

## **CYCLING IN THE CITY AND REDUCTION OF GREENHOUSE GAS EMISSIONS: THE CASE OF MEXICO**

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### **Summary: Cycling in the City and Reduction of Greenhouse Gas Emissions: The case of Mexico**

Cycling in the city has become fashionable. The example of Lyon with the introduction of Velo'V in 2005 is particularly interesting. Could similar policies be applicable to Mexico and Latin American cities where the use of the bicycle has been progressively abandoned but is now regaining a new image? What could be its potential impact on diminishing greenhouse gas emissions? After a rapid review of various experiences in Europe and Latin America, we will start with the example of Puebla, a medium-sized city in the Center-East of Mexico, for which we have data of an opinion survey (2007-8) on the practice of the bicycle. We will add the example of Monterrey, a northern city, with the results of two surveys (2008). This comparative analysis leads to conclusions on the feasibility of such policies in a South American context and its impact in terms of sustainability. An approximation of the emissions in urban transportation saved by the practice of the bicycle for utilitarian and leisure purposes and intermodality Bike-Public Transport gives us a reduction of the emissions around 3% of urban transport of persons and 0.5% of total emissions and could reach close to 5% of the urban transport emissions and 1% of global emissions in more extreme scenarios. If we add the impact of policies favoring intermodality Bike-Public Transport, the total impact reaches 5% on emissions of urban

transportation of persons or 1.0% of total emissions. In the case of a more extreme scenario the reduction could reach 9% of urban emissions and 1.8% of global emissions.

**Key words:** Bicycle, non-motorized transportation, Mexico, global warming, Lyon, Puebla, Monterrey.

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### **Résumé:**

Le vélo en ville est un thème devenu à la mode. L'exemple de Lyon avec l'introduction du Vélo'V en 2005 est particulièrement intéressant. De telles politiques seraient-elles applicables dans des villes du Mexique et d'Amérique latine où la pratique du vélo bien que longtemps dévalorisée commence à être à l'ordre du jour et quel en serait l'impact potentiel sur la diminution des gaz à effet de serre ? Après un rapide survol d'expérience européennes et d'Amérique Latine, nous partirons de l'exemple de Puebla, une ville moyenne au centre-sud du Mexique, pour laquelle nous disposons d'une enquête d'opinion (2007-8) sur la pratique de la bicyclette. Nous ajouterons l'exemple d'une ville du Nord, Monterrey à partir de deux enquêtes d'opinion (2008). Cette comparaison nous permettra de tirer des conclusions sur la faisabilité de telles politiques dans un contexte sud-américain et sur leur impact possible en termes de développement durable. L'estimation des ordres de grandeur des émissions du transport urbain évitées par la pratique cycliste utilitaire et de loisirs nous donne une réduction de ces émissions de 3% du transport urbain et de 0.5% des émissions globales dans le cas d'un scénario moyen et pourrait atteindre environ 5% des émissions urbaines et 1% des émissions globales dans un scénario volontariste plus extrême. Si l'on ajoute l'effet induit de hausse de l'usage des Transports Collectifs par des politiques favorisant l'intermodalité vélo-TC, l'impact total pourrait être de l'ordre de 5% des émissions de transport urbain des personnes ou de 1.0% des émissions globales et dans le cas d'un scénario plus extrême la réduction pourrait atteindre 9% des émissions urbaines et 1.8% des émissions globales.

**Mots clés:** Bicyclette, transport non motorisé, Mexique, réchauffement global, Lyon, Puebla, Monterrey.

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## **CYCLING IN THE CITY AND REDUCTION OF GREENHOUSE GAS EMISSIONS: THE CASE OF MEXICO.**

