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ACCESSIBILITY TO WORK BY PUBLIC TRANSIT AND ITS SOCIAL DISTRIBUTION IN LILLE, FRANCE

AN EQUITY APPRAISAL

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In this paper, we develop a proxy measure to appraise equity in urban mobility policy by applying the theoretical framework of Martens (2011). Using the commuting trips database of 2006 on the large Lille urban area, and geo-localized employment data from the French Census of 2010, we compute an indicator of the spatial accessibility to work by public transport (PT) at the municipal level, as the "good to redistribute". This allows to identify the municipalities the most lagging behind in terms of PT travel time to reach the average "potentially accessible job market". Then, starting from general observations on social differences among commuters for accessing to the labor market, we aggregate this indicator at the scale of commuter groups – by gender, educational background, socio-professional category, immigration status and household structure. Lastly, we simulate the reduction of PT travel times to work by successively 20% and 40% from the least served communes and we analyze the effects at the stage of travelers groups (i.e. "members of the society"). Interpreting results in the light of the sufficiency approach (i.e. the retained "yardstick rule"), we conclude that only transport-oriented policy is not the panacea to address equity and that cross-sectoral solutions are needed

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1. Introduction

Although no consensus has been found for defining the concept of equity in the mobility sector (COST Action TU 1209, 2014) it is common to mention equity in transport planning documents (Foth *et al.*, 2013). Recommendations for appraising the economic, social and/or territorial implications from a transport project, and thus revealing equity issues, are often specