# PASSENGER MOBILITY AND CLIMATE CONSTRAINTS: ANALYSING ADAPTIVE STRATEGIES

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**ABSTRACT**

Today, numerous works conclude that transport seems to be completely coupled to economic growth. Therefore, as a direct consequence of economic development, transport sits today as one of the major final energy consumers and one of the most important sources of carbon dioxide emissions. Furthermore, in the absence of major technological change, this unsustainable situation will most undoubtedly get worse in the future.

In this paper we analyze what different types of public policies aiming at sharp reductions in GHG emissions imply on passenger transport and how they can be linked to new behavior patterns affecting time use and consumption. For this, we use the TILT (Transport Issues in the Long Term) model's core microeconomic choice model IT-UP (Integrated Tools for Utility-based Planning). Through this analysis, we explain the interest of adaptive strategies for GHG mitigation.

Keywords: Greenhouse gas, long term, scenario, transport, sustainable development.

## I. INTRODUCTION

Today, numerous works conclude that transport seems to be completely coupled to economic growth. Therefore, as a direct consequence of economic development, transport sits today as one of the major final energy consumers and one of the most important sources of greenhouse gas emissions (GHG). Furthermore, in the absence of major technological change, this unsustainable situation will most undoubtedly get worse in the future.

Furthermore, recent scientific insight has shown that in order to reduce the climate change risk (overshooting a 2°C increase in global temperatures), global emissions should be cut by at least 50 % in the next 40 years. Consequently, for developing and developed economies to be able to attain the 50% mark, industrialized countries must reduce their emissions by at least 75%. This is not an easy task, in order to plan for these drastic reductions, numerous studies (BANISTER & HICKMAN; KATO & ITO *et al;* LOPEZ-RUIZ & CROZET; SCHADE & HELFRICH *et al*; SCHIPPER & NG *et al*; SPERLING & LUTSEY) have looked into different options on how to get to this desired future. These studies concur on the fact that new technologies and their widespread use will be necessary in order to attain considerable GHG reductions, but they also agree that these new technologies will not be enough for industrialized countries to get to their objectives. Indeed, most works conclude that it would also be necessary to increase the match between new technology supply and consumer demand through the use of incentive economic instruments.

In this manner, GHG mitigation strategies imply the need to set up a certain number of public policies ranging from inciting technological progress, to tolls, to intermodal development or even rationing (tradable emission permits). Currently, an increasing number of countries have started to set up different types of programs to try to influence behavior in passenger mobility (especially personal vehicle mobility) and curb emissions from the transport sector, but are these initiatives enough?

This paper has three aims: Firstly, we explore –on the basis of long-term scenarios for the French economy- how a continued trend in the vehicle market (although promising concerning GHG reductions because of lower consumption factors) is not viable in the long-term future from an infrastructure point of view. Secondly, we offer insight on how requiring changes in behavior through public policies can offer more viable solutions for mitigation of GHG emissions in developed economies. Lastly, we will explore how policies aiming at mitigation of emissions can cause imbalances on a microeconomic level which lead to envisaging adaptive strategies in order to increase policy acceptability.

In order to better explain how we have carried out our analysis, we will present the reader with a brief description of the overall inner workings of the model used for this paper (TILT) while focusing particularly on the microeconomic module (IT-UP) which will be used extensively throughout the paper.

## II. THE TILT MODEL (TRANSPORT ISSUES IN THE LONG TERM)

The TILT model has been designed to be a long-term equilibrium model by combining a macroeconomic and a microeconomic structure in a backcasting approach that takes into account new motor technologies and facilitates sensitivity and impact assessments through five modules that work on three different geographical scales (urban, regional and interregional) :

- a macroeconomic model based on a re-foundation of the energy-environment modeling structures in order to properly assess long-term modifications of demographic variables and their impact on economic productivity and time use. This module was adapted from the BASES module in the VLEEM model (Consortium VLEEM, 2002),
- a microeconomic model based on discrete choice modeling -adapted from ant algorithms- (LOPEZ-RUIZ, 2009) that takes into account transport cost, infrastructure capacity and quality of service,
- a vehicle fleet dynamic model that analyses technological impact based on market penetration probabilities for new motor technologies and vehicles' survival rates,
- a public policy model that joins a sensitivity analysis and a multicriteria analysis in order to offer a detailed assessment of the effects of different public policies on oil consumption and GHG,
- an impact assessment model based on an input-output equilibrium analysis that details impacts on employment and production by sector.

