PIRANDELLO®,
A NEW TOOL FOR URBAN PLANNING

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"It's not by perfecting the candle that we invented electricity[1]"

In urban transport, traffic and economic studies generally are based on the principle that job and population densities are known and stable during the studied period. The development of urban concession projects of a duration of 70 years has brought about the need to integrate the urban evolution that results from the very existence of the new infrastructure: it's then necessary to integrate the matrix of travel demand as part of the model, and therefore to create an urban model. After ten years of effort, VINCI Group has created a global urban model, called Pirandello®. This model looks for the balance point between the forces tending to concentrate people towards the city center (the attractiveness of the services offered) and those tending to spread them out (the search for spatial comfort and green space). Using an analysis of the urban population based on income level and job category, Pirandello® determines the logic of housing localization by income level and that of companies looking to increase their profits. It can also be used to test principles of urban planning, toll policies for zones or infrastructure, and CO^2 emissions. Pirandello® measures the global socio-economic efficiency of projects or regulations. It's an easy to use decision-making assistant in the planning and the living dynamics of major metropolitan areas.

[1] Saying of a French architect- innovator of the early 20th century

Key words: urban model, economic evaluation, accessibility, spatial comfort

THE GLOBAL APPROACH TO CITIES

The current weakness of the economic approach to cities

In the interurban field, the scientific knowledge of the economy of transport is pertinent and is regularly improved. Government commissions, technical administrations, the General Council of Bridges and Roads, the Ministry of Finance, universities, companies, engineering consultancies, and many others have all addressed this subject[2]. In addition, numerous reports issued by important experts regularly advise groups of decision-makers such as the French Counsel of Economic Analysis and the Economic and Social Counsel[3].

In the urban field, on the other hand, there are far fewer global economic studies apt to lead to a concrete decision. Research documentation is often theoretical and therefore difficult to apply to a specific project. The interaction between the structure of transport networks and the urban profile (housing, jobs) has always been known, but qualitatively rather than quantitatively. Urban land use models exist, but they require in general the econometric determination of numerous parameters[4], combined with the formulation of a large number of hypotheses. This renders their development complex, if not impossible. In the absence of such tools, the global economic and social aspect at the scale of an agglomeration is very rarely quantified.

As for the impact of toll policy on the behavior of inhabitants, the notion of bitterness[5] is just about the only recent idea to cast some new light upon the subject.

[2] Reports from CGPC (General Council of Bridges and Roads), the Court of Auditors, of the Senate, university studies...
[3] Rexecode-Prud'homme report, Boiteaux reports and many others
[4] As for example in so called « hedonic analyses »
[5] See the article in Transports n° 402, July-August 2000

It’s unfortunate, because the question of urban economics is very concrete, whether viewed under the angle of sustainable development (social, economic, and environmental) or specifically under that of urban renewal and its financing.

In effect, the key point is the following: the amount of money available to finance a project is a percentage of the socio-economic profit that it generates. The more the project- or the urban renovation- brings socio-economic profit, the easier it will be to put financing in place. Moreover, the opportunity that the generalization of long-term financing (concessions and partnership contracts) creates today will be that much better used once the socio-economic profit generated by the project is known, so allowing the fraction of the profit that can be used for financing to become apparent. Who would take the risk of financing without a good understanding of the receipts and therefore of the profitability of the project?

The construction of schools, stadiums, and the major transport projects such as the A 86 West and Roissy Express structure the city and modify the appeal of districts of the city. A good knowledge

- of the improved well-being or wealth generated, and
- of the location of this wealth within the city

makes setting up financing easier.

This is particularly true for transport infrastructure, and even more so for toll facilities. The added well-being generated, and its location, play a key role in whether to create the facility. The political decision in general weighs a certain feeling of the economic advantages of the purchase against a global estimation of the costs. It’s to measure this feeling as objectively as possible that we have created the urban model described below.

To illustrate our argument, let's look at some recent transport projects. Of all the toll-based transport projects studied over the last twenty years, the only two to have been carried out are the oldest, and therefore the best integrated within the agglomeration from the urban point of view :

- The A 14 – along the historical axis drawn under Henri IV and Louis XIII – and

- The A 86 West, the sketch of which appears in all urban master plans of the Paris Region since 1932 (the Prost Plan in 1932, the Sudreau Plan, and especially the Delouvrier Plan in 1965).

In contrast, the rapid demise of the LASER, MUSE, RSP, HYSOPE, and VILLEXPRESS projects shows that the argumentation given for their development in the years from 1985-1995, didn't correspond to all the complexity of the subject.

In effect, these projects had three major defaults:

- a tendency to neglect urban phenomena which occur at both ends of tunnels;

- a tight politico-administrative approach, in the measure that the projects were limited to particular departments, to the detriment of the global Paris Region perspective;

- a lack of global economic and dynamic vision.

Going back to the A 86 West project, we see that 20 years ago, the principle of the concession had already been retained. At the end of the 90's, a concession tender was invited, and the Cofiroute company was awarded the contract.

Forecasting traffic and revenues was of course critical, and the duration of the contract was so long (more than 60 years), that there was a problem simply extrapolating the results given by the classic 4-step transport model. It was necessary to create a new process, aiming to estimate what the urban structure could be like in the long term. This forecast had to be done in terms of future travel demand (all transport means considered), as well as in sociological terms, in order to determine the future willingness to pay. The frequency of use of the transport infrastructure in the long term can thereby be found, as well as the estimation of future revenues. This was the beginning of the conception of the global urban model.

This model therefore requires building a *convenient and usable urban model* and not improving an existing transport model. It's necessary to render *endogenous* the determination of population and employment localization, and consequently render endogenous the determination of the Origin/Destination matrix, O/D, instead of projecting it in a theoretical calculation more or less elaborated from exogenous hypotheses of population and employment localization. This O/D matrix can then be used in the framework of a classic transport model.

This model must offer a global method of representing the city, in which the economic approach and social approach - using income brackets and housing prices – are the foundations of the description, the "transport" aspect being only one of the tools serving to calculate the population and employment localization.

The methodology was put in place progressively over a dozen years, from 1995 to the beginning of 2008. The major development steps of this methodology have been highlighted through articles in various trade publications, notably *Etudes Foncières, Transports, and Les Cahiers du Conseil Général des Ponts et Chaussées*. (cf. Annex 1).

The methodology retained

Five steps were necessary in order to assemble such a model, in which the principle itself was

validated by leading specialists within the public sector[6].

Step no. 1 : improve the social knowledge of the agglomeration

In order to do this, it's necessary to examine the question of transport in the Paris Region based upon the three following aspects[7,8] :

- household economy – and not only that of administrations or transport companies - in taking the market segmentation (by income brackets) as the fundamental axis guiding the construction of the model ;

- the population and employment density, which broadly represents transport demand;

- the economic logic of the agglomeration, considered as a machine creating financial wealth and well-being[9].

[6] INRETS, French Institute of Urban planning, Creteil University, DAEI, DGUHC,…
[7] « "Transport means and density»" by V. Piron, Etudes Foncières, n° 65 from March 1995
[8] « Knowing how to choose a means of transport» by V. Piron, Etudes Foncières, n° 68 from September 1995
[9] « Speaking of the value of time in the calculation of transport costs» by V. Piron, Etudes Foncières, n° 69 from December March 1995

Step no. 2 : modernize the IT tools used for the traffic and revenue forecasts and their suitability for field observations

Step no. 3 : integrate the political and psychological aspect of urban tolls to determine a rule of acceptability

Step no. 4 : contribute to the development of the economic and legal tools allowing to conclude contracts for carrying out transport infrastructure.

Step no. 5 : design a global urban model which allows us to include within the modelization process the establishment of the Origin/Destination matrix. To do this, the model incorporates :

- a methodology of the residential localization of inhabitants, and

- a methodology of the setting-up of companies, both of which are functions of the network structure of the existing city, and of its key sociological data.

In addition to studies developed by Vinci and Cofiroute, this urban model synthesizes previously developed theories within the fields of "transport","urbanism", and "economy". It draws on commonly available public databases and of course encompasses the traffic model specifically adapted to the Paris Region, developed according to the work of the first two steps. Its great originality lies in allowing for a synthesis between very separate approaches (transport, urbanism, economy), and applying it to an existing agglomeration. It was named Pirandello® and patented last year.

It's now possible to use it to test the different hypotheses concerning transport policy (infrastructure projects, tolls to charge), to test the housing policy that the political deciders will be led to study, and to facilitate the design of coherent urban operations (housing, employment, and transport).

The detail of the development steps of modelization, the political and legal tools (steps 1 to 4) are given in Annex no. 1.

PIRANDELLO®, THE GLOBAL MODEL OF URBAN BALANCE

The principle of the Pirandello® model

In traditional traffic models, transport needs are deduced from a given population and employment without using radical methods. This is already a complex problem...

By so doing, it is supposed that the only behaviors available to residents faced with a modification of transports are a change of itinerary, a change of means, and a reduction in their mobility.

This is in complete contradiction with the observation : Total mobility in transport is in effect constant in time, and users rarely change itinerary or means, not to mention residential mobility.

It's therefore necessary to take into account in the behavioral representations of users/residents, three new important mechanisms :

- the first is selecting the destination of journeys in function of time and transport cost : an increase in time reduces the "range" of journeys, but not their number.
This is a derivation of the "theory of accessibility" developed by J-G Koenig and later by J. Poulit that allows us take into consideration the constancy of mobility;

- the second is the choice of localization of households, in function of price per m², accessibility, and their revenues- households looking for a place of residence which maximizes their satisfaction;

- the third is the mechanism of the formation of real estate prices and new constructions, the price and the constructions being linked to the demand.

In this manner, a representation of the *urban balance* is obtained, which takes into account the set of classic behaviors of households (other than the time of departure...), of businesses, and of property owners. This allows for a representation of *journeys from the agglomeration with respect to urban balance* to be drawn up.

The objective is to determine the effects resulting from the set of actions of the economic actors in presence. In addition, the global urban model allows us to determine :

- the direct effects (for example the reduction in distance traveled following an urban toll operation) and;

- the indirect effects (after a period of time, a new distribution of population and employment and a new balance in the price of real estate will result). The short- and long-term effects can then be compared.

The point of view of the household : Two contradictory forces

The evolution of agglomerations is a fairly slow process, giving priority to the micro-economic desires of residents and the business community before responding to regulatory evolution or plans. It's impossible to go against the desires of the population or to go against those of the business community.

On the demand side, two micro-economic desires have the opposite effects : the quest for accessibility (which encourages a densification towards the urban centers) and the quest for larger living surfaces or offices (which encourages a de-densification of the urban centers).

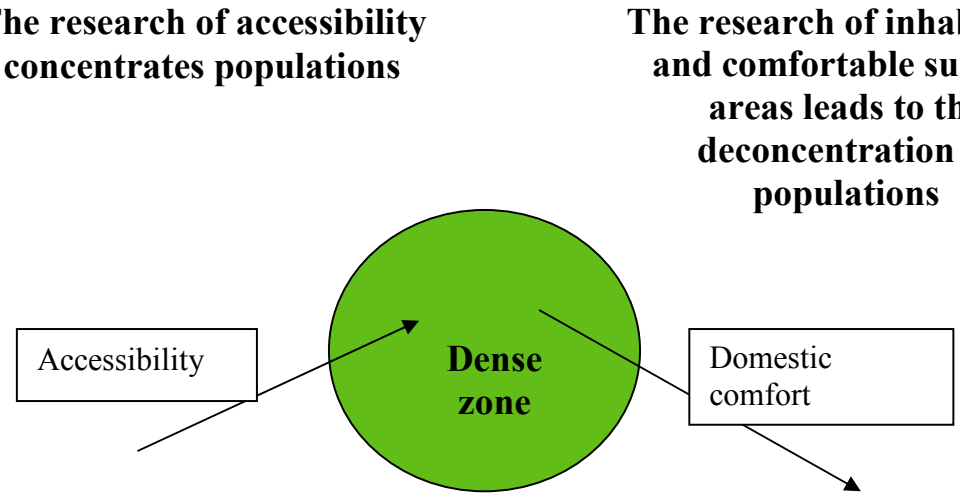
These two aspects have been studied and rigorously quantified :

- by theoretical monocentric urban models,

- by the discrete choices theory[10],

- by the so called de Bussière's model[11] which analyses the variation of the densities within the agglomeration and describes the de-densification speed of European and American agglomerations in function of time, see diagram 1.

DIAGRAM 1 :



[10] McFADDEN (1974), applied to transport by J.-G. Koenig, than taken in common practice by J. Poulit and J.-G. Koenig

[11] René BUSSIÈRE (1973), revalidated and revised by A. Bonnafous et Y. Crozet from LET (Transport Studies Laboratory)

The business point of view : accessibility versus surface price

The business point of view differs noticeably: the surfaces per employee vary little between the center and the periphery, but the price per m² of office space when correlated with employee productivity shows major variations. This point of view will be developed in a future article.

The urbanist's point of view

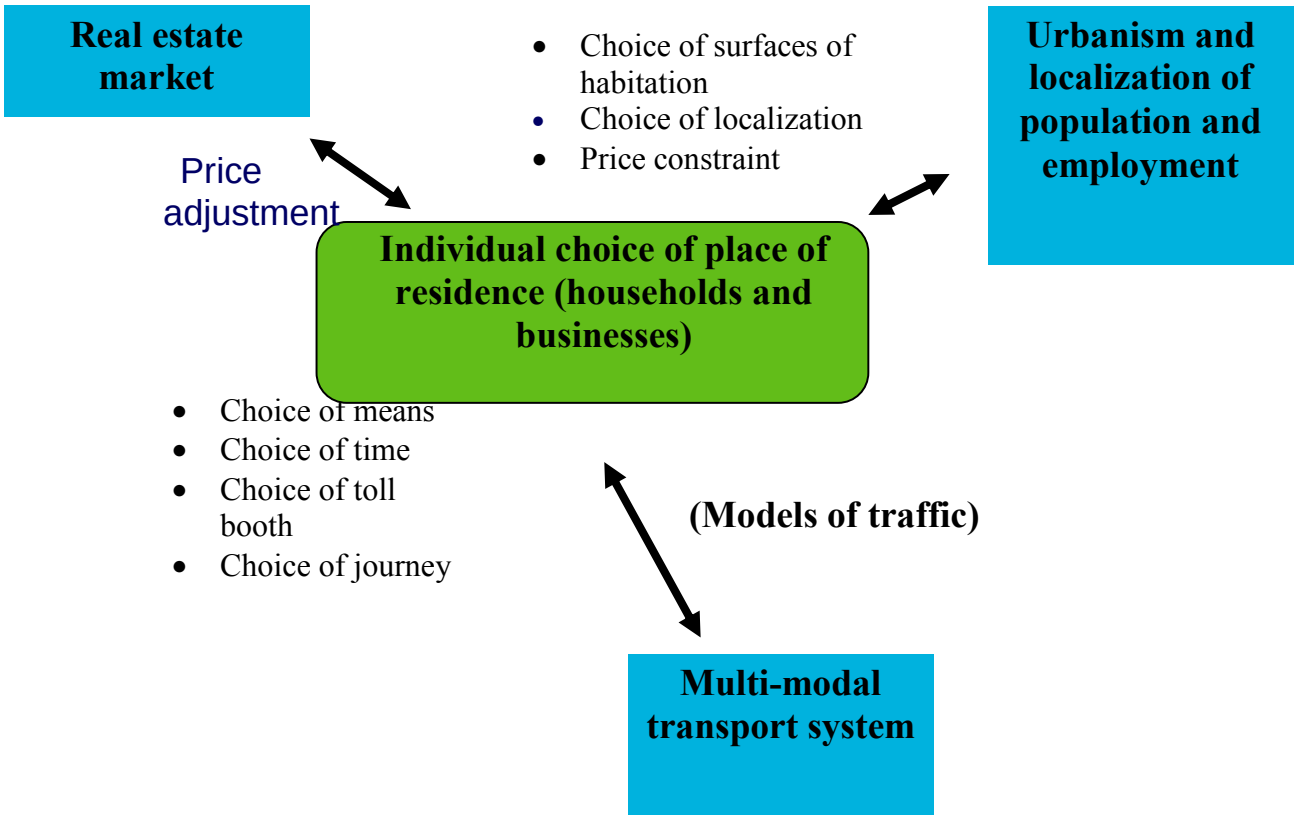
The desires of households and businesses make up only a part of the complete picture, because other mechanisms enter into play on the supply side. This essentially relates to the possible evolution of constructed surfaces and of transport infrastructures, an evolution which constrains urbanization and influences prices. The taking into consideration of these two mechanisms is described in a more detailed manner further below.

The model's objective

To anticipate the evolutions of distribution of populations (and of employment) following a modification of the real estate supply, the transport supply, the tarification, or the economic conditions. The key mechanism here is the choice of place of residence of the Paris Region inhabitant.

The estimation can only be done after taking into consideration the behaviors of households and the regulatory constraints of urbanism. Considering the contradictory effects mentioned above, a balance model is called for. Moreover, this model must be numerical in order take under consideration the specificities of transport networks and the current regulations of urbanism so as not to become just a theoretical tool, see diagram 2.

DIAGRAM 2 : **General principal of the model**



Formal description of the model

The formal description of the developed model is comprised of four parts :

- the description of the "resources" and the "agents" used in the model ;

- the description of the economic values used (essentially accessibility and domestic comfort) ;

- the description of the equations of the model ; it can be seen, and this is an important point about the model, that there is a relatively low number of equations ;

- the description of the "balances" retained ; there is a balancing point for each of the resources of the model.

It can be seen on several occasions that numerous equations of the model can be expressed in the form of an optimal program (for example, the traffic assignment following a principle of Wardrop). But this

property is generally not used in the calculations, except with the calibration procedure, which is explicitly written in the form of an optimal program.

In addition, and even if the model's illustration uses the Paris Region, the following description is general: it would be possible to apply the model to any city or fair-sized agglomeration, as long as there are housing, employment, and revenue by household databases, and a correctly adjusted traffic model.

The resources and the agents

There are three "resources" :

- habitable surface and office surface ;
- constructible surface ;
- network capacity (road and mass transit).

At the same time, there are two explicit "agents" :

- the residents
- employment.

Habitable surface and office surface

In the Pirandello® model, the surface area of the housing and offices are considered, and not the number of rooms.

Habitable surface and office surface are defined for each geographic zone, but are not homogenous. There is a component linked to the "standing", which is more highly valued by "high" income households than by "low" income ones. In addition, habitable surface and office surface are not fungible.

Specific attention has been given to "HLM's", public housing. In effect, there is a large proportion of "off-market" housing, the allocation of which is a function of sociological and political parameters in

priority to market parameters. A specific distribution law has been designed to represent, by zone, this means of allocating housing.

Constructible surface

Historically, there has been a major trend towards de-densification, and consequently towards the building of housing and offices in low-density zones. This phenomenon creates competition between the central zones and the low-density ones for an increase in property capacity. However, independently of local policy, not all towns have the same welcoming capacity.

Transport network capacity (road and mass transit)

The road and mass transit capacities are one of the keys to urban development. In a certain manner they are comparable to surface area, in that their capacities are a direct function of the paved surface. It can be observed that in the Pirandello® model, mass transit has a capacity, which allows us to determine the increase in frequency, for example on a micro-economic basis. It can be said that the model's objective is to determine the optimal allocation of surface area within a given agglomeration.

The residents and employment

The residents and employment are considered independently : there is no identification of employees as being residents. Interaction occurs within the accessibility calculation for each agent. The residents are classified according to household income (eight revenue classes), as found in available databases. Employment is observed by individual income and then regrouped into a coherent household income.

Aggregated Economic values used

These are :

- household accessibility ;
- business accessibility ;
- domestic comfort
- business comfort

Household accessibility

Classic formulation

Each household, at the moment of choosing its future housing considers the location, defined by the district and the ease of travel to other districts : We live in a district , and not only in an apartment or residence. It's necessary to evaluate the "economic" attractiveness of a district in function of objective parameters, in which the variation can be measured.

The accessibility theory here is a very pertinent tool to explain the attractiveness of major urban centers: it's preferable for a wide variety of reasons, permitting the inclusion of a large range of services (restaurants, specialty shops,...). It takes into consideration the transport supply (in the form of generalized time) and the destination opportunities (in the form of usefulness).

Accessibility is classically defined by an exponential formulation (even if this is not the best possible formulation), and with p_j population (or any other value of a demographic character) and a term indicating the decrease with distance (or more exactly the generalized time or cost) for the revenue class r):

$$A(i,r) = \sum_{dest} p_j e^{-\lambda_r(\theta.r^{\alpha}.tt_{ijr}+c_{ijr})} \qquad \text{(GE1)}$$

Where : A(i,r) is the accessibility of the zone i for the revenue class r ;

α and λ_r are constants defined by adjustment ;

tt_{ijr} is the transport time from zone i to j for the revenue r ;

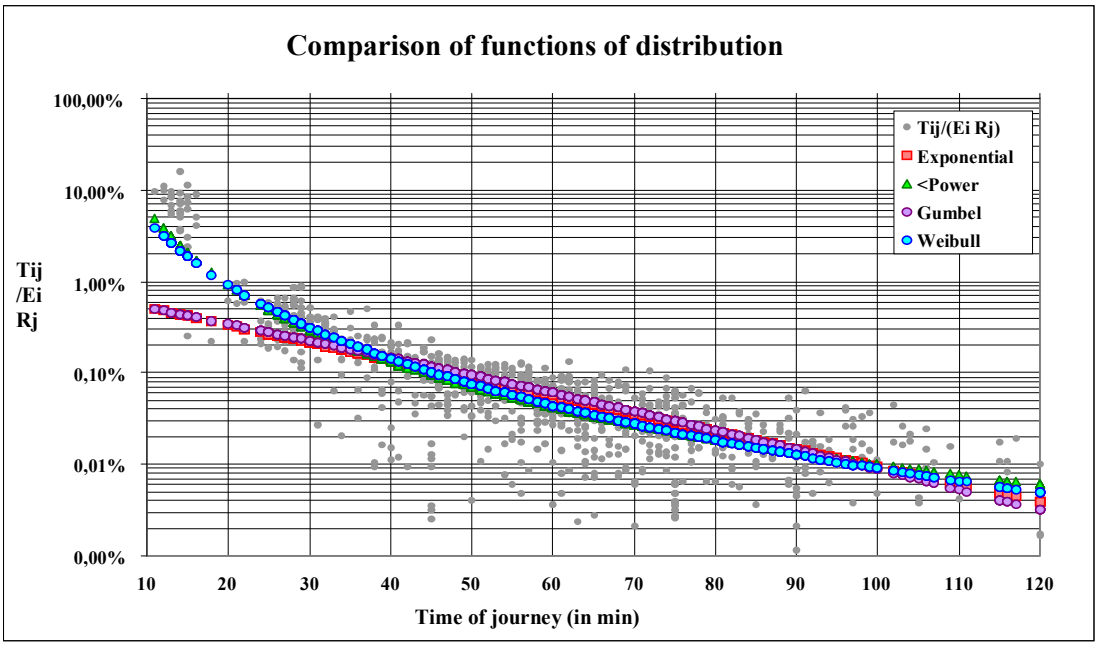
c_{ijr} is the transport cost from zone i to j for the revenue r ;

p_j is the population of zone j.

The accessibility is expressed here in units of population or employment. It's a "non-local" indicator, in the sense that it incorporates population, employment, and travel time throughout the network.

It can be seen, by the way, that the time parameter, $\lambda_r.\theta.r^{\alpha}$, is actually independent of revenue, and in addition the time adjustments are sufficiently satisfactory, even when the exponential law is applied, see diagram 3 :

DIAGRAM 3 : **Comparison of the distribution functions**



In these conditions, the equation has to be rewritten in the following form, presenting only one λ, term:

$$A(i,r) = \sum_{dest} p_j e^{-\frac{\lambda}{\theta.r^{\alpha}}(\theta.r^{\alpha}.tt_{ijr}+c_{ijr})} \qquad \text{(GE2)}$$

The compensatory income corresponding to the accessibility A for a fixed number of journeys, can then be looked for. This constancy of number of journeys is a result of observation since 1976 in the Paris Region (on average 3.5 journeys per day and per person of more than six years old) and little dependent on place of residence, see table :

Mobility all means by place of residence				
	1976	**1983**	**1991**	**2001**
Paris	3,73	3,64	3,67	3,61
Inner Suburbs	3,33	3,43	3,39	3,48
Outer Suburbs	3,5	3,4	3,5	3,46

In these conditions, it can be shown that there is :

$$u(i,r)^{acc} = \frac{\theta.r^{\alpha}}{\lambda}\log\left(\sum_{dest} p_j e^{-\frac{\lambda}{\theta.r^{\alpha}}(\theta.r^{\alpha}.tt_{ij}+cij)}\right) \qquad \text{(GE3)}$$

In this equation, θ is the proportionality factor of value of time per hourly revenue. It's therefore a coefficient close to 1, but for a same person can deviate more or less from 1 in function of journey (in other words, it's a distribution of probabilities...).

This formulation therefore generalizes the classic equation of the monocentric model following two directions in which the accessibility is calculated uniquely in relation to the employment zone presumed to be punctual and in the center of the agglomeration, and for a unique value of time.

It's important to notice that the function of the accessibility thus defined is a function of pure demand, in which case saturation does not appear : the summed probability for the totality of journeys within a particular zone might exceed 1! Saturation is taken into account in the effective calculation of the demand matrix, i.e. in the choice of destinations.

"Birds of a feather flock together" or the natural segregation of cities

These classic statistical laws give the accessibility formulation in function of the population or employment should be completed to take into account the sociology of factual meetings: in effect, meetings mainly occur within the socio-professional category or between people having similar revenues. In these conditions, it is necessary to "overweigh" journeys having a greater sociological proximity and to the contrary to "underweigh" the probability of a meeting between people with highly differing revenues. In other words, it's necessary to define an "equivalent population" of a given revenue, seen from another revenue class.

The technique retained preliminarily consists in finding a balance between classes in the following manner :

$$p(i,rj,rk)^{*} = p(i,rj).(1+|k-j|)^{-\gamma} \qquad \text{(GE4)}$$

or : p(i,rj,rk)* is the "population equivalent" of the zone i of the revenue class j seen by the revenue class rk;

p(i,rj) is the population of the zone i and the revenue rj ;

γ is an elasticity defined by adjustment.

The accessibility of households : complete formulation of p_j

Actually the accessibility of the residents relates to both population and employment. This gives the following formula :

$$p_j = \sum_{rk} p(i,rk).(1+|k-j|)^{-\gamma} + \varpi \sum_{rk} e(i,rk) \qquad \text{(GE5)}$$

or : e(i.rk) is the number of the class of employment k in the zone i ;

ω is a constant determined by adjustment.

Alternative formulation of household accessibility

The exponential formulation of accessibility can be replaced by the "at constant elasticity" formulation which allows a more precise adjustment of the law of demand for long distances and short distances, typically less than 20 min and more than 2 hours, as shown in the preceding diagram. From a micro-economic point of view, this favors the relative variation of the accessibility compared to the absolute variation. In these conditions there is :

$$A(i,r)^{*} = \sum_{dest} p_j (\theta . r^{\alpha} . tt_{ij} + cij)^{-\mu} \qquad \text{(GE6)}$$

The accessibility of businesses

A similar formulation of accessibility is retained for businesses, but it relates to employment only. In addition, the principle "birds of a feather flock together" does not apply to professionals, or not at least with the retained segmentation.

In these conditions, there is

$$p_j = \sum_{rk} e(i,rk) \qquad \text{(GE7)}$$

The choice of localization of businesses corresponds explicitly to a strategy of maximization of profit. It's logical, and reassuring to see that the rationality of behavior observed in households exists in businesses as well.

The service sector is the dominant sector of the Paris Region economy. It's been quite a some time since most industrial companies moved their production away from the agglomeration., leaving to this region only the commercial, administrative, and research tasks, elements which require high accessibility.

In Pirandello®, the productivity equation for service sector employment is written :

$$u(i,r) = k.S_r^{\alpha}.e^{A(i).\beta} - S_r - (\phi(i) + \pi(i)).Surf(i) + \varepsilon_{ir} + \eta(r)$$

What is completely fundamental in this approach to productivity is the following observation, which will be the subject of a future article : a direct link between regional GDP and accessibility using a simple "Cobb-Douglas type" equation can be established :

$$\sum_i \sum_r k.S_r^{\alpha}.e^{A(i).\beta} = PIB.régional$$

Adjustments have been made on the Pirandello® zoning for weighted maximum likelihood constraint. To set the orders of magnitude, the productivity of an identical salary in high accessibility zones (for example central Paris) is around 40 % more than that of a low accessibility zone in the outer suburbs. This fundamental observation justifies the absolute necessity of making additional investments in order to maintain the competitiveness of the Paris Region, and can be used as a key to evaluate the wealth created by new investments.

It's the track to use when looking for financing for future infrastructure.

Domestic comfort

Formulation

In parallel, and from a micro-economic point of view only, it is clear that the majority of households have a desire (and consequently a willingness to pay...) to live in suitable surface areas and even have a garden. There is therefore an increasing desire over time to live in larger surface areas, linked to a higher standard of living. It is supposed below that the level of satisfaction, measured directly by the willingness to pay, is linked to the surface area, the proportion of individual residences, and to revenue according to a formula of the type :

$$u(s,r,\varepsilon)^{espace} = k\ p_0 s_0 \cdot \left(\frac{s}{s_0}\right)^{\alpha} \left(\frac{r}{r_0}\right)^{\beta+\varepsilon} (1+\gamma.pli) \qquad \text{(GE8)}$$

$0 < \alpha < 1$

$0 < \beta < 1$

or : ε is a distribution of probability, not necessarily normal, but centered ;
for buildings of low standing
ε< 0 ;
for buildings of high standing
ε> 0 ;
$p_0, s_0, k, \alpha, \beta, \gamma$ are constants determined during the adjustment.

The objective of the distribution of ε's is to take into account the "standing" of an apartment, in which the service rendered is not at all limited to the surface, but includes many other parameters : amount of sunlight, building type, floor, equipment, service quality... To set orders of magnitude, the standard deviation is on the order of 20%.

Simply stated : satisfaction linked to housing follows the concept of diminishing returns, that revenue increases, that there is a considerable marginal utility for very small surface areas, and that the "standing" is valued differently by wealthy households and by poor households. To give orders of magnitude, s0 is on the order of 20 m² and p0 is similar to a medium-priced habitation. It's important to observe that the marginal usefulness of domestic comfort can take values as high as necessary for the balance calculations in the measure where there is :

$$\forall r > 0, \lim_{s \to 0}\ u'(s,r) = +\infty \qquad \text{(GE9)}$$

As for establishing the housing prices, the parameters of the Pirandello® model have been calibrated in such a way as to reflect the most recent Paris Region studies launched by the PUCA[12,13]

[12] PUCA (Plan Urbanism Construction Architecture) urban research organization which depends of the Ministry of Equipment (MEEDDAT)
[13] See notably "Housing Markets and urban segregations in the Paris Region" research launched by PUCA and developed by B. Filippi, C. Funès, H. Nabos, A. and C. Tutin.

Business comfort

In the same way, “business comfort” can be defined as the surface area per person, available to employees. The term referring to individual residences is not used.

USE OF THE PIRANDELLO® MODEL

This model has a unique characteristic for an urban model : *it is usable.*

As opposed to numerous urban models, the number of equations is low, and the number of parameters used to reconcile the results with real–life situations is equally limited.

It took a long time to establish the Paris Region model: several years of methodological research for information were necessary, as well as the analysis and the establishment of coherence among varied databases. However, these days, creating an urban model for an agglomeration having good databases is no longer difficult, and can be done rapidly (in a couple of weeks, according to the available databases). Next, given the calculation capacity of current computers, it’s possible in about 10 days of work to program and test simple tarification hypotheses or additional transportation infrastructure, and have “balanced” results, all things equal elsewhere, in terms of localization of population by income bracket, housing price, business localization, socio-economic benefits, fuel consumption, ... or any other parameter linked to transport and housing.

