliquées de Grenoble* (IMAG: Grenoble University IT and applied mathematics research institute); ALMA (see above), which was responsible for implementing the model; and Cambridge Systematics Europe in charge of developing the model. The model was initially used to evaluate the impact on mode choice of different policy scenarios: increases in petrol prices, reimbursement of public transport commuting costs, doubling of parking costs, etc. It was also used to test the impact on mode split of the first tramway line to be commissioned in the city. The Grenoble experience was later "transferred" to Nantes.[111]

This study and its after effects also illustrate the transition from the cumbersome IT environment of the previous period with its enormous machines to today's PC environment. In the early days of the study, the data was available on magnetic tapes and centralized on a

tion (Thèse de docteur-Ingénieur), Université Lyon II–Ecole Nationale des Travaux Publics de l'Etat, 1983; L. Hivert, "Modélisation de la demande de Transport: présentation critique de l'outil désagrégé", DEA de Recherche Opérationnelle, Université Pierre et Marie Curie-Paris VI, 1985; Pascal Bouyaux, "Modélisation désagrégée des transports urbains: une application à la ville de Rennes", *Revue d'Economie Régionale et Urbaine,* n° 5, 1988, p. 783-809; P. Bouyaux, "Modélisation behavioriste de la demande de transport urbain"; D. Chevrolet, "Deux études de transport urbain. Ordonnancement des phases d'un carrefour; modèles désagrégés de déplacements dans l'agglomération grenobloise", Ph.D. dissertation (Thèse de doctorat (3e cycle)), Université de Grenoble, 1986 (in this thesis the author pursues the modeling work carried out at the beginning of the 1980s in Grenoble in collaboration with Cambridge Systematics Europe, see below). See also: A. de Palma and J. F. Thisse, "Les Modèles de choix discrets", *Annales d'Economie et de Statistique,* n° 9, 1987, p. 151-190; Martin Manheim and Moshe Ben-Akiva, "Les Modèles désagrégés", in Emile Quinet (ed.), *La Demande de transport,* Paris: ENPC, 1982, p. 119-134.

107 On GLOBAL, see Bernard Labbe and Claude Scherrer, "Un Modèle Global pour l'évaluation des projets d'extension des réseaux de transport public en région parisienne", in AFCET (ed.), *Traffic Control and Transportation Systems*, Amsterdam: North-Holland Publishing Company, 1974, p. 677-688. In recent times, the RATP's GLOBAL model and SEMALY's TERESE model were those most frequently used to forecast traffic in new French urban public transport infrastructure. See GESMAD, "Evaluation des modèles de prévision de trafic", Rapport final pour le compte de la DRAST, Paris, 2000.

108 Cambridge Systematics Europe was set up in the late 1970s in The Hague, and became the Hague Consulting Group (HCG) in 1985 (information gleaned from the CV of Andrew Daly, currently Research Professor at Leeds University, Institute for Transport Studies. Andrew Daly was Director of Cambridge Systematics Europe and co-founder and Director of HCG: see http://www.its.leeds.ac.uk/staff/staffProfile.php?personId=2565: last accesed on December 23, 2009). Most of HCG was in turn merged into RAND Europe in January 2001. Concerning the models developed by Hague Consulting Group, see *inter alia* James Fox, Andrew Daly and Hugh Gunn, *Review of RAND Europe's Transport Demand Model Systems*, Santa Monica (CA): RAND, 2003.

109 Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours)", ch. 3.

110 See *inter alia*: RATP and Cambridge Systematics, "Etudes des politiques de transport en region Ile-de France: mise au point et utilisation des modèles désagrégés de choix modal", Paris, RATP-Direction Générale des Etudes, June 1982; RATP and Cambridge Systematics Europe, "Estimation et application de modèles dégagrégés de choix de mode et de destination pour les déplacements 'autres motifs' basés sur le domicile", RATP-Direction du Développement, January 1985; Jacqueline Rousseau and Catherine Saut, "Un Outil de simulation de politiques de Transport: IMPACT 3", *Revue Générale des Chemins de Fer,* December 1997, p. 77-83.

111 CETUR, "Les Déplacements domicile-travail et domicile-école. Modèles désagrégés de choix modal. Application au cas de l'agglomération de Grenoble", 1985 (on the cover page we read that this report was first drafted in English by Mr. A. J. Daly of Cambridge Systematics Europe B.V.); MELATT, CETUR, CETE de Lyon, CETE de l'Ouest, "Modèles désagrégés: principes généraux, méthodologie, applications (Grenoble, Nantes)", Journées de rencontre sur les modèles désagrégés, 10-11 juin 1986, 1986.

Honeywell-Bull Multics computer located at Grenoble University. Data was processed using FORTRAN programs. A series of computer programs known as SLOGIT (1982 version), developed by Cambridge Systematics and written in basic FORTRAN for mainframes were used to estimate and analyze the Logit-type disaggregate model. After the Grenoble "experiment" came to an end, most of the programs were rewritten and enhanced, and most subsequent research carried out in France used the new version known as ALOGIT (1984). At the same time, research was carried out on micro computers using a program written in Pascal for Apple II and Apple III. The development work was carried out by Cambridge Systematics in The Hague and London and the application phase was completed in London and Grenoble.

To complete our introduction to disaggregate modeling in France in the 1980s, we should mention a study carried out between January and September 1987 at the main French transport research institute INRETS (see above) to forecast traffic on the future ORLYVAL rail link to Orly Airport. This project also involved a foreign private consulting firm, the British-based MVA Consultancy,[112] which collaborated with the University of Montreal's *Centre de Recherche sur les Transports* (CRT: Center for Research on Transportation).[113]

In the 1990s, other French bodies availed themselves of the services of foreign engineering consulting firms (some of which opened French branches – see below) in order to use disaggregate modeling techniques. In late 1994, RATP developed a new simulation tool that would update its old IMPACT model (see above), and requested the services of MVA Consultancy, which delivered the final product in 1996 (IMPACT 3, a joint trip destination and mode choice disaggregate model).[114] In 1996-1997, MVA carried out a study in Lyon that also used disaggregate modeling on behalf of CERTU and publicly funded.[115] In the early 1990's, *Syndicat des Transports de l'Ile de France* (STIF: Transport Authority for the Greater Paris Area) decided to have its own passenger trip forecasting system to carry out its own analyses of the impacts of transport policies on new public transport schemes, with the view to being independent of transport operators (like RATP) or other public bodies in the *Ile-de-France* (Greater Paris region). During 1994 and 1995, it commissioned the Hague Consulting Group (formerly Cambridge Systematic Europe, see above) to develop a travel demand forecasting system for the *Ile-de-France* area, essentially the enlarged Paris Region. The resulting ANTONIN model (Analysis of Transport Organisation and New Infrastructure) comprised a series of disaggregate models. Since the end of the 1990's, STIF carries out its own studies with the help of ANTONIN. In 2004, a decision was taken to update the entire modeling framework (the update concerned mainly the following points: 1) the computer and software environment; 2) updating to reflect recent surveys and other relevant data; and 3) re-estimating based on this new data).[116] Finally, in the late 1990s, one of the key actors in transportation modeling in

112 The origins of MVA Consultancy go back to 1961 when one of the founding fathers of urban travel demand modeling, Alan Manners Voorhees (1922-2005), set up Alan M. Voorhees and Associates (on Voorhees and his firm, see Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours)", ch. 2). In 1976, the European subsidiary of this consulting office, set up in 1968, became Martin and Voorhees Associates (Brian Martin was a researcher at MIT in the early 1960s and a former member of the Great London Council). In 1983, the management of Martin and Voorhees Associates acquired the company from its American owners, and its name was changed to MVA (in the early 1990s, MVA Group consisted of MVA Consultancy, MVA Asia and MVA Systematica, that is the Software Products Division of MVA). In 1993, MVA was acquired by SYSTRA, a French rail and urban transport consultancy whose main shareholders are the French public operators RATP and SNCF, and a number of French Investment banks. MVA Consultancy was recently renamed Systra Ltd (http://www.systra.co.uk/). Information taken from the following sources: "Brian John Whitley Large", *Transportation*, vol. 17, n° 4, 1990, p. 331; http://www.mvaconsultancy.com/company/history.htm: last accessed March 28, 2013).

113 L. Hivert, J. P. Orfeuil, P. Troulay, "Modèles désagrégés de choix modal: réflexions méthodologiques autour d'une prévision de traffic", Rapport INRETS n° 67, Arcueil: INRETS, 1988. On CRT, see Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours)", ch. 4.

114 Concerning IMPACT 3, see Rousseau and Saut, "Un outil de simulation".

115 CERTU and ADEME, "Comportements de déplacement en milieu urbain: les modèles de choix discrets. Vers une approche désagrégée et multimodale", Lyon, June 1998.

116 Concerning ANTONIN, see: Neïla Bhouri, "Intermodalité: Bilan et perspectives des systèmes informatiques", Arcueil: INRETS, February 2002, p. 66-70; Fox et al., *Review of RAND Europe's Transport Demand Model Systems*, p. 41-55; Jan Gerrit Tuinenga, Marits Pieters (RAND Europe) and Laurence Debrincat (STIF), "ANTONIN: updating and comparing a transport model for the Paris Region", *Association for European Transport and Contributors 2006* (http://abstracts.

the 1960s, IAURIF, once again looked to the US for example and launched its own in-house disaggregate mode choice model.[117]

Aside from these disaggregate models that were practically "made to measure", disaggregate modeling was also used in France from the mid-1990s with the arrival of commercial software related to urban travel demand modeling (see below).

2.2.2. Simplification: the strategic model

Like disaggregate models, strategic models were first developed outside France in the 1980s, mainly in Birmingham, London and Edinburgh, before reaching the country in the mid-1990s.[118] In geographical terms, strategic models adopt a simpler approach to travel demand forecasting. For a given area, the number of zones under consideration may be divided by ten in relation to traditional "four-step" modeling. But at the same time, the strategic model includes more socio-economic variables and a larger area, thus giving a regional perspective to trips generated from and taking place within a given urban area. Strategic models are not intended to replace more traditional types of modeling but may be used to quick-test the numerous scenarios envisaged and to greatly reduce the number of options that will subsequently be tested by more traditional urban travel demand modeling.

The key actor in strategic modeling in France is SEMALY (renamed Egis Rail in 2007), which became a private engineering consulting firm in 1992 and developed a strategic model known as MOSTRA (*MOdèle STRAtègique*) for Lyon with the help of a research institute, *Laboratoire d'Economie des Transports* (LET) and funding from the Ministry for Infrastructure and local government. In 1995, a prototype was developed, followed by a working model in 1996, which was adapted for the cities of Grenoble and Bordeaux in 1997-1998. Further developments in the model were carried out in Bordeaux in 2001-2002 with the roll-out of the third-generation MOSTRA.[119] The model is also being used in tandem with DAVISUM, wich is a software for the assignment step (concerning DAVISUM, see below) within the scope of transport programs in the Clermont-Ferrand urban area.[120]

2.2.3. Transportation Modeling in the era of commercial, international software

Alongside disaggregate and strategic modeling which, as we have seen, was in France's case a mainly imported phenomenon, the 1990s also witnessed the arrival in France of a number *of multimodal* software transportation planning tools that could accommodate both privately-owned cars and public transport.[121] Most have also come from abroad, and are currently used

aetransport.org/paper/index/id/2542/confid/12: last accessed July 10, 2014).

117 Dany Nguyen-Luong, "Recherche sur le choix modal en milieu urbain", Paris, IAURIF, June 2000. The author spent from September to November 1999 in the United States to witness the state of the practice in the home of modeling (see Dany Nguyen-Luong, "Modèles de prévision de trafic aux Etats-Unis. Application à l'élaboration des plans de transports régionaux", Paris, IAURIF, January 2000).

118 Concerning strategic modeling, see, for example: A. S. Fowkes, A. L. Bristow, P. W. Bonsall and A. D. May, "A Short-cut Method for Strategy Optimisation Using Strategic Transport Models", *Transportation Research Part A*, vol. 32A, n° 2, 1998, p. 149-157; in French, see Sophie Masson, "Interactions entre système de transport et système de localisation: de l'héritage des modèles traditionnels à l'apport des modèles interactifs de transport et d'occupation des sols", *Les Cahiers Scientifiques du Transport*, n° 33, 1998, p. 79-108.

119 Concerning MOSTRA see *inter alia*: V. Lichère, "Le Modèle stratégique de simulation des déplacements", *Revue Générale des Routes,* n° 773, 1999, p. 45-46; LET-SEMALY (report drafted by Charles Raux), "Modèle stratégique de déplacements de l'agglomération lyonnaise (version 1). Tests de sensibilité, erreurs et incertitudes liées à la prevision", Lyon, January 1998; CERTU, "Modèle multimodal de l'agglomération bordelaise. Analyse des principales caractéristiques du modèle MOSTRA", Lyon, December 2007.