The TILT model is centered on the simple idea of defined behavior types -in which speed/GDP elasticities play a key role- in order to determine macroeconomic transport demand estimations. The TILT model supposes that modal split in transport is directly linked to the idea that modal speed; transport times, transport management and household/firm locations determine modal shares. In this manner, the model's main hypothesis is that transport modal saturation rhythms can be varied -in the model- through public policies that have an effect on household/firm location and speed/GDP elasticities (LET-ENERDATA, 2008 and LOPEZ-RUIZ, 2009).

Furthermore, the model is also able to asses the system's sensitivity to public policies, investment needs in infrastructure and economic impact of different public policies whilst taking into account microeconomic choices. In this manner the TILT model structure enables the user to calculate energy consumption and pollutants emitted by transport activity (freight and passengers) on different geographical scales based on behavior patterns that can be influenced by public policies. In sum, the model has three main functions:

- modeling passenger-kilometers and ton-kilometers coherent with a micro/macro equilibrium structure according to motor technology used for journeys and area of service,
- modeling the vehicle park according to: age; motor technology; and year of production (for freight and passengers),
- modeling and assessing public policy impacts on $CO_2$ emissions, infrastructure investment needs as well as overall impact on the economy.

By joining these three functions of the different TILT modules, it is possible to build scenarios that:

- quantify the consequences of transport on the environment whilst detailing the systems' structure according to behavior and organizational changes and motor technology,

- give a precise view of traffic by motor technology, gas consumption and emission levels for each type of transport according to service distances, type of vehicle and transport cost,

- assess impacts of different policy pathways according to different scenario configurations.

These results, coupled with the model's structure, make TILT a powerful tool for building and exploring scenarios. The utility of the TILT model lays not only in its capacity to be flexible concerning different transport policies, changes in demography, behavioral differences as well as changes in transport structure and cost but also in its capacity to integrate a microeconomic insight module, on which this paper will be focused.

The TILT microeconomic sub-model lets us understand how, according to past tendencies (characterized by the coupling between growth and mobility), future public policies will impact demand for transport services as well as trade-offs linked to behavioral change and infrastructure use on different geographical scales.

IT-UP is largely inspired by developments done on ant algorithms (DORIGO, M. Di CARO, G. GAMBARDELLA, L.M, 1999) and their application to freight and passenger transport (LOPEZ-RUIZ H.G. 2009). This model relies on the idea of a representative agent that optimizes its transport decisions by taking into account opportunity (defined as the sum of goods and services that can be consumed in a period of time, LINDER, S. 1970) and cost in respect to a certain level of service on infrastructure -measured through a lateness index (LOMAX. T. TURNER. S, 1997).

IT-UP considers that the lateness index is defined by the difference existing between normal transit time and real transit time. This last indicator is useful in factoring in speed, distance and time into the calculation of the choice model and has the convenience of being comparable between modes.

In this manner, the proposed framework lets us asses the representative agent's choices that are coherent with the transport structure and its level of service. In the model, the value assigned to each choice (aij(t) –which refers to the choice of mode used to move from point *i* to point *j*) is calculated using the following equations:

(1)

$$a_{ij}(t) = \frac{\left[\tau\ (t)\right]^{\alpha}\left[\eta\right]^{\beta}}{\sum_{1 \in Ni}\left[\tau(t)\right]^{\alpha}\left[\eta\ \right]^{\beta}} \qquad \forall j \in N_i$$

Where:

$$\eta = \frac{\sum goods\ \&\ services}{(time + accestime) * \cos t} \quad (2)$$

and

$$\tau(t) = Lateness\ index(t) \quad (3)$$

The inherent logic of the microeconomic module is particularly useful in technico-organizational public policy assessments as it enables an analysis based on the idea that public policies are implemented as increasing/decreasing constraints on the system, in view of getting to a certain objective. Consequently, this facilitates the building of scenarios where a wide variety of social effects on different levels and aspects are comprised. In this manner, the TILT model is capable of giving insight on how changes in the transport structure linked to environmentally oriented public policies might influence passenger behavior in the future.

The following paragraphs will show how the theoretical framework of the IT-UP model can assess social effects on a public level for new behavior patterns that will undoubtedly need to be accompanied by clearly defined adaptive strategies.

## III. BAU SCENARIO OVERVIEW, CAR MARKET TRENDS AND INFRASTRUCTURE INVESTMENT ASSESSMENT

In 2008, the TILT model was used to develop three technico-organizational scenarios in order to quantify the effects of climate oriented policies in the transport sector (LET-ENERDATA, 2008. The original version of the report is in French, a detailed description in English, can be found in LOPEZ-RUIZ & CROZET, 2010). The main aim of these scenarios was to test the efficiency of public policies (modeled as growing constraints – ranging from promoting new motor technologies to public policies aiming at multimodality and decoupling transport activities from GDP) on GHG emissions.

In this study, the underlying principle of incremental constraints on the system allowed to present three different scenarios that allow a quick comprehension of the GHG reductions that can be obtained through policy mixes. Consequently, the scenarios offer a good representation of the general policy pathways usually accepted as being efficient and viable options for long-term oil consumption reductions. On this basis we will develop how the presented microeconomic framework can help in the analysis for each scenario and can give insight on adaptive strategies for sustainable planning.

The 2008 LET-ENERDATA report assessed sustainable transport scenarios for the French economy with a specified objective of -75% in GHG by 2050 through the identification of the different equilibriums possible that allow the attainment of the specified future. From these possible equilibriums, the three that best depict the range of solutions available –through public policy- were chosen:

- promoting strict technology standards – business as usual (BAU),
- green multimodality,
- decoupling transport activities from economic growth (GDP).

The results for each scenario were obtained by modeling a mix of different policies aiming at sensible changes in transport behavior and new motor technologies. Each of these scenarios imply different characteristics (a list of the main hypothesis can be found in annex) that are tightly linked to modal shares and demographic dynamics.

In sum, the first scenario is a business as usual (BAU) situation with strict technology standards. This scenario depicts a 48% reduction in emissions whereas the other two scenarios (multimodality and decoupling) represent a reduction of a little over 75%. In the following paragraphs we will first present the details of the BAU scenario and then we will go over the two alternative scenarios.

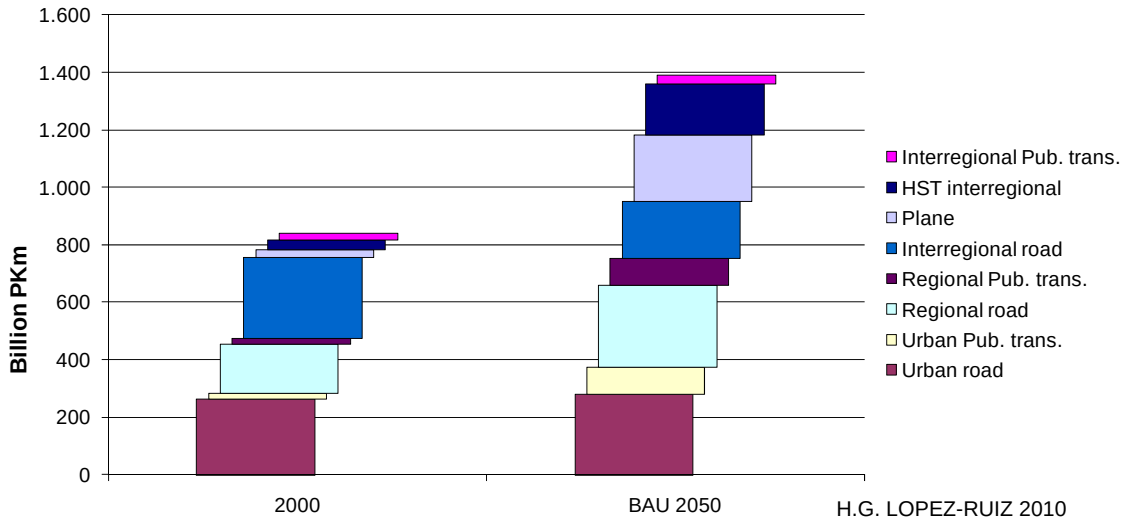
*Promoting strict technology standards (BAU)*

The BAU scenario represents a situation where the Speed/GDP elasticity for passengers is of 0.33 and where transport times are stable (1 hour per person per day). This scenario lets us appreciate:

- mobility in a situation where there is no major public policy affecting behavior and/or the system's regular performance (continued infrastructure investments and optimization is supposed)
- the effects of new motorization technologies on total $CO_2$ emissions

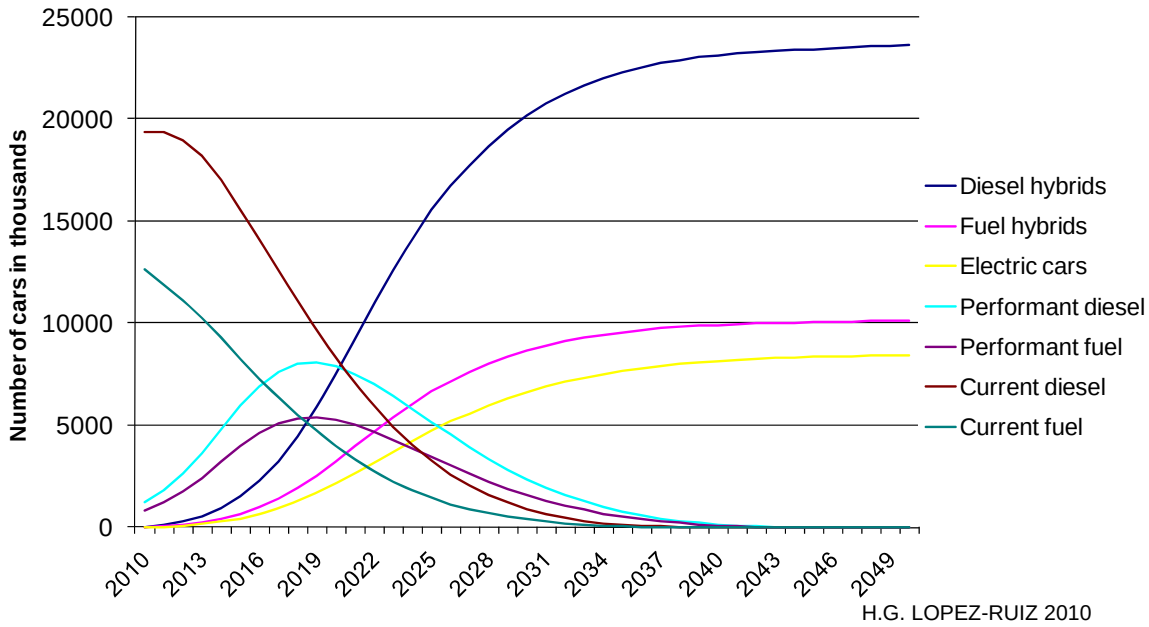
In this manner the BAU scenario lets us evaluate the contribution of strict and realistic technology standards that –according to our calculations- would lead to half of the reductions of the $CO_2$ target.

**Figure 1 Passenger mobility BAU**



As we can see in figure 2, if we suppose that hybrid vehicles go into the market in 2010 and electric vehicles are marketed by 2015, the modeled vehicle fleet, for this scenario, would be mainly composed of hybrid vehicles in 2040. This change in technology (coupled to the fact that electricity in France is mainly produced by nuclear reactors) would ensure, in a BAU case almost a 50% reduction in $CO_2$ emissions.

**Figure 2 Total number of cars per type of motor technology**




If we take a more detailed look into the details of this scenario, we observe that it is a scenario based on an inelastic market structure largely dependent on private vehicles with high oil prices and a very good offer in public transport. This translates into a scenario that is very dependent on road transport and, thus, dependent on road infrastructures. Therefore, if we suppose that market trends in cars continue to follow current practices, it is more than likely that spatial demand for car use –thus infrastructure needs- will grow accordingly. In order to carry out this assessment, we calculated the investments (see table 1) that would be required throughout the 40 year period, to 2050, for new infrastructures in a BAU scenario (operation costs are not included). In sum, spending on infrastructure would remain at a 1.4% of GDP level (which is roughly the same as in 2007) with most of it going to road infrastructures.

**Table 1 Investments in new infrastructure**

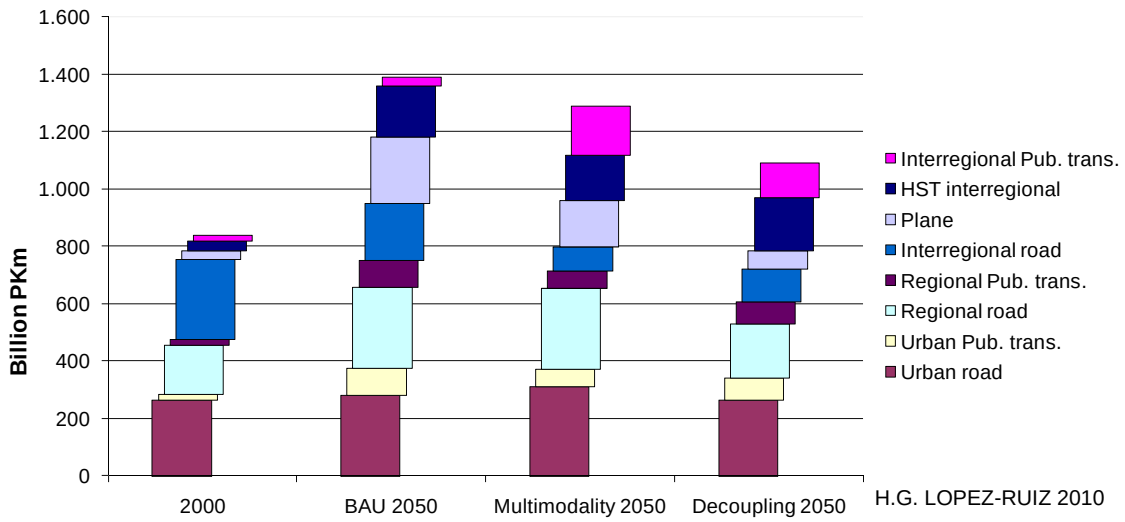
| **Billions of €** | **Mode** | **2050 Pegasus** | **Per annum** | **% of GDP** | **Year 2007** | **% of GDP** |
|---|---|---|---|---|---|---|
| **Investments** | Road | 1043 | 21 | 0,7% | 12 | 0,9% |
| | Rail | 747 | 15 | 0,5% | 2 | 0,2% |
| | Public Trn. | 137 | 3 | 0,1% | 2 | 0,2% |
| | Others | - | - | - | 1 | - |
| | **Total** | 1927 | 39 | 1,4% | 18 | 1,4% |
| H.G. LOPEZ-RUIZ 2009<br>**Note: - means not applicable - Values are in 2000€** | | | | | | |

Although it would seem like an ideal situation, because we would not be spending more money than we are today, the dilemma behind these results is linked to the fact that it might be a loss of money to have continued high investments on road infrastructure when it can be spent on something else. A BAU scenario with continued investments in road infrastructure would mean a reduction of almost 55 million tonnes of $CO_2$ (Mt $CO_2$), thus a ratio of 35€ invested in infrastructure per mitigated $tCO_2$. Although this ratio is highly speculative and narrow sighted, it is very self illustrative, especially when it will be compared to its value in other scenarios in the following section.

## IV. EXPLORING ALTERNATIVE SCENARIOS

Although the BAU scenario results in almost a 50% reduction in GHG emissions, this result is far from the desired 75%. Consequently, the LET-ENERDATA report analyzed two alterative scenarios that look into the effects of public policies aiming at changing behavior. These two scenarios offer a great basis for exploring how sustainable scenarios would shape future investment needs in the transport sector. In the original report, these scenarios are presented as different possibilities to attain important GHG reductions through multimodality and/or decoupling from GDP. The differences between each scenario are linked to the transport structure where: speed/GDP elasticities, modal speeds and transport times differ accordingly to public policy aims. Therefore, each scenario implies different characteristics and thus different types of results that are tightly linked to modal shares and demographic dynamics. Before going into the details of each scenario, the reader can review the mobility results on figure 3.

**Figure 1 Passenger mobility for all scenarios**



*Promoting green multimodality*

In this scenario, market oriented policies constrain the use of high carbon footprint modes which lead to an increase in the use of slower transport options that have smaller carbon footprints. In this scenario, the 75% reduction objective is nearly attained by favoring greener modes through an increase in transport costs according to their speed and associated emissions. As a result, the multimodal scenario shows a change in behavior patterns where the main effects are:

- a trade-off between the system's need for speed (coupled to growth),
- an increase in transport.