### **I. INTRODUCTION**

In front of global warming and its multiple causes linked to human activity and the type of socio-economic-urban development chosen, we observe great discrepancies in the per capita emissions of greenhouse gases (GHG) at the same level of economic development. For example, in the United States, it is twice that of Europe or Japan. The production of GHG is the result of many variables, from which the most important are: the volume of population, the type of technology adopted, behavior patterns and urban form. In Northern countries the level of population is more or less stabilized, the technology is progressively getting cleaner, but the behaviors are still aligned on increasing consumption in a context of urban sprawl which leads to more GHG emissions. In countries of the South the context is very diverse depending on the level of development. If we look at future prospects, the threat will come from emerging countries where the rate of growth of population is still high, the economic development rapid, and the behaviors aligned on the American model, with a high consumption of energy – and certainly from China, not because of a pursuing demographic growth but mainly because of a strong economic growth, the impact of which will be only slightly tampered by strong ageing of the population – probably from India where we will encounter a combination of strong demographic growth and strong economic development – and most probably not from Africa where we will see high demographic growth but slow economic growth. The countries of Latin America will see a strong demographic growth, probably also a strong economic development and possibly behaviors aligned on the North American model.

Moreover, the sources of GHG emissions are diverse and linked to the life style requiring energy, the growth of motorization, the deforestation, agriculture, etc. (Stern Report, 2006). To slow down the actual tendency of increasing GHG emissions, we rapidly arrive to the conclusion that we will need a sum of many measures, even very small ones, mainly in developed or emerging countries.

In the present paper we will focus on urban transportation of persons and the impact of the implementation of policies favorable to non-motorized modes. Transportation of persons account for around 30% of GHG emissions in the United-States and Canada and around 20% in Latin America due to lower motorization and higher densities. In countries of Northern Europe many cities have kept an important use of the bicycle and we observe an upsurge of its use in cities where it had almost disappeared. In this manner, the examples of Lyon and Paris as well as other European cities (Barcelona, Sevilla,...) show us that changes in behaviors are possible and that they can be rapid. For example, in the case of Lyon and Paris, the objective is to change the modal share of the bicycle from less than 1% to 8% in ten years.

We will try to measure the feasibility of such measures and their impact on the GHG emissions taking in account various factors: the source of the modal change: from what modes does it occur? Auto? Public Transport? Walking? And what impact can it have in terms of reduction of vehicules\*km and GHG emissions, taking into account that short trips with cold motors pollute more and also not forgetting leisure trips, the importance of which is not negligible. After a rapid revue of the pro-bicycle policies of Lyon and Bogota and their impact,

we will focus on the case of the City of Puebla, Mexico, probably a good example of mid-sized cities of Latin America, for which we have recent data from an opinion survey realized during the winter 2007-8 on the public (residents, tourists, firms,...) on the theme of the introduction of pedestrian zones, bicycle lanes and a system of bicycle renting. We will also use data from a survey done in Monterrey in 2008.

## **II. THE PROGRESSION OF THE BICYCLE: THE EXAMPLE OF LYON AND OF EUROPEAN CITIES**

The practice of the bicycle in European cities is very diverse. It reaches high levels in Northern cities (around 20% to 30% of all trips) (Papon, 2002) and very low levels in cities of Southern Europe, like in France, Spain or Italy with a few exceptions in cities where pro-bicycle policies have been implemented such as Strasbourg (8%). But things are changing and such policies like those taken in Lyon and Paris with the implementation of cycle paths and bicycle renting have an important impact of the practice of the bicycle. Policies favorable to the use of the bicycle in the city have proven to be efficient.

### **1. The Example of Lyon**

The practice of the bicycle had almost disappeared in Lyon with only 0.73% of total trips in 1995. It had reached 1.64% in 2006, a progression in one year most probably due to the introduction in May 2005 of the renting system in self service, Vélo'V, introduced in the central part of the urban area of Lyon to promote the use of the bicycle not only of leisure but also for utilitarian purposes.

The renting of bicycles in self service (Rent a Bike) is part of a diversity of services offered for the urban practice of the bicycle, some of which are the renting for a short period (a day or half a day), the renting for a long period (a few months), the "gardiennage" or the "vélo-stations". The Rent a Bike facilitates the use of the bicycle by making it easier, more flexible. It permits to the users to take a bike in any station on the territory covered by the service and to bring it back in any other station of the territory. A membership card or a credit card gives access to this type of service. The cost is very accessible for the user. However, the system Rent a Bike may be costly for the enterprise responsible of the service, which, in most cases, needs a complementary financing with publicity (linked to the urban furniture) and sometimes may need public subsidies. JCDecaux and Clear Channel are responsible of the vast majority of ongoing projects. The great advantage of the system Rent a Bike in comparison to the use of a personal bicycle is that it facilitates intermodality since it is not necessary to transport the bicycle in the car, the bus or the metro to use it for the total trip, which favors long trips combining bike-public transportation. Moreover, in many occidental cities, to use the bicycle in the city has become fashionable, and the Rent a Bike enjoys a good image *a la mode*. The social perception of the mode of transportation is important.

Lyon has actually 400 stations distributed on the territory every 300 meters or so, on a good proportion of the areas of Lyon and Villeurbanne. The stock of bicycles is of around 4 000, some of which are under repair. The repair costs (wear, voluntary degradation and thefts) is around 1,000€ per year and per bike (Transflash, 2006). The membership cost is cheap (1 € per week or

ou 5 € per year). For each renting, there is a free period of ½ hour to 1 hour (depending on the type of membership) followed by a paying period (from 0,5 to 1 € per additional hour). Based on Household Origin-Destination surveys of Lyon in 1995 and 1996 we can measure the rapid change in mobility behavior in favor of the mode Vélo'V and general use of the bicycle. These surveys were realized with the standard methodology of the household surveys of the CERTU with respective samples of 13,997 and 27,573 persons<sup>1</sup>. We may note that the perimeter of the last survey was delimited to correspond to the first survey. The results obtained show the strong evolution of the practice of the bicycle in 11 years. Between 1995 and 2006 it has progressed by 124% in the urban area of Lyon.

### *1.1. Who are the cyclists ?*

The population of cyclists, defined as the residents who have used a bicycle for at least one of their trips captured during the day of the survey, is composed of 75% men and of 25% women, in 1995 but also in 2006. This disequilibrium is surprising since the mobility patterns by gender are much more similar now than yesterday. Also, the proportion of cyclists is higher for adults in the age group 30-35 years.

In volume, we notice the importance of workers, whose proportion passes from 41% of the total population of cyclists in 1995 to 59% in 2006, in disfavor of the other categories (students included). In spite of this evolution, in relative terms, it is in the category of students that the practice of the bicycle remains most important (4.7% of the students are cyclists vs. 3.5% of the workers). Between 1995 and 2006, the social composition of the cyclists, measured by the level of schooling, has progressed in favor of the population of higher incomes. The graph 1 indicates that the more schooling, the lower was the practice of the bicycle in 1995 and that by 2006, the tendency was completely reversed. The positions by social categories confirm this tendency with a proportion of executives<sup>2</sup> among the population of cyclists which explodes in 11 years, and passes from 6% to 12% while during the same period the workers (qualified and non-qualified) diminishes from 23% to 15%. This reinforces the idea that the image of the cyclist is important and that it should be positive to favor the use of the bicycle and an eventual modal change from the auto to the bike.

The case study of Lyon shows us that the residents concerned by the practice of the bicycle are today mainly working adults (and to a lesser extent, students), with a high level of education and living in the center. Their living space is one with high residential densities and where we find a concentration of activities.

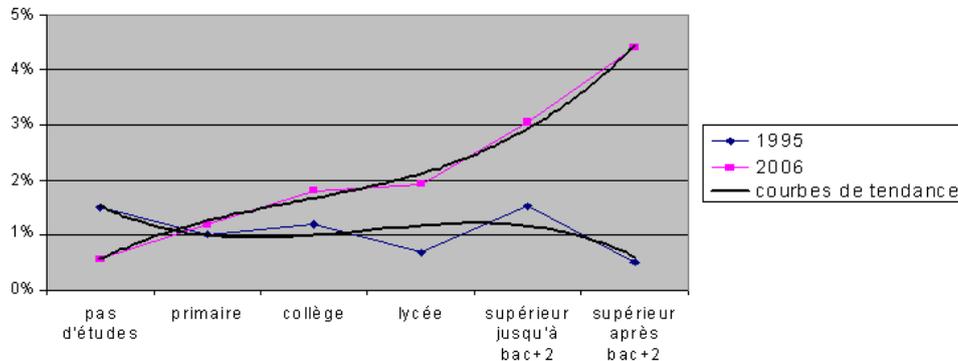
The instauration of the System Velo'V was accompanied by a revolution of the image of the bicycle in Lyon. This is an essential point if we wish a positive evolution of the practice of the bicycle in cities of the South in general, and more specifically in cities of Latin America where the image of the "functional" use of the bicycle is associated with poverty.