120 CETE de Lyon, "Le modèle multimodal du Grand Clermont. Fiche Technique", Bron, August 2008.

121 The software related to urban travel demand modeling and being used on PCs in France at the end of the 1980s was as follows: the French (state-sponsored) OPERA, DAVIS, TERESE, and the (commercial) Canadian EMME/2 (see: CETUR, "Les Etudes de prévision de trafic en milieu urbain. Un outil pour l'aménagement urbain (Fiche d'information 17)"; CETUR, "Les Etudes de prévision de trafic en milieu urbain. Guide Technique", p. 41, p. 43, p. 44). According

by both public actors and private engineering consulting firms. Unlike software that merely provides an interface between the model itself and the user – e.g., specific software for coding the network and its interface, or software for graphically representing the results generated by the model –, this new software is a veritable *tool-box* that allows users to try out several mathematical methods (several types of model) for each of the steps in the urban travel demand modeling process: trip generation, trip distribution, mode choice and route assignment.[122]

EMME/2 (*Equilibre Multimodal/Multimodal Equilibrium*) was one of the first examples of commercial forecasting traffic software to arrive in France. Its design as an experimental product goes back to the late 1970s in the *Centre de Recherche sur les Transports (*CRT: Center for Research on Transportation) of the University of Montreal. In the early 1980s, the same centre developed a second version of the software, that is EMME/2, which was taken up and enhanced in the mid-1980s by INRO (Informatique et Recherche Opérationnelle), a private firm with strong ties with the CRT (in 1999 the cost of a license varied between €15,000 and €105,000).[123] In France, EMME/2 has been used by CETE Méditerranée and CETE Nord-Picardie, as well as by several local authorities such as those in Lille, Montpellier, Marseille, Toulon, and Bordeaux.[124]

TRIPS is another imported software package widely used in France (at the end of the 1990s, the cost of a license varied between €13,500 and €33,200). It is associated with the private consulting firm MVA.[125] TRIPS has been used by several local authorities such as those in Strasbourg, Lyon, Saint-Etienne and the Côte d'Azur. The (aggregate) "four-step" model developed by DREIF (MODUS) used TRIPS software in its 1997 version. There were more than twenty TRIPS applications in France up to 1999.

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to one modeler, the FABER model, which developed in the late 1960s (see for example, Centre de calcul du CETE de Rouen*,* "Système Faber 1130 8K Version 1: introduction au système"*,* Bibliothèque de programmes*,* April 1969 – document available at the SETRA Library), was still being used regularly (along with OPERA) in the late 1980s whereas, according to the same practitioner, EMME/2 was considered at this time to be a "relatively recent arrival in France" (see A. Boeswillwald, "Introduction au débat: les outils disponibles et les besoins d'améliorations", *Déplacements*, n° 4, 1990, p. 35-36).

122 Unless we specifically state the source, information concerning the software used in France since the early 1990s is taken from the following documents: CERTU, "Les logiciels de planification des déplacements urbains"; GESMAD, "Bilan des pratiques et attentes de modélisation des collectivités locales"; Bhouri, "Intermodalité: Bilan et perspectives des systèmes informatiques"; CETE de Lyon, "Coûts et processus d'élaboration d'un modèle multimodal: enseignement de différentes experiences", Bron, May 2005; CETE de Lyon, "Le Modèle multimodal du Pays de Montbéliard. Fiche Technique", Bron, August 2008; CETE de Lyon, "Modèle multimodal des déplacements de la région grenobloise", Lyon, August 2008; CETE Méditerranée, "Pratiques de modélisation dynamique du trafic dans les agglomerations", Aix-en-Provence, August 2009. We should also note that a number of CETEs (de l'Ouest, Nord Picardie, Lyon, Sud-Ouest, Méditérranée) as well as CERTU made also use of HieLoW (Hierarchical Logit for Windows), a software providing a calibration of multinomial logit and hierarchical models based on the method of maximum likelihood, developed in academia in the 1990s and distributed by the Belgian company STRATEC (http://www.stratec.be/site/HielowFR.htm: last accessed March 29, 2013).

123 On EMME, see Konstantinos Chatzis, "Un Logiciel canadien de planification des transports nommé EMME: du prototype universitaire au marché mondial (milieu des années 1970 à nos jours)", in Claudine Fontanon and Irina Gouzévitch (eds.), *Les Ingénieurs civils en Europe: expertise et mobilité, fin XVIIIe-XXe siècles*, Paris: Editions Garnier (forthcoming).

124 The EMME/2 assignment module, one of the most widely used throughout the world, was tested and compared to DAVIS at the end of the 1980s by CETE Méditerranée*,* on behalf of CETUR, without any significant differences in the results provided by the two models being detected within traffic configurations which were not overloaded. See CETUR, "Les Etudes de prévision de trafic en milieu urbain. Guide Technique", p. 43. More recently, EMME/2 has been compared with another iconic French model of the 1970s, TERESE (see Cécile Godinot, "TERESE, les hirondelles et les marguerites: prévisions de trafic pour le tramway de Montpellier – confrontation à la réalité et à une modélisation alternative sous Emme/2", Rapport de stage, DESS Transports urbains et régionaux de personnes, Lyon, September 21, 2004. TERESE had already been subjected to a number of evaluations: see: Xavier Godard, "La Modélisation de la demande en transport collectif urbain", in "Rapport de la 58ème table ronde d'économie des transports: Bilan de la modélisation de la demande"*,* Paris, Conférence Européenne des Ministres des Transports, 1982, p. 49-64); C. Berenguer, "Evaluation de la modélisation des trafics sur la ligne D".

125 On the origins of TRIPS in the late 1960s in the United States, see Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours)", ch. 2. In the 2000s, TRIPS was a part of the large commercial software package named CUBE Voyageur, a suite of software products that also includes TP+, Tranplan and MinUPT. CUBE Voyageur has been developed by Citilabs, set up in 2001 as a result of the merger of the Software Products Division of MVA (MVA Systematica) and of the American firm Urban Analysis Group. By the late 1990s, 800 TRIPS licenses had been granted worldwide. According to its Website, Citilabs currently supports over 2500 cities in over 70 countries across six continents (http://www.citilabs.com/: last accessed on July 10, 2014).

Among the other imported modeling software packages being used in France in the 1990s we should mention MinUTP (multimodal), an American-developed package and one of the most widely used applications worldwide.[126] IAURIF (now known as IAU-îdF) acquired MinUTP in the 1990s,[127] and ANTONIN, STIF's disaggregate model, uses TP+, the successor of MinUTP. POLYDROM (cost €21,300 in 1999), which had been developed since 1977 by Casimir Rham, the creator of the now defunct firm of Systems Consult based in Monaco, was used on a subcontracting basis by the city of Brest.