However, there are two different kinds of limitations to this model : one is that it doesn’t consider (for the moment) the area outside of the studied zone, meaning :

- that it can't say how many people will leave the studied territory if the housing and transport investments don't live up to what's expected of a dynamic agglomeration[14] ;

the other is :

- that it can't say at what speed the urban balance calculated will be established: it therefore needs to be used as a trend indicator.

These two inconveniences don't prevent at all using Pirandello® to test the economic and financial economic profitability of public investments, such as those necessary for the redevelopment of a city (public facilities, transport infrastructure), or tarification policy.

An application example : The Paris Region master plan

The ongoing research on the Paris Region master plan offers a good application subject for Pirandello®.

The master plan of planning and development designed in 1965 for 14 million inhabitants launched the transport network structure and the construction of the new towns. The 1976 plan is an adjustment of the 1965 plan. It keeps the major transport and mass transit infrastructures, and notes the problem created by the concentration in the West of white-collar workers, and in the East of households with the least money, leading to a social segregation of the urban agglomeration, see diagram 4.

The SDRIF project of 1990 kept a strong development dynamic, but the final result (SDRIF of 1994) reflects a will to strongly reduce the major investments, particularly in housing and transport infrastructure. The environmental dimension was emphasized more than previously, but still without a reliable socio-economic calculation, especially in regards to housing. The result is that 14 years later, there is a lack of housing, which has led to the lowered attractiveness of the Region, and an increase in

[14] 6 % of Paris Region employment is occupied by people who prefer living outside of the Paris Region, for reasons of comfort and economic balance of the household.

the unemployment rate (higher than the average rate in France, whereas the situation was the opposite in 1999).

As early as 1995, it became clear that the methodology employed for the design and approval of the new SDRIF was not the right one for two major reasons. One was that a Malthusian interpretation of the new ecological constraints led to a reduction in transport investment, public as well as road and, correlatively, in housing construction, leading to the crisis we are in today. The other was that the decentralization of the powers of urbanism led to strengthening of power of the people who didn't want to "go for it", compared with the people who "did".

The result is easy to see. The region is losing its economic efficiency and its social harmony because no heavy investment is coming in to fight against the saturation of the transport infrastructures, or against the well-known, powerful and spontaneous forces of urban segregation.

The observation of reality in the way it was studied by the PUCA – and which the model has integrated – clearly shows that the valorization of a zone (housing value people's salaries) is linked to accessibility.

In examining the operations:

- of the Plaine towns, linked geographically to the Stade de France,

- of the renovation of Marseille center, linked to the Prado-Carénage Tunnel, to the renovation of the docks, and to the arrival of the TGV at St Charles Station,

- of the Lyons agglomeration (Vaise district and presqu'ile),

it can be observed that on each of these subjects there was a strong desire for urban renewal, associated with heavy transport investment and public facilities. After several years, the result is in, and the districts have been transformed by a win-win operation because the collectivity progressively recoups expenditures in the form of additional taxes linked to the economic activity into which it had invested to launch the urban process.

In the Paris Region, the 1965 master plan launched the new towns, the transport network structure, and the redevelopment of the "suburban poles". The master plan director of 1976, commenting on that of 1965 expressed himself as follows:

In built-up zones, the major concern was restoring the urban fiber through concentration, in a few chosen spots, of employment and the services susceptible of assuring transport to hundreds of thousands of inhabitants. The transport infrastructures playing a predominant role in the success of these secondary centers were located near the suburban ring road (becoming since the A 86) and in the best cases directly served by public transport. The effort was heaviest in the particularly disadvantaged Eastern zone of the agglomeration.

Of the eight "poles" envisaged in 1965 : la Défense, Herblay, Saint-Denis (Stains-Villetaneuse), Le Bourget, Bobigny, Rosny-sous-Bois, Créteil, and Rungis, the Herblay pole was withdrawn in 1969, while that of Vélizy was added.

If the objectives to which the urban centers must answer were clearly defined, their contents remained more indicative than imperative in order to seize planning opportunities that would develop [15].

The spontaneous tendency toward segregation that all cities show implies that some pockets of poverty will form (for example the northern part of Department 93), which can not develop without massive investments, first public, then private.

Today, the priority is on finishing the transport network and continuing the redevelopment of the "suburban poles", in keeping with the terminology of P. Delouvrier. This will reduce over time the urban segregation measured by the PUCA. Taking the example of the northern Seine St Denis, where the location relative to the Roissy Airport, to Paris, and to the highways ought to make it a "privileged suburb", while in reality it is still far from that goal...

We must therefore consider redevelopment projects of urban centers, coupled with toll road projects linking the wealthier zones with the poorer zones. Mass transit projects should be built along the same principle, creating a transfer of wealth from the wealthier zones to the poorer zones.

CONCLUSION : PATHS FOR FINANCING INFRASTRUCTURES

The Pirandello® model helps us figure the impact of any development on the price of housing and the setting-up of offices. It's possible to deduce from it who the winners will be and how much will be made from the investments. From this estimation, the sums to be invested are not ultimately considerable compared to the wealth of the regions (in the order of 1 % to 1.5 % according to the case), it's possible to make rational decisions to determine the logical and politically acceptable basis to determine a necessary imposition to concretely launch the operations. The creation of a specific fund, as was the case in Oslo during the setting-up of the urban toll, or in the Paris Region, with specific development taxes is then conceivable, being politically explainable.