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<sup>1</sup> We thank the SYTRAL for their authorization to use data of the 2006 survey.

<sup>2</sup> Executives in the private sector as well as in the public sector.

Grap 1 : Proportion of cyclists by level of education in Lyon, in 1995 and 2006



(without schooling, primary, secondary, high school, university-level 1; university-level 2)

Source : calculated with data of the O-D Household surveys.

## 2. The case of Paris and of other European cities

The City of Paris has implemented its system of Rent a Bike, the Velib', in July 2007. In 2008 the system had already 1,450 stations for 20,600 bicycles and the use of the bicycle has passed from 2% to 3% of total trips. The objective is to attain 4 to 5% in 2010 and 6 to 8% in 2020. As in the case of Lyon, the administration of the system is done by the publicity firm JCDecaux which finances the operation with publicity on the urban furniture. Other formulas are also possible, as for example, in Barcelona where the administration is done by Clear Channel and the financing is assured by the surplus in parking revenue. These systems have spread out rapidly and we can find them now in various European cities: In France: Toulouse, Dijon, Marseilles,...; in Austria: Vienna; in Spain: Barcelona and Sevilla, to give only a few examples.

## III. THE PRACTICE OF THE BICYCLE IN LATIN AMERICA

### 1. The case of Bogota

The City of Bogota has implemented in December 2000 a integral plan of transportation favoring the use of the public transport and non-motorized modes, the STIM (*Sistema Integrado de Transporte Masivo*) known as the *Transmilenio*. This plan included, among other things, the implementation 300 km of cyclo-routes. To these measures other elements were introduced to favor the use of the bicycle such as the day without autos in the center, every year. These policies induced, as shows Table 1, a strong progression of non-motorized modes, which passed from 9% to 13% of total trips between 1998 and 2002. The use of the bicycle has passed from 0.58% in 1996 to 4.4% in 2005, with 2% in cyclo-routes (Suero, around 2005). Policies favorable to non-motorized modes can therefore be efficient even in cities where we would a priori think the contrary. Other examples in Europe, like Barcelona where the use of the bicycle was very low, give similar results.

Table 1 : Modal split, Bogota 1998 and 2002

Mode	1998	2002
Public Transport	72%	73%
Auto	16%	11%
Non motorized	9%	13%
Others	3%	3%

Source : Bogotá ? Como vamos ? (2002), from telephone surveys ; STT (2003), from 7,600 face to face surveys).

## 2. The case of Puebla

Puebla is a mid-sized city of Mexico of 1.3 million inhabitants located 2 hours driving south-east of Mexico City. According to the last Origin-Destination survey (1994), the modal split was the following: auto: 19%, public transportation: 48%, walking: 27%; bicycle: 2%; others: 4%. The demographic context is one of rapid growth (average annual growth between 1.5% and 2%) and individual motorization augments around 3 times that of the population (Bussière, 2005). The modal split of public transport should be around 40% today.

What is the situation of the non-motorized modes – bicycle and walking ? A recent study based on surveys done face to face in various places of the city with a sample of 1,162 persons gives us an idea of the perception of these modes and their potential (Bussière *et al.*, 2008). The surveys were realized between November 2007 and January 2008 with the following distribution, each with a distinct questionnaire : residents of Puebla : 586 ; tourists : 301 ; enterprises : 113 ; informal merchants or *ambulantes* : 99 ; paying parking lots : 63.

Although the best source to obtain the modal split is the household Origin-Destination Survey, without a recent survey, our person to person survey on a sample of persons encountered in public spaces gives us a good idea of the actual modal split, which would be the following: auto-driver 32.4% ; auto-passenger 12.6% ; public transportation: 40.3% ; taxi : 0.3% ; bicycle : 1.9% ; walking : 9.7% ; others : 0.7%. The residents of the Historic Center walk much more with 24% of total trips at the expense of auto-driver, the modal split of the other modes being comparable. We finally have a modal split of non-motorized modes similar Bogota before the instauration of the *Transmilenio* and fairly higher for the bicycle.

The questionnaires administered seeked to measure the opinion on : the implementation of pedestrian zones in the Historical Centre, cycle-paths and a system of Rent a bike inspired on the European example. The answers of the different questionnaires give us an interesting insight on the potential of non-motorized modes if adequate policies were adopted. Firstly, 60% of the residents of Puebla express a dissatisfaction of the actual situation of transportation in the Historical Center. Also, 76% declare using the bicycle. This mode, even though it represents a small proportion of the total trips, stays very present and could have a potential.

The residents of Puebla approve by 76% to transform the Zócalo (Central place) and the neighboring streets in a walking zone ; by 74% to introduce cycle-paths in the Historical

Center ; by 59% to introduce cycle-routes outside the Historical Center; by 68% to introduce a system of renting bicycles with a price competitive with public transportation. At the question: Would you use the bicycle routes? 74% answered yes.

The tourist activity in Puebla is important. The tourists are very favorable for the implementation of policies pro non-motorized : 89% say that they would prolong their stay if the Zócalo (Central Place) and neighboring streets was transformed in a pedestrian zone and if were introduced bicycle paths and a system of Rent a Bike: 22% would prolong their stay one day, 29% two days; 28% three days ; 13% four days or more. A rapid calculation of the economic impact of the daily spending of tourists with a keynesian multiplicator of 1.5 gives us an impact of more than 5 billion pesos annually (around 570 million dollars US at the moment of the study).

What is the opinion of the businesses located in the Center, close to the proposed pedestrian zones? They are also favorable by 59% to make the Center pedestrian and 46% think that these measures will benefit their business. The informal business or “ambulantes” approve by 60% the introduction of measures favorable to non-motorized modes and 81% say that they would respect the public spaces reserved to pedestrians and bicycles. The parking lots of the Center are favorable by 48% for policies favorable to make the Center pedestrian and 59% are favorable for bicycle-routes.

According to this survey it seems that the local population, the tourists and the businesses are very receptive to the introduction of policies favorable to non-motorized modes and that the direct economic impact of such policies would be largely positive due to the importance of the tourist activity in Puebla, without taking in account other positive impacts such as decongestion, a better air quality and, finally, a better quality of life.

### **3. The case of Monterrey**

Monterrey is a northern city of Mexico of 3.7 million inhabitants, located at 230 km south of the US border. Due to this proximity to US, we find a higher level of motorization than in southern cities with the following modal split, according to the Origin-Destination Survey of 2005 auto-driver : 23.8% ; auto-passenger : 12.8% ; public transportation: 43%, transport of personnel by firms: 2.1% ; school transportation : 1.4% ; taxi : 6.3%, bicycle: 0.8%, walking and others : 10%,

Based on two surveys realized during the autumn of 2008 (LOGIT, 2009) on users of public transportation: one on 300 users of public transportation, the other 1 514 car drivers.

From the first survey on users of Public Transportation, 75% of the respondents are favorable to an intermodality between public transport and the bicycle with a possibility of parking and 58% declare that they would use it. Women are more favorable than men for this type of intermodality (78% vs. 74%) but slightly less favorable to use it (65% vs. 44%).

The second survey, gives the following results. Firstly, 95% of the car drivers say that they would use the new system of public transportation (a proposed line of Bus Rapid Transit) if it was modern, rapid, with air conditioning and if it would reduce the time of travel, at the condition however that the waiting time does not increase, or the proportion decreases to 65%. 91% of the car drivers are favorable to the implementation of cyclo-routes and incitative parkings with little gender differences. To the question if they would use the system, the level of

approbation is high but men are more favorable (85%) than women (76%). We find here a gender difference similar to Lyon but less pronounced.

These results show clearly that the population, the users of public transportation or car drivers, are open to policies favoring the use of the bicycle and an intermodality bicycle-other modes.