The case of the Karlsruhe-based German engineering consulting firm PTV (*Planung Transport und Verkehr Group*), founded in 1979,[128] deserves a special mention, as its products have been increasingly popular in France since the 1990s. The cities of Grenoble, Clermont-Ferrand, Lyon, Paris, Toulouse, Nantes and Rennes as well as IAU-îdF have been among the users of this German company's software (especially DAVISUM, which incorporated the experiences of 400 users worldwide in the late 1990s[129]). In the 1990s, Barbier de Saint-Hilaire, the creator of the French DAVIS model in the early 1970s (see above), entered into an arrangement with the German firm to incorporate certain features of DAVIS (tolling and congestion) into the modeling chain of their VISEM/VISUM software,[130] developed from the 1980s on.[131] This had the advantage of being a multimodal model that was already available on the international market. The newly-created software, known as VISEM/DAVISUM (which cost between €6,400 and €57,900 in 1999[132]), offered a complete (multimodal) chain model.

Finally, we should note the recent arrival in France of TransCAD, a software package first released in 1988 and developed by the US firm Caliper Corporation (founded in 1983), which is currently one of the most popular urban travel planning models.[133] The French government acquired TransCAD in 2003. The software was tailored to central government needs through the development of "add-ons", known as "the TransCAD SETRA modules", created by a SETEC International – Caliper consortium; it was disseminated to the various CETES in 2006[134]. In 2004-2005, the long-established French engineering firm of SETEC International developed a multimodal model for the City of Toulon using TransCAD.

The advent of desktop computing and forecastinf traffic software that we have just mentionned has triggered radical changes in the makeup of modeling teams: thus, the part of computer scientists in charge of translating the model into a programming language has diminished in favor of modelers.[135] Nevertheless, current developments, taking place mostly in

126 In the mid-1990s, MinUTP had been installed at over 400 sites worldwide and cost €12,200 in 1996. On the MinUTP, whose origins can be traced back to the early 1980s, see Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours)", ch. 4.

127 Nguyen-Luong, "Recherche sur le choix modal en milieu urbain", p. 9.

128 Concerning PTV, see: Eric Baye (en collaboration avec Jean-Michel Cusset), "L'Ingénierie-conseil de prévision et de régulation du trafic en Allemagne et en Suisse germanophone", Rapport pour le compte de la DRAST, Lyon, January 1995; http://www.ptvgroup.com/en/welcome-to-the-ptv-group/: last accessed July 10, 2014; http://en.wikipedia.org/wiki/PTV_AG: last accessed July 10, 2014.

129 Ludovic Broquereau, "DAVISUM, un outil de modélisation multimodale des transports", *Revue Générale des Routes*, n° 773, 1999, p. 37-41.

130 VISEM: trip generation, trip distribution and mode choice steps; VISUM: assignment step. In the mid-1990s, there were over 200 VISEM/VISUM users, and about 40 people were working on the software production side. See Baye, "L'Ingénierie-conseil de prévision et de régulation du trafic en Allemagne et en Suisse germanophone", p. 61.

131 François Barbier-Saint-Hilaire, Markus Friedrich, Ingmar Hofsäß, Wolfgang Scherr, "TRIBUT: A Bicriterion Approach for Equilibrium Assignment", Karlsruhe, PTV, n.d.

132 In the mid-2000s, the cities of Toulouse and Grenoble paid €37,000 (not including VAT) for a software license for 3,000 zones.

133 On Caliper and TransCAD, see Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours)", ch. 4.

134 SETRA, "Les Outils d'évaluation des projets routiers: d'Ariane à TransCAD (Rapports d'études)", Paris, February 2010.

135 Prior to the use of TRIPS, the DREIF's model, MODUS, required three teams: a methodology/modeling unit made up of 3 people, an IT/computer graphics unit composed of 6 people and a unit involved in carrying out route and public transport surveys (3 people). In total, IT personnel used to account for *half* of all staff. The various programs integrated within CONVEX (run on UNIX) and IBM (run on MVS) were written in FORTRAN. The programs integrated within UN stations (run on UNIX) mad use of ARCINFO and AUTOCAD software. The interface graphics programs were

academia, of a new generation of transportation forecasting models are reinstating IT teams as an important part of the modeling process.

developed on AUTOLISP (see Lichère, "MODUS. Modèle de déplacements urbains et suburbains", p. 12). Through the example of MODUS, we can appreciate the extent to which the advent of this new global commercial software created a radically different working environment for modelers.

3. The French urban travel demand modeling landscape in the 2000s

The French urban travel demand modeling landscape in the 2000s was the direct result of all of the aforementioned developments.

First off, we should stress the importance of private consulting firms,[136] including non-French firms with an international presence, such as MVA and PTV that had both opened branches in a number of French cities.[137] Such firms were major users of commercial, non-French software, which they had sometimes developed themselves. In the early 2000s, and just before PTV France was set up in 2004, there were six major French private consulting firms with modeling capabilities: ISIS (parent company: EGIS/Caisse des Dépôts); MVA France (parent company: SYSTRA), SEMALY (parent company: EGIS/Caisse des Dépôts), SETEC; Thalès I&C (parent company: Thalès), SYSTRA (parent company: SNCF and RATP). Within these firms, in 2001 there were about 150 people working in transportation planning although not all of these were modelers proper.[138]

A small number of local and regional authorities also have some technical modeling facilities.[139] The various CETEs maintain a presence in the modeling landscape although this is now really attributable to the role they played in the 1970s and 1980s.[140] In symbolic terms, the "withdrawal" of public bodies, whose expertise has largely been transferred to private engineering consulting firms, is apparent in the fact that the CERTU (formerly the CETUR), which used to commission government engineers to draft urban travel demand modeling reference manuals now uses private engineering consulting firms to prepare these documents.[141]

Research in the field of urban travel demand modeling (within institutes such as INRETS (now IFSTTAR), universities, engineering schools and the *Centre National de la Recherchee Scientifique* (CNRS: National Centre for Scientific Research) appears to be characterized by insufficient staff levels and fragmentation.[142] Nevertheless, we should stress that over the past fifteen years or so research activity has actually been stepped up, particularly around provin-

136 Concerning French consulting firms specialised in urban travel demand modeling in the 1990s and early 2000s, see in particular the following works: Debizet, "L'Evolution de la modélisation des déplacements urbains en France, 1960-2005. Le poids de l'organisation institutionnelle des transports"; Debizet, "Crise ou mutations de l'expertise"; Debizet, "Déplacements urbains de personnes: de la planification des transports à la gestion durable de la mobilité"; Baye, "L'Ingénierie-conseil de prévision et de régulation du trafic en France"; Baye and Debizet, "Des nouvelles problématiques urbaines à l'innovation de l'expertise transport/déplacement. Mise en parallèle et convergence".