In the Paris Region, if we refer to the link established above between the accessibility of businesses and the GDP of the region, it is easy to see that the added investments necessary to make up for the investment delays is largely compensated for by the taxes generated by the added economic activity of the region. The funds would be reimbursed over a 40-year period.

[15] There is no much improvement that it can be made today to this text.

Needless to say, this economic approach requires coherent and global operational guidance over the development zone for the duration of the operation. This is an issue of another nature, but which is nevertheless a determining factor for a real economic policy. ■

ANNEX 1

1 - Modelization tools of road transport

At first, we closely examined the validity of transport modelization tools in the Paris Region[16,17]. The A 86 operation was the core around which were developed the analyses and the new approaches relating to, for example the representation of traffic jams and the fine segmentation of the clientele of toll roads (optimal tarification for the concessionaire). Numerous travel time measurements led us to modify the structure of the Cofiroute model to better take traffic jams into account. Studies on the value of time and the willingness to pay were particularly systematic, drawing on the analyses of existing toll facilities throughout the world, whether or not they were successful in the process of having a proper segmentation of the clientele.

2 - Political tools

We next studied the political acceptability of road tolls[18]. The main idea is that within the urban zone, models aren't able to take into account the frequency of use of a toll facility by a given car driver, and don't correctly take into account the choice – or the degree of obligation – to use a toll road as opposed to another itinerary or another means of transport. And yet, this plays a fundamental role in the political perception of a toll on a public urban road, and therefore on the political decision of whether to build this type of road. The successful example of the Prado-Carénage Tunnel in Marseille and the relative failure of the Lyons Northern bypass revealed some particularly interesting figures.

We then studied, particularly in the Paris Region

- the descriptive parameters of the city (floor area ratio, density of human activity, density of wealth, and hedonic values).

[16] "Value of time in transportation infrastructure", V. Piron, Transports n° 377, February – March, 1996
[17] "Traffic models in urban areas, a methodology that remains to be invented", V. Piron, Transports n° 379, September-October, 1996

• the costs linked to the automobile and the costs linked to mass transit, by separating the financial cost paid directly by the user from the financial cost borne by the collectivity, by differentiating the journeys according to motives and geographic localization.

• the pertinence zones of different types of mass transit, the question of the urban toll, as well as the heavy truck toll in the Paris Region[19].

The question of political acceptability being central to the execution of the Master Plan as it was drawn up in 1965, we have looked at it again, with a detailed analysis of driver behaviors as well as those of political decision -makers vis-à-vis the urban toll, and have defined with Claude Abraham a value allowing us to numerically estimate "the bitterness" of people who are on the verge of choosing between a toll road or a non-toll road, and who can't afford to pay the toll. This estimation would allow for, if people felt like it, the introduction of a bit of rationality into toll policy discussions[20] and, the quieting of some chronic complainers during public inquiries.

In a convenient and systematic way, we recalculated the "bitterness" generated by the infrastructure of which Vinci was the concessionaire, and this gave us reassurance in our approach to this subject[21].

3 - Economic and legal tools

Accordingly, it was possible to follow the quantified economic analysis of the Prado-Carénage tunnel in Marseille[22], which has had a powerful impact on the structuration of the city center, more powerful

[18] "The political acceptability of road tolls, a few European examples", V. Piron, Transports n° 385, September-October, 1997

[19] "The urban-interurban issue is now global", V. Piron, Transports n°393, January-February, 1999

[20] "Transport, urban planning and tolls : can political acceptability of tolls be quantified", V. Piron, Transports n° 402, July-August 2000.

[21] "Practical application of the notion of bitterness", V. Piron Transports n° 408, July-August 2001

[22] "Economic benefits and financial performance of the Prado-Carénage tunnel in Marseille", Transports n°416, November-December 2002.

than the Northern Lyons bypass has had on the Lyons agglomeration. The urban models (monocentric urban model and the discrete choices theory) were considered. When making the economic calculations the problem of the discount rate of the collectivities became apparent, and the high rate, set by France in 1988, proved to be inadequate for the present period of time, especially if one takes into account the long-term constraints generated by the increased pressure of ecological constraints.

At the Inter-ministerial Committee for Regional Planning and Development (CIADT) in December 2003, the Ministry of Equipment asked the Prime Minister's services to have the Commissariat Général du Plan launch a revision of the discount rated, the rate serving to evaluate the economic profitability of public investments, notably in the transport sector. Vinci was able to relate its experience on these subjects and helped lower the State economic discount rate from 8 % to 4 %. During discussions, the question of the different types of contracts was also considered: contracts entirely paid by public financing through taxes or development of Public Service Delegations (DSP) to appeal to the final user. New criteria appeared, adapted to periods of high transitory indebtedness of the State: the maximization of the socio-economic benefit for each public Euro invested. The results of the studies and discussions were summarized in the Lebegue report published in January 2005[23].

However, in numerous cases, the public infrastructure can not just appeal to the final user for the construction and exploitation financing : hospitals, police stations, gendarmeries, prisons, universities...This is why Vinci has actively participated in the setting-up of partnership contracts[24,25], which complement the DSP concessions when the commercial income does not permit adequate financing.

[23] "The Commissariat Général du Plan report on the revision of the discount rate of the State. Available on the Internet.
[24] "Public-Private Partnerships, lever for the investment, activity, and employment", C. Saint-Etienne, V. Piron, La Documentation française, 2006.
[25] "An evaluation guide for partnership contract", IGD Ouvrage collectif, Monitor issues, March 2004.