#### IV. BICYCLE USE AND GLOBAL WARMING

These examples of Latin American cities which show a potential for the use of the bicycle like Bogota, Puebla or Monterrey incite us to try to quantify the impact of the use of the bicycle on the reduction of CO<sub>2</sub> emissions. The estimations which will follow are based on our own calculations with data collected locally and from scientific studies. Our objective is not to give an exact estimation of CO<sub>2</sub> emissions as attempts to do the National Institute of Ecologia of Mexico. This institute applies for Mexico the models developed by the U.S. Environmental Protection Agency (Eastern Research Group, 2000). These methods are applied to case studies, for example quantify the impact of the implementation of a BRT in Mexico, the *Metrobus* (Instituto Nacional de Ecología de México, 2006). Let us not forget that the results of a model, even the most sophisticated, will depend on the initial calibration and that in this area we often lack of exact data. Our objective here is to give an idea of the magnitude of the possible reduction of CO<sub>2</sub> emissions due to non-motorized modes.

After a brief presentation of the context of CO<sub>2</sub> emissions in Mexico, we will present the main results of the reduction of CO<sub>2</sub> emissions which could induce the use of the bicycle in Puebla in 2005. Furthermore a scenario of growth of the proportion of the use of the bicycle will be applied over a period of 15 years and we will present an estimation of potential reduction for the year 2020 in a context where policies favorable to the bicycle were adopted. Finally, from the results of the survey in Monterrey on intermodality Bike-Public transport, we will present a simulation of the possible impact of such a practice based on the data of the City of Puebla.

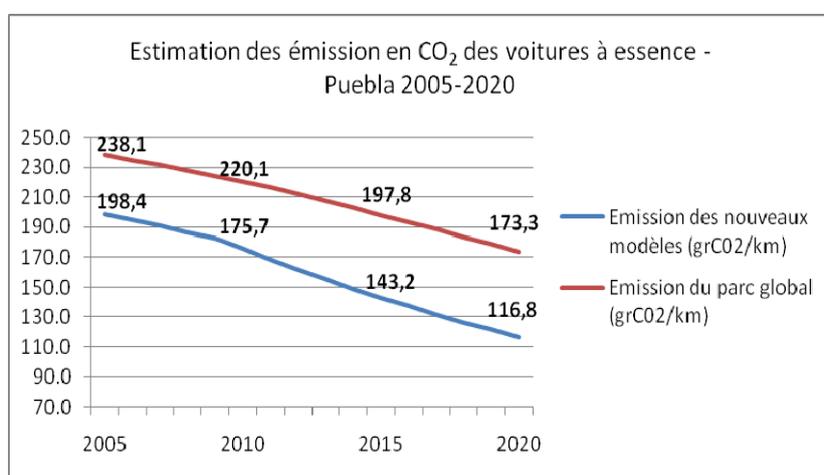
Mexico had global emissions of 553 Mt CO<sub>2</sub>eq of GHG in 2002 (Instituto Nacional de Ecologia de México – Secretaria de Medio Ambiente y Recursos Naturales, 2002) and the country has since exceeded the level of 600 Mt CO<sub>2</sub>eq. This positions Mexico in tenth position of countries emitting CO<sub>2</sub> gases in volume (Blodgett, Parker, 2008). The sector of transportation represents approximatively 20% of the emissions with 114 Mt CO<sub>2</sub>eq in 2002.

The main data used in our study is based on the automobile fleet of Puebla; this data is available at the Department of Transportation and Communications of the State of Puebla (Secretaria de los Transportes y de las Comunicaciones del Estado de Puebla , 2006).

The methodology used is based on a Canadian study (Bussière, Bernard, 2000) realized for Vélo Québec. The method consists, at first to calculate the emissions of all modes of transportation in Puebla, then to quantify the practice of the bicycle and the impact that would have generated the trips made in bicycle if they had been made by bus, lighter public transportation (*combis*), and automobile with the hypothesis that for each mode, supply adjusts to the level of demand. The base year chosen is 2005, corresponding to the year for which we have a complete overview of the motorized fleet of Puebla. For each year until 2020 we applied growth rates of different categories of vehicles according to socio-demographic trends. Once the motorized fleet projected, we calculated the emissions of CO<sub>2</sub> for each category of vehicles, a

total of 11. This was done taking into account the level of emissions in 2005 for Mexico for each category according to new vehicles. To obtain a global level of emissions (new and old vehicles) we calculated for each year a level of emissions for new vehicles based on the precedent year with a correcting factor to take in account the technological progress. We supposed a rate of renewal of the automobile fleet of 8% per year and an improvement in technology (or annual diminution of emissions of new vehicles) of 2% between 2005 and 2010, and of 4% between 2010 and 2020. The progressive improvement of emissions of new vehicles seems to have a slow impact on the emissions of the total fleet: according to our model, the emissions of the total fleet were 238,1 grCO<sub>2</sub>/km and that of the new vehicles was of 198,4 gr CO<sub>2</sub>/km in 2005, which leads us, respectively to 173,3 grCO<sub>2</sub>/km and 116,8 grCO<sub>2</sub>/km (graph 2) in 2020.