Indeed, since the characteristics of this scenario imply a speed/GDP elasticity equal to zero, translates into an increase in transport times (roughly 1 hour and 20 minutes per person per day). Thus, this scenario is based on market oriented public policies in an infrastructure intensive situation (because transport distances and public transport traffic increase sharply). In this manner, it lets us appreciate that a mix of technology and policy can get us to the wished reduction target but at the cost of slower transports speeds, higher transport times and continued investment needs in infrastructure (see table 2).

*Promoting decoupling between transport activities and GDP*

The main issue in this scenario is a trade-off between an elevated transport cost and average transport distances. Indeed, transport costs (both in time and in money) are considered to be higher than in the multimodal scenario. This results in economic agents choosing to modify their household/firm locations and develop a proximity intensive way of life.

This scenario implies a Speed/GDP elasticity equal to zero but, since transport distances increase less rapidly than in the BAU and the multimodal cases, transport times are reestablished around one hour per person per day. In this manner, the decoupling scenario leads the way to reductions in GHG emissions that go over the 75% objective through market mechanisms, regulation and spatial planning.

This new equilibrium based on proximity gives the system a better opportunity for the implementation of low range 0 emission vehicle technologies and also requires lower investments on transport infrastructure.

As we can see in table 2, a decoupling scenario lets us appreciate a situation where mobility increases from the 2000 level (and less than in a BAU or multimodal scenarios) but where infrastructure needs are not as overwhelming as in the two previous scenarios. Nevertheless, we need to take into account that as transport distances get shorter, cities get denser and this implies high costs in urbanism investments (which are not calculated in table 2).

**Table 2 Investments in infrastructure for all scenarios**

| Billions of € | Mode | 2050 Pegasus | Per annum | % of GDP | 2050 Chronos | Per annum | % of GDP | 2050 Hestia | Per annum | % of GDP | Year 2007 | % of GDP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Investments** | Road | 1043 | 21 | 0,7% | 384 | 8 | 0,3% | 140 | 3 | 0,1% | 12 | 0,9% |
| | Rail | 747 | 15 | 0,5% | 1529 | 31 | 1,1% | 992 | 20 | 0,7% | 2 | 0,2% |
| | Public Trn. | 137 | 3 | 0,1% | 74 | 1 | 0,1% | 77 | 2 | 0,1% | 2 | 0,2% |
| | Others | - | - | - | - | - | - | - | - | - | 1 | - |
| | **Total** | 1927 | 39 | 1,4% | 1987 | 40 | 1,4% | 1209 | 24 | 0,9% | 18 | 1,4% |

H.G. LOPEZ-RUIZ 2009
**Note: - means not applicable - Values are in 2000€**

In sum, these three scenarios and their assessment gives us a clear view of how the allocation of funds in planning for $CO_2$ reductions will be a crucial factor. Indeed, the value of $CO_2$ reductions per euro invested, in a BAU scenario (35€), is a bit higher than that of the multimodality scenario (33€) and higher than the decoupling scenario (20€). In our view, this ratio is important in the sense that the two alternative scenarios present a situation where, even though investments needs are high (maybe even higher than the BAU if we add urban planning costs in the decoupling scenario), the choice of infrastructure in which the community would be investing would seem more sensible.

Furthermore, investment calculations for the scenarios clearly illustrate that the implementation of different long-term policy mixes entails a (re-)optimization of agents' (passengers and firms) choices based on transport cost, infrastructure availability and the opportunities offered by transport services. Therefore, these sustainable scenarios imply private social effects linked to welfare variations associated to trade-offs between transport expenditure; house/firm location; accessibility; transport monetary budgets and *in fine* consumption of goods/services. These variations are important to understand in order to define how acceptability of these different public policies can be increased through adaptive strategies.

## V. ADAPTING TO CHANGE

In order to assess how change in behavior will influence adaptive strategies in the long term, it is necessary to take into account how changes in passenger behavior –as a result of public policy- will undoubtedly have an effect on the system. For this, IT-UP can offer some insight into how the (re-)optimization linked to public action in different scenarios can lead to household budget (money and time) reallocation effects that will have an important impact on other sectors (which will have a loopback effect on transport).

As long as the inherent principle of transport policies will be based on rendering high carbon footprint transport less attractive (through cost, speeds, level of service, etc.) than low carbon footprint transport, the results stemming from the policy's macroeconomic changes will most certainly influence microeconomic choices in other domains. These effects will be different for each country, network and set of public policies.

In this manner, if we assess the IT-UP results for the French multimodality scenario, we see that as constraints on speed and emissions come into play as a signal aiming at changing behavior patterns, there is a sharp increase in the use of rail and public

transport. This, in turn, implies that average speed in the system should invariably go down and transport times should go up (more or less depending on the evolution of car use elasticity).

This situation seems particularly difficult because it translates into: paying more (for car users) for lower transport speeds (an all modes) and thus loosing potential value added time (VAT) that could be spent increasing revenue. In this setting, we can easily deduct that increasing the sum of goods and services (opportunities) linked to transport activities might help to counterbalance the situation of lost VAT (in other words increasing the numerator in equation 2)

If we follow the same line of reasoning, the logic behind a decoupling scenario is very influenced by proximity services and public policies at play are largely related to spatial planning and infrastructure investment. In a decoupling logic, the main trade-off at play is directly linked to localization strategies and production organization aimed at decoupling transport distances form GDP growth. This entails a densification of main cities and production sites which would, in turn, translate into a sharp increase in the use of urban and regional road networks.

Unlike the multimodality scenario, transport cost characteristics in a decoupling logic lead to more stable transport money budgets because transport distances grow at a slower pace. Nevertheless, if a decoupling scenario is not followed by an adaptive strategy based on a fast increase in the supply of proximity solutions as consumer behavior is modified, an important loss of welfare could be observed.

In sum, a multimodality scenario implies paying more for the same opportunities with higher transport times and, in consequence, a microeconomic equilibrium requires adaptive strategies looking to counterbalance lost welfare by increasing opportunities. In a decoupling scenario, due to the fact that constraints are even higher than in a multimodality scenario, opportunities must increase even more (becoming proximity opportunities) in order to counterbalance overall distance reductions and stay within an equilibrium.

Moreover, the need for adapting to mitigation is reinforced by the fact that as constraints on oil consumption grow, more and more passengers will turn to public transport services. Consequently, a second underlying factor (the first being the before mentioned microeconomic equilibrium hypothesis) that explains the need for planning adaptive strategies is: market power. Indeed, as private vehicle costs rise, public transport use will also rise and, in consequence, this will imply a decrease in price elasticity of demand in public transportation and thus cause a shift in market power. This change in market power will most undoubtedly profit users instead of transport operators. Consequently, the system would be pushed towards a change in how opportunities are conceived by operators and planners.

Indeed, as market power shifts, the need for a change in the way that opportunities are assessed, planned and evaluated would become more and more pressing at the risk of welfare loss. As a result, assessment methods would have to start taking into account the time it takes to access opportunities (*c.f.* the denominator of equation 2).

Currently, certain dense networks are already starting to carry out this type of analysis, for example the Access To Opportunities and Services (ATOS) index (COOPER, S.

WRIGHT, P. & BALL, R, 2009) proposed by Transport for London in order to improve planning measures.

Indeed, just as the UK's planners have begun changing their metrics in order to take into account these new behavior patterns in transport activities, ITS specialist and planners will have to evolve in order to seize the opportunity to offer new services and explore new markets that will be based on a choice model taking into account adaptive strategies that conceive the utility of the representative agent as not only being a function of opportunities but also of the goods and services that are accessible to him in a reasonable lapse of time:

Accordingly, this change in how the utility function of users is integrated into the planning process will imply a differentiation within transport time budgets and how it is perceived by the agent's choice model (*c.f.* equation 2). In this sense, the choice model would change in order to take into account the effects that access time would have in a situation where we differentiate the time needed to consume and also the time it takes to get to that consumption.

As public policy evolves, changes in the transport system will suppose behavioral modifications. This situation will face planners and industry deciders with a new challenge: to plan according to a utility function that will not only depend on the opportunities an agent has but also on the possibility of actually being able to consume them. In this manner, all changes linked to public policies affecting time use should be accompanied by adaptive strategies.

## VI. CLOSING REMARKS

On the basis of the three scenarios, different ways of attaining planned $CO_2$ reductions were analyzed and discussed. In sum, realistic technological hypothesis show that a 50% reduction in emissions is a clear possibility and that going further based on new technologies would require very big advances in zero emission vehicles.

Nevertheless, in the absence of these new technologies, the remaining reductions in emissions are possible through different types of policy mixes that come down to:

- encouraging important modal shifts that would translate into a decrease in total average speed which would in turn make transport times go up,

- encouraging modal shift accompanied by a decoupling of transport distances. Consecutively, this would help to maintain stable transport times.