137 PTV France Traffic was set up in 2004 with its headquarters in Strasbourg and has a branch office in Lyon (http://company.ptvgroup.com/en/landing-pages/fr/ptv-france-traffic-fr/produits-et-services/: last accessed July 10, 2014). In the early 2010s, MVA had offices in Paris, Lyon, Marseille et Lille; http://www.mvaconsultancy.com/locations.html: last accessed March 28, 2013).

138 Figure drawn from Baye and Debizet, "Des nouvelles problématiques urbaines à l'innovation de l'expertise transport/déplacement", p. 38-45.

139 GESMAD, "Bilan des pratiques et attentes de modélisation des collectivités locales"; Debizet, "L'Evolution de la modélisation des déplacements urbains en France, 1960-2005. Le poids de l'organisation institutionnelle des transports", p. 18.

140 Certain seasoned modelers who have spent their entire career in the various CETEs now declare that current urban travel demand modeling within the French public sector is a total failure (see Facq, "Les Fondements statistiques de la science française des déplacements urbains", interview n° 9).

141 CERTU, "Modélisation des déplacements urbains de voyageurs. Guide des pratiques", Lyon, March 2003, written by SETEC consulting firm; CERTU and ADEME, "Comportements de déplacement en milieu urbain: les modèles de choix discrets", most of which was written by MVA. These may be compared with the manual published by CETUR in 1990 (CETUR, "Les Etudes de prévision de trafic en milieu urbain. Guide Technique"): the two people who wrote up the guide and the related working group of 15 people were engineers and other civil servants working for various state bodies (CETE, INRETS, DDE…). MVA and other consulting firms have also drafted a number of other guides and reports for various departments of the French Ministry for Infrastructure. See, for example: Michael Clarke (MVA), "Modèles de déplacements en milieu urbain: l'expérience américaine", Rapport pour le compte de la DRAST, Paris, October 2000, and the bibliography in CERTU, "Modélisation des déplacements urbains de voyageurs. Guide des pratiques".

142 See Eric Baye, Philippe Blancher, Arnaud Chi and Vincent Lichère, "Bilan de compétences des laboratoires de recherche français en matière de modélisation des déplacements de voyageurs et de marchandises", Rapport pour le compte d'ADEME, Lyon, October 2002.

cial clusters,[143] thanks mainly to public funding.[144] Despite their differences, these research projects align themselves, with current international trends in travel demand modeling, and most of them share the same basic aim of modeling transport-urbanization interaction (we have to bear in mind that the "traditional" modeling we have been dealing with up until now only analyses the "transport" component). Carried out by academics, some of these research projects have already produced results than can be used by the practitioner. It was the case of METROPOLIS, a software package developed by the Université de Cergy-Pontoise's THEMA/TT&R research institute, which differs from a "static" road traffic assignment model in that it deals with changes in traffic over the period simulated while taking into account the time of departure on the basis of the desired time of arrival and the estimated travel time.[145] METROPOLIS software was acquired in 2003 by PTV, which incorporated it into its DAVISUM software.[146] Another research project whose results seem to have translated into operational practices is the integrated land-use and transportation model for the Paris region known as *Pirandello*, developed by Cofiroute, a major French road builder.[147] We should also point out that Dynalogic, a traffic microsimulation software developed by the French firm Dynasim and providing visualizations of modeled traffic flows has been integrated within CUBE, a commercial software package by Citilabs.[148]

The training of modelers remains fairly "basic" according to a number of those directly concerned,[149] and mostly involves "on-the-job" learning. There were few quality academic training courses available in France in the early 2000s. Apart from a small number of lessons on modeling on offer at *Ecole des Ponts et Chaussées*, we should mention in particular the modeling course provided jointly by Université Lumière Lyon II and *Ecole Nationale des Travaux Publics de l'Etat,* a Lyon-based engineering school that essentially produces engineers for the French State.[150] For years, the private engineering firm MVA Consultancy made its TRIPS software available free-of-charge to the heads of this academic program for demonstration purposes. In the early 2000s, the course lecturers used public funding to develop a travel demand modeling courseware. This computer-based tutorial file available in CD-ROM format

143 This represents a major contrast with the period 1960-1975. For example, very few *Ponts et Chaussées* engineers are involved in contemporary research. Nevertheless, we should mention Fabien Leurent (X-1985), who has conducted research into route assignment issues among others, and who is heading a small group of modelers at *Laboratoire Ville, Mobilité, Transport* (LVMT), a joint research center of IFSTTAR, *Ecole des Ponts et Chaussées* and Université Paris-Est Marne-la-Vallée. See F. Leurent, "Curbing the Computational Difficulty of the Logit Equilibrium Assignment Model", *Transportation Research Part B*, vol. 31, n° 4, 1997, p. 315-326; Id., *Structures de réseau et modèles de cheminement*, Paris: Lavoisier, 2006.

144 Jean-Philippe ANTONI (ed.), *Modéliser la ville: formes urbaines et politiques de transport*, Paris: Economica, 2011.

145 Concerning METROPOLIS, see: THEMA/TT&R, CORE, RAND-EUROPE (HCG France), "Calage et résultats de simulations dynamiques sur des réseaux de grande taille", Rapport final du projet QUATUOR, April 2002; Fabrice Marchal, "Contribution to Dynamic Transportation Models", Ph.D. dissertation, University of Cergy-Pontoise, December 2001; André de Palma and Fabrice Marchal, "Real Case applications of the Fully Dynamic METROPOLIS Tool-box: An advocacy for Large-scale Mesoscopic Transportation Systems", *Networks and Spatial Economics*, vol. 2, 2002, p. 347-369; André de Palma and Robin Lindsey, "Modelling and Evaluation of Road Pricing in Paris", *Transport Policy*, vol. 13, 2006, p. 115-126.

146 Institut d'Aménagement et d'Urbanisme Ile-de-France, "Projet SIMAURIF. Perfectionnement et valorisation", Paris, July 2008, p. 15; the CV (February 2011) of André de Palma, the "spiritual father" of METROPOLIS (http://www.ces.ens-cachan.fr/Files/cvlong201102.pdf: last accessed July 11, 2014).

147 See: Vincent Piron and Jean Delons, "Pirandello, un nouvel outil d'aide à la décision", *Transports*, n° 449, 2008, p. 161-171; M. Kryvobokov, J. B. Chesneau, A. Bonnafous, J. Delons and V. Piron, "Comparison of Static and Dynamic Land Use-Transport Interaction Models: Pirandello and UrbanSim Applications", *Transportaion Research Record*, n° 2344, 2013, p. 49-58.

148 http://www.citilabs.com/cube-dynasim-4: last accessed July 13, 2014. Concerning Dynasim and similar software (including VISSIM by PTV), see Gusri Yaldi, "The Use of CUBE Dynasim and aaSIDRA for the Analysis of a Signalized Intersection", Master Thesis, School of Natural and Built Environment, University of South Australia, January 2006 (available at: http://ura.unisa.edu.au/R/?func=dbin-jump-full&object_id=65202: last accessed July 11, 2014).

149 Fabien Leurent, "Portée et limites des modèles de trafic", Rapport pour le compte de la DRAST, Arcueil: INRETS, January 1996, ch. 3; Ministère de l'Equipement, du Logement, des Transports et du Tourisme/Conseil général des Ponts et Chaussées – Ministère de l'Economie et des Finances/Direction de la Prévision, "Transports urbains et calcul économique", Document de travail, n° 97-1, Paris: Ministère de l'Economie, des Finances et de l'Industrie, 1997, p. 73; Bay and Debizet, "Innovation et bureaux d'études dans la planification des transports urbains".

150 Concerning this course, which is now part of the TURP masters program (TURP: *Transports Urbains et Régionaux de Personnes*), see: http://www.let.fr/Master-TURP: last accessed July 11, 2014.

is used for the course in question but is also intended for other trainers or even professionals that wish to self-train.[151]. It is worth noting here that among the researchers involved in this courseware, some are in the vanguard of national research in regards to household travel surveys.[152] Alongside these university courses, occasional training is provided to sector professionals by *Ponts-Formation* which is affiliated to *Ecole Nationale des Ponts et Chaussées*.[153]

151 Concerning this courseware, see Patrick Bonnel, "Transport Modelling Coursware", lecture given at the Workshop on "Building the Transport Profession – Comparative Approaches to Training in Europe", *Association for European Transport 2004* (available at: http://abstracts.aetransport.org/paper/index/id/1824/confid/10: last accessed July 11, 2014).

152 See for exemple: Patrick Bonnel and Michel Le Nir, "The Quality of Survey Data: Telephone versus Face-to-Face Interviews", *Transportation*, vol. 25, 1998, p. 145-167; Caroline Bayart and Patrick Bonnel, "Combining Web and Face-to-Face in Travel Surveys: Comparability Challenges", *Transportation*, vol. 39, 2012, p. 1147-1171. Patrick Bonnel is also the co-author of several research works dealing with various aspects of urban travel demand modeling: Jorge E. Cabrera Delgado and Patrick Bonnel, "Aurait-on pu prévoir l'allongement des distances des déplacements urbains observé ces vingt dernières années avec le modèle de distribution gravitaire", *Les Cahiers Scientifiques du Transport*, n° 62, 2012, p. 33-64; Jorge Cabrera Delgado and Patrick Bonnel, "Quelle dynamique temporelle pour le modèle à quatre étapes?", Rapport final pour le compte de l'ADEME (Groupe 1 du PREDIT 3), Lyon, LET, August 2012.

153 See, for example, Ecole Nationale des Ponts et Chaussées – Ponts Formation Edition, "Modélisation des déplacements", March 8-9, 2005, documents available at ENPC Library (FC 3992); Debizet, "Déplacements urbains de personnes: de la planification des transports à la gestion durable de la mobilité. Mutations d'une expertise", p. 271-276.

Conclusion

This working paper is an attempt to analyze the history of urban travel demand modeling in France from the 1950s up to 2000s. To carry our this project, the author made use of an analytical framework that treats modeling practices as a production process: in addition to the "product" itself, i.e., the characteristics of the model, the paper focused on: 1) the various actors, individuals and institutions – such as the research bodies and training institutions, private consulting engineering firms and government technical departments, involved –, in urban travel forecasting; 2) the "raw materials", such as household travel surveys; and 3) the "means of production" (software and hardware) required for the production and implemen-tation of this type of modeling.

The analysis highlights a historical trajectory made up of two major periods: the first one (1955-1975) was marked by the dominant presence of central government; it was followed by a second period characterized by the rise of private, mostly foreign engineering firms, and the development of several related software products marketed at international level.

The period from 1955 to 1975 was marked by a national production of original urban transportation modeling in which central government played a decisive role. It was generally French state engineers who imported such models from the United States and oversaw their implementation and development in France. During the 1960s and early 1970s, engineers working for the French government produced a number of models on the mainframe computers of the time. They also commissioned the services of a number of French private engineering firms that were then involved in urban travel demand modeling. This intense period of original national modeling output ceased around the mid-1970s when the French state selected a small number of models from among the available "products" on the market. These models were subsequently standardized, disseminated and implemented throughout the national territory via local public agencies.

The second period (from the 1980s to the 2000s) differs from the preceding one in a number of respects. First off, central government agencies began to withdraw from developing new urban travel demand models and confined themselves to simply update household travel survey data, and to adapt existing models to newer hardware (personal computers, for example). As a result of this withdrawal by central government, the key vectors of change in French urban travel demand modeling from the 1980s have comprised a few major private consulting firms.[154] Most were foreign, and some have opened branches in France. The increasing importance of the private consulting firms in this field of modeling has been accompanied by the development of a number of related software products (most of them foreign), some of which have been designed and distributed by the same firms. These software prooducts are marketed at international level and have been massively used since 1990 in France as well as in other parts of the world by private consultants and by government agencies as modeling supports.

Having summarized the history of urban transportation modeling in France from the 1950s, I would like to use the rest of this conclusion to do two things :1) provide an explanation for this national trajectory that differs in several respects from transportation modeling experiences in other countries similar to France; 2) broaden my analysis by examining the specific case dealt with here (history of urban travel demand modeling) as part of a more general trend concerning the current production and use of "hybrid" objects such as engineering models, i.e., objects that regularly incorporate academic research findings but are also widely used for practical applications.

154 Let us note here that, more often than not, these private consulting firms have been working for local government bodies (Debizet, "Déplacements urbains de personnes: de la planification des transports à la gestion durable de la mobilité. Mutations d'une expertise"; Debizet, "L'Evolution de la modélisation des déplacements urbains en France, 1960-2005. Le poids de l'organisation institutionnelle des transports").

As we have already pointed out, the history of French urban travel demand modeling sketched out in this working paper highlights a "discontinuity" at the level of the actors involved: after being a stakeholder of great significance in the period between 1955 and 1975, central state gradually withdrew from transportation modeling. As a result, the key vectors of change in French urban travel demand modeling from the 1980s have comprised a few major private consulting firms. And while the increasing importance of the private sector in this filed of modeling after the 1980s appears to be a fairly general trend all over the world,[155] comparative research would appear to indicate that it took on a specific form in France. Indeed, unlike the US, Germany or the UK, France cannot "boast" of having produced consulting engineering firms with an international stature in the domain ou urban travel demand modeling.[156] As we have persistently stressed, the renewal of French modeling after the 1980s was largely down to the actions of foreign actors (engineering consulting firms and producers of related software). So why have French modeling capabilities lagged behind from an international perspective? Let us leave aside "contingent" factors, and focus instead on a series of "structural" ones.