Graph 2 :Estimation of emissions of CO<sub>2</sub> of automobiles (gasoline) in Puebla 2005-2020.



Note: Emissions of new models and global park. Source : Own calculations.

In the calculation of the practice of the bicycle we did a repartition of « utilitarian » activities and « leisure » activities and distinguished between week-day activities and weekends and holidays. This distinction permits to transfer the cyclist activity towards 3 modes (Auto, Public Transport-Bus, Public-Transport-light) with different coefficients (we used: transfers of the bike utilitarian practice: 30% towards Auto and Public Transport; transfers of the bike leisure practice: 50% towards the Auto and 25% towards Public Transport). The initial modal split of the bicycle was 1.5% of total trip in 2005. It has been set in 2020 at 4% in a first scenario, and at 8% in a second scenario.

Table 2 summarizes the main results of the estimation of the emissions of CO<sub>2</sub> in Puebla due to the cyclist practice in 2005 and 2020 in a scenario where the modal split of the bicycle augments between 2005 and 2010 from 1.5% to 4.0% of total trips. This practice permits the economy of 27,901 tons de CO<sub>2</sub> en 2005 et de 52,545 tons of CO<sub>2</sub> in 2020, that is, 24,644 supplementary tons with the modal split of 4%. Compared to the emissions of CO<sub>2</sub> emitted by urban traffic in Puebla these figures represent respectively 2.0% and 3.4% of the total, excluding the trucking activity, that is, around 0.4 % to 0.68% of total emissions of CO<sub>2</sub>.

Table 2 : Reduction of CO<sub>2</sub> emissions of public transportation due to the practice of the bicycle in Puebla 2005 and 2020 (scenario at 4% in 2020)

	Unities	2005	2020
Modal split of the bicycle	%	1.5	4.0
Cyclist activity	<i>cyclists.km</i>	158 571 747	514 858 060
Cyclist activity - utilitarian	<i>cyclists.km</i>	63 670 793	206 729 267
Cyclist activity - leisure	<i>cyclists.km</i>	94 900 954	308 128 793
Rate of emissions CO <sub>2</sub> for the automobile – gasoline	<i>gr CO<sub>2</sub>/km</i>	238	173
Rate of emissions CO <sub>2</sub> for bus – by passenger	<i>gr CO<sub>2</sub>/km</i>	102	60
Rate of emissions CO <sub>2</sub> for light public transport - by passenger	<i>gr CO<sub>2</sub>/km</i>	75	55
Emissions of CO <sub>2</sub> generated if the cyclists would have partially used the automobile*	<i>Tons CO<sub>2</sub></i>	21 908	37 455
Emissions of CO <sub>2</sub> generated if the cyclists would have partially used the bus*	<i>Tons CO<sub>2</sub></i>	4 103	8 366
Emissions of CO <sub>2</sub> generated if the cyclists would have partially used light Public Transportation*	<i>Tons CO<sub>2</sub></i>	1 890	6 725
Total emissions due to a transfer of the cyclist activity on the three modes	<i>Tons CO<sub>2</sub></i>	27 901	52 545
Total emissions of transportation in Puebla	<i>Tons CO<sub>2</sub></i>	1 773 620	1 979 941
Total emissions of transportation in Puebla without trucking	<i>Tons CO<sub>2</sub></i>	1 385 078	1 557 877
Reduction of emissions without trucking due to the cyclist practice during the week	%	0.7%	1.0%
Reduction of emissions without trucking due to the cyclist practice during the weekends and holidays	%	1.3%	2.4%
<b>Reduction of emissions of CO<sub>2</sub> of urban transport without trucking</b>	%	<b>2.0%</b>	<b>3.4%</b>
Reduction of emissions of CO <sub>2</sub> of urban transport	%	1.6%	2.7%

\*Note: The rates of transfer towards the automobile, the bus, and the light public transport used were respectively: 0.7; 0.2; 0.1 for the utilitarian cyclist activity and of 0.5; 0.25; 0.25 for the leisure activity.