In this setting, this paper offered a brief view of current developments concerning organizational solutions that could lead to a reduction in oil consumption and emissions through important changes in the transport structure and behavior patterns and proposes a quantitative analysis of investment needs for different policy mixes.

On this basis, this paper gives insight on how policies aiming at modifying passenger behavior could heighten the pressure put on infrastructure demand (road, rail, etc

depending on the scenario) and will be an important issue in long-term planning for mitigation.

In addition, we would like to identify three main points on the relationship between policy and their impact on adaptive strategies:

**Mitigation leads to systemic changes.**

On a regional and interregional level "low-emission high speed transport" for passengers is something that already exists and that will most certainly keep on being promoted as a solution to GHG emissions. Nevertheless, planning for mitigation will most certainly bring about big changes on how public transport is conceived, by planners as well as users, and how it might be better utilized.

**Change needs flexibility.**

Integrating the user into the planning process will bring about important changes in time use and consumption behaviors accompanied by the continued development of proximity services. All of this implies the need for innovative transport solutions and new consumer services. In this manner, associating freight policy strategy and passenger policy strategy with urban and transport planning will be important in order to gain flexibility whilst continuing to open new markets for new types of behaviors and consumption patterns. These integrated policies for mitigation will undoubtedly require careful planning.

**Flexible cities adapt over time.**

Although, the actual lack of quick answers to the climate risk problem will most certainly continue to be an important subject in future-studies and even though innovative ideas will help overcome this problem, it will most certainly take time to seriously address all problems involved with transport activities. However, adaptation based planning should not to be underestimated as it offers great opportunities for mitigation acceptability.

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## ANNEX

| Scenario Characteristics | | 2000 | Pegasus 2050 | Chronos 2050 | Hestia 2050 |
|---|---|---|---|---|---|
| **URBAN** | | | | | |
| ***Freight*** | ***Km/h*** | | | | |
| | *-Road urban* | 50 | 60 | 52 | 52 |
| ***Passengers*** | ***Km/h*** | | | | |
| | *- Private car urban* | 23 | 30 | 25 | 25 |
| | *- Public transport urban* | 20 | 24 | 20 | 22 |
| **REGIONAL** | ***Km/h*** | | | | |
| ***Freight*** | *- Road regional* | 50 | 60 | 52 | 52 |
| | ***Km/h*** | | | | |
| ***Passengers*** | *- Private car regional* | 58 | 67 | 58 | 55 |
| | *- Public transport regional* | 58 | 68 | 57 | 54 |
| | | | | | |
| **INTERREGIONAL** | ***Km/h*** | | | | |
| ***Freight*** | *- Rail+Plane national* | 40 | 63 | 45 | 45 |
| | *- Rail+Plane international* | - | 70 | 70 | 70 |
| | ***Km/h*** | | | | |
| ***Passengers*** | *- Private car interregional* | 110 | 115 | 90 | 90 |
| | *- Public transport interregional* | 80 | 90 | 80 | 80 |
| | *- High speed rail interregional* | 250 | 250 | 250 | 250 |
| | *-Plane* | 500 | 500 | 500 | 500 |
| | | | | | |
| **TOTAL** | | | | | |
| **Freight (nat/inter)** | ***Km/h*** | **43** | **54/52** | **43/52** | **43/52** |
| ***Passengers*** | ***Km/h*** | **45** | **50** | **37** | **37** |
| **Elasticities** | | | | | |
| **Speed/GDP** | | - | 0,33 | 0 | 0 |
| **T.Km/GDP** | | - | 0,6 | 0,6 | 0,3 |
| **T.Km/International trade** | | - | 1,6 | 1,6 | 0,25 |
| **Macroeconomics** | | | | | |
| **Population** | | 64 | 67 | 67 | 67 |
| **Average Yearly GDP Growth** | | | 1,5 | 1,5 | 1,5 |
| **Child per household** | | 2,19 | 2,15 | 2,15 | 2,15 |
| **Productivity rate** | | 100 | 225 | 225 | 225 |
| **Transport Time Budget** | | 1 | 1 | 1,2 | 1 |
| **Note: - means not applicable** | | | | | H.G. LOPEZ-RUIZ 2009 |