The first factor that needs to be examined is the well known duality of the French higher education system, where the so-called *Grandes Ecoles* (Great Schools), which include a great number of engineering institutes, co-exist with the much less prestigious universities. The non-integration of many engineering schools – including *Ecole des Ponts et Chaussées* with its close links to the *Corps des Ponts et Chaussées* – within the university system has long been at the root of the absence, or virtual absence, for reasons of scale among others,[157] of systematic research within French engineering institutes.[158] Consequently, the production of new knowledge in the engineering sciences has frequently been a function of extra-academic contingencies (e.g., the willingness of the state to tie up a significant number of its engineers on a specific research project for a considerable period of time).

It appears that the good health of French traffic forecasting modeling during the1960s and early 1970s was largely due to the sustained involvement of the *Corps des Ponts et Chaussées* in urban affairs during this period,[159] reflected in large-scale mobilization over a relatively long period of human and material resources in favor of travel demand modeling projects.[160] Conversely, the decline of this type of modeling in France post 1980 – a dearth of original national production when compared with the previous period and developments in other countries – is surely bound up with a number of developments in this State engineering corps that occurred after the 1980s.

The first travel modeling-unfriendly development in the *Corps des Ponts et Chaussées* was the decentralization of the 1980s. Faced with the reduction in responsibilities that decentralization meant for the *Corps* (and let's not forget that it represents central government) the *Ponts*

155 On the American case, see Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours)".

156 As we have seen, the French company SYSTRA did acquire the British-based firm of MVA in 1993, however this was and largely remains (for the moment, at least) a purely financial transaction.

157 In the early 2000s, there were about 230 French institutes entitled to award engineering qualifications handing out an average of 110-115 diplomas each. Even though a comparison between different national engineering training systems is always a tricky business, these figures bear out one incontestable fact: the degree of fragmentation in engineering education in France is far greater than in countries with comparable social and economic structures. See Konstantinos Chatzis, "Coping with the Second Industrial Revolution: Fragmentation of the French Engineering Education System, 1870s to the Present", *Engineering Studies*, vol. 1, n° 2, 2009, p. 79-99.

158 Concerning the history of French engineering education, see : Chatzis, "Coping with the Second Industrial Revolution"; Konstantinos Chatzis, "Theory and Practice in the Education of French Engineers from the Middle of the 18th Century to the Present", *Archives Internationales d'Histoire des Sciences*, vol. 60, n° 164, 2010, p. 43-78.

159 Concerning such involvement, see Jean-Claude Thoenig, *L'ère des technocrates. Le cas des Ponts et Chaussées,* Paris: L'Harmattan, 1987 (1st ed.: 1973).

160 As we have seen in the first section of this paper, between 1960 and 1975, several *Ponts et Chaussée*s engineers practiced forecasting traffic modeling. The Ministry for Public Works and the Ministry for Infrastructure (after it was set up in 1966) also supported French urban travel demand modeling by hiring large numbers of people who were subsequently assigned to modeling tasks in various structures (especially the different CETEs) and by contracting private consulting firms to work on a number of modeling projects.

et Chaussées engineers – the younger members of the *Corps* in particular – began leaving the Ministry for Infrastructure in droves and in a quite disorderly fashion for an array of public and private sector positions. Since the 1980s, *Ponts et Chaussées* engineers have moved into a broad range of professional disciplines and are now present in sectors that are far removed from their traditional spheres, such as urban planning and transport.[161] And urban transportation modeling has not escaped the effects of this "dispersion", which seriously affected the corps's capacity to develop collective strategies and deploy significant resources around targeted services and goals.[162]

The impact of decentralization has been compounded by the increasing transformation of French State engineers from technicians into managers. And as regards managers, "the more you move around, the more managerial experience you acquire". Such mobility is especially prized within the Ministry for Infrastructures and more generally in the higher echelons of the French public sector.[163] However, the production of scientific and engineering expertise requires a certain degree of stability over time, and this condition has not been met in the case of urban traffic forecasting. Indeed, most of the *Ponts et Chaussées* engineers involved in travel demand modeling in the 1960s and 1970s, such as Mercadal and Koenig (see earlier), subsequently abandoned their careers as modelers – Barbier de Saint Hilaire was exceptional in this respect.

Another key factor in understanding the French post 1980s modeling landscape is the manner in which central state departmentst "managed" the expertise accumulated between 1960 and 1975. As we have seen, the period of sustained production of expertise was followed by *standardization* of the knowledge and know-how generated for the purpose of disseminating them in a uniform manner throughout the national territory, especially via the CETEs. Is it possible to link this manner of producing and handling such expertise to the situation regarding urban travel demand modeling in France over the post 1980 period, characterized among other things by a poor capacity of the main French actors to innovate? We are tempted to answer in the affirmative. This sequence: "making intensive use of resources to establish new practices over a relatively short period (first stage), followed by standardization of such practices (second stage)" – a sequence which is also apparent in other spheres of French expertise[164] – appears to be a double-edged sword. While well drafted standards may ensure good results (on average), by providing a framework and guidelines for local practices, they do so at the cost of making operational practices much more rigid and the organizations employing such standards far less receptive to innovation.[165] It is no surprise that the innovative capacity of the CETEs was being eroded when they were being tasked with deploying standardized models with virtually no increase in their human resources, while the body responsible for these same CETEs, i.e., the *Corps des Ponts et Chaussées*, was progressively reducing its commitment to urban travel demand modeling. It is also worth noticing that the CETEs' poor innovative record in this area of technical expertise also affected the innovative capability of the entire French system related to urban travel demand modeling, because of the specific role played by the CETEs in French engineering circles. Indeed, the CETEs acted as service providers for local authorities in the field of transportaion planning, and dominated the market of

161 Concerning changes in the *Corps des Ponts et Chaussées* post 1980, see Chatzis and Ribeill, "L'Espace des carrières des ingénieurs de l'Équipement"; Julie Gervais, "La Réforme des cadres de l'action publique ou la fabrique d'un 'nouveau corps' des ponts et chaussées. Impératifs managériaux, logiques administratives et strategies corporatists (fin du XXe siècle)", Ph.D. dissertation, Université Lyon-2, 2007.

162 Consequently, after the 1980s the number of *Corps des Ponts et Chaussées* engineers involved in modeling fell sharply.

163 Compared with other countries, the professional trajectories of French higher civil servants are characterised by rapid career progression and frequent job changes. See Jean-Michel Eymeri, "Comparer les hauts fonctionnaires en Europe: variations sur le thème de la carrière", in Françoise Dreyfus and Jean-Michel Eymeri (eds.), *Science politique de l'administration. Une approche comparative,* Paris: Economica, 2006, p. 28-46.

164 It would not be difficult to find similar sequences in other engineering domains in France. For the case of storm-drain design practices, see Konstantinos Chatzis and Gabriel Dupuy, "How to Dispense with Empiricism: The 'Caquot Formula' and Post-war Drainage Policy in France", *Water Policy*, vol. 2, n° 4-5, 1999/2000, p. 267-281.

165 For a theoretical approach to this question see Mary Douglas, *How Institutions Think?,* Syracuse (NY): Syracuse University Press, 1986. For concrete examples, see Konstantinos Chatzis, *La Pluie, le metro et l'ingénieur: contributions à l'histoire de l'assainissement et des transports urbains (XIXe-XXe siècles)*, Paris: L'Harmattan, 2000.

transportation modeling in France for a long time (more precisely, up to until the arrival of foreign private consulting firms). As a result, domestic private engineering consulting firms, severely weakened by the economic crisis of the 1970s, the decline in orders from the public sector, and competition from the different CETEs, proved unable to develop innovative practices in this field of transportation modeling.[166]

We consider the changes that appeared in the French urban travel demand modeling landscape post 1980 – i.e., the rise in private international engineering consulting firms and the widespread use of commercial software engineering – to be symptomatic of a more general trend in the production and use of objects that may be qualified as "hybrid" insofar as they both incorporate sophisticated knowledge developed in academia and are disseminated on a massive scale for practical purposes. For a number of years, the private sector has been increasingly involved in producing and marketing scientific and technical knowledge that was previously the exclusive domain of the public sector.[167] If we take the case in point, it is clear that since the 1980s, the increasingly internationalized private consulting firms have gradually supplanted government departments in various countries as the chief repository of forecasting traffic expertise.[168] And they now have considerable resources at their disposal. For example, Cambridge Systematics employed 280 people or so in 2011, and PTV around 450 people worldwide in 2010/2011.[169] In 1995, MVA already employed some 250 people.[170] In order to design its software products, among them EMME, INRO enlisted the services of thirty or so "Knowledge Workers"[171] in 2011: six among them held a Ph.D. degree and other nine a Msc. Degree.[172] All these private firms have forged close links with academic research and have succeeded in incorporating a number of theoretical innovations into their modeling practices. Cambridge Systematics is very close to MIT, PTV and INRO have also forged tight bonds with the academic world, the University of Karlsruhe and the University of Montreal respectively.[173] Tony May, now Emeritus Professor at Leeds University and former Director of the Institute for Transport Studies (ITS), worked for the British-based firm of MVA from 1985-2001.[174] But as well as their links to academia, these firms also use various "devices" – such as awarding prizes to users, for example – to harness the intelligence and experience of their clients with the ultimate aim of enhancing their own expertise.[175]

166 On this point, see in particular Baye, "L'Ingénierie-conseil de prévision et de régulation du trafic en France", especially p. 35.

167 There is now a large body of research literature focusing on the increasing importance of the market in producing scientific and technological knowledge. See: Dominique Pestre, *Science, argent et politique. Un essai d'interprétation*, Paris: INRA Editions, 2003; M. Norton Wise, "Thoughts on the Politicization of Science Through Commercialization", *Social Research*, vol. 73, n° 4, 2006, p. 1253-1272; Philip Mirowski, *Science-Mart: Privatizing American Science*, Cambridge (Mass.): Harvard University Press, 2011.

168 We should remind the reader that the increasingly widespread use of the consulting services of international firms by central governments is part of a broader trend affecting many spheres of expertise, including law. See: D. Saint-Martin, *Building the New Managerial State: Consultants and the Politics of Public Sector Reform in Comparative Perspective*, Oxford: Oxford Univrsity Press, 2004; M. Kipping and L. Engwall (eds.), *Management Consulting: Emergence and Dynamics of Knowledge Industry*, Oxford: Oxford University Press, 2002; Christian Lahusen, "Commercial Consultancies in the European Union: the Shape and Structure of Professional Interest Intermediation", *Journal of European Public Policy*, vol. 9, n° 5, 2002, p. 695-714; Y. Dezalay and B. C. Garth (eds.), *Dealing in Virtue. International Commercial Arbitration and the Construction of a Transnational Legal Order*, Chicago: The University of Chicago Press, 1996.

169 K. Chatzis, "La Modélisiation des déplacements urbains en France depuis les années 1980, ou la domination progressive du champ par le secteur privé".

170 Eric Baye, "L'Ingénierie-conseil de prévision et de régulation du trafic au Royaume-Uni", Rapport pour le compte de la DRAST, March 1997, p. 39.

171 Daniel Lee Kleinman and Steven P. Vallas, "Science, Capitalism, and the Rise of the 'Knowledge Worker': The Changing Structure of Knowledge Production in the United States", *Theory and Society*, vol. 30, n° 4, 2001, p. 451-492.

172 Chatzis, "La Modélisiation des déplacements urbains en France depuis les années 1980, ou la domination progressive du champ par le secteur privé".

173 Ibid.; Chatzis, "La Modélisation des déplacements urbains en Amérique du nord et en France (1945 à nos jours)", ch. 3 and ch. 4.

174 http://www.its.leeds.ac.uk/people/t.may: last accessed July 12, 2014.

175 Beginning in 2007, PTV has handed out the "PTV Vision Scientific Award" for research projects that used software developed by the corporation. The papers submitted are judged by an international jury composed of several world-renowned transportation academics. Concerning the role of the user in producing technical-scientific knowledge and

So, will the increasing involvement of the market in producing and using scientific and technical knowledge fulfill the promises and expectations of the advocates of this new alliance between science and economic interests? Or will this commercialization – with all the attendant problems of "product" access and control, for example – need to be "domesticated" in the public interest by the powers that be? In any case, both the public and private actors involved in urban travel demand modeling need to sit down and seriously consider these questions.[176]

know-how, see the article by N. Oudshoorn and T. Pinch, "User-Technology Relationships: Some Recent Developments", in Ed. Hackett, O. Amsterdamska, M. Lynch and J. Wajcman (eds.), *The Handbook of Science and Technology Studies*, Cambridge (Mass): The MIT Press, 2008, p. 541-565. Note that "user groups" exist for all commercially available transportation planning software by Caliper, PTV, Citilabs and INRO, where members get together on a regular basis.

176 See for example the contention of Leurent, "Portée et limites des modèles de trafic", ch. 3, for whom the role of the state should now be that of "certificator" of operational traffic forecasting models produced and deployed by private actors. See also Debizet, "Déplacements urbains de personnes: de la planification des transports à la gestion durable de la mobilité. Mutations d'une expertise".