Despite of a proportion of cyclists which has more than doubled in percentage, the proportion of the total reduction of emissions due to the practice of the bicycle has progressed by only 70% between 2005 and 2020. This is due essentially to the increasing motorization taken in account in the model.

Other scenarios permit to measure the amplitude of possible impacts of the practice of the bicycle on the reduction of CO<sub>2</sub> gases. Thus if the modal split of the bicycle reaches 8% instead of 4% in 2020, a rate that many European cities have already attained or surpassed, the reduction

of CO<sub>2</sub> induced in proportion of the emissions of urban transport passes from 2.7% to 5.3%, an equivalent of 1.1% of total sources of total emissions, which is far from being negligible.

Also, given the results very favorable to intermodality Bike-Public Transport of the opinion survey of Monterrey, we thought useful to try to approximate the impact of policies promoting this practice on the augmentation of the use of Public Transportation, based on the data of Puebla. With the same model we calibrated the impact of a change in modal split in favor of Public Transportation with the hypothesis that 15% of the trips made by cyclists would lead to a transfer towards Public Transportation from Auto with average trips of 15 km in Public Transportation. In a scenario where the modal split is 4% for the bicycle, we obtain a transfer of 0.6% of total auto demand towards Public Transportation (scenario 1) and in the case of a scenario where the modal split of the bicycle is 8% we obtain a transfer of 1.2% (scenario2).

The impact of scenario 1, trucking excluded, gives an additional reduction of CO<sub>2</sub> emissions of 1.14%. If we add the various cumulative effects, the total impact becomes important. Thus, for example, the cumulative impact of a modal split which would 1.5% to 4.0% and a modal transfer of 0.6% in favor of Public Transport from the autos would give a total impact of 4.9% of emissions of CO<sub>2</sub> caused by urban transportation of persons (3.8% with trucking) and of 1.0% of total emissions. The scenario 2, with a modal split of 8.0% in 2020 and a transfer of 1.2% towards Public Transport would give an impact of 9.0% of urban transportation of persons (8.2% with trucking) and of 1.8% of total emissions.

Although these results may vary in function of the rate of occupation of autos and of Public transportation, they show that the potential benefits of the use of the bicycle in the city are important.

## V. CONCLUSION

The European experiences show undeniably that the bicycle is a viable option in mid-sized cities and also in metropolises as in Paris. The transportation policies of the sixties centered only on motorized modes are now outdated and the city planners are searching solutions to have more friendly cities for the non-motorized trips.

In Mexico, based on the example of Puebla, which could be to a large extent, representative of a mid-sized city in Latin America, we can conclude that the population is largely open to the implementation of policies favorable to the use of the bicycle in the denser parts of the city, the historical centers, but also, as seen in the example of Monterrey in corridors of massive transportation where the bicycle could be used as a mode of intermodality with public transportation if appropriate measures were taken, such as safe parking stations for bicycles at the principal stations of Public Transportation. Even though various cities of Mexico are sensibilized to the practice of the bicycle in the city, we will need maturing of the idea and that pro-bicycle measures be an integral part of urban transportation planning.

In the paradigm which we presented an estimation of magnitude of the reduction of emissions of CO<sub>2</sub> due to urban transportation, induced by the practice of the bicycle gives us a reduction of 3% of urban transportation of persons and of 0.7% of global emissions in medium scenarios of the practice of the bicycle for utilitarian and leisure purposes. If we add the indirect impacts due to a modal shift favorable to Public Transportation in a context of measures favorable to intermodality Bicycle-Public Transport, the impact could reach close to 5% of urban emissions and 1% of global emissions in medium scenarios and, respectively 9.0% and 1.8% in

more extreme proactive scenarios. In terms of impact on global warming, the effect is thus perceptible and policies favorable to the use of the bicycle in the city appear to be one of the many measures possible which will be necessary to attain the objective of a reduction of global emissions of GHG. Furthermore, these policies, according to various experiences have other positive effects such as a better quality of life in the city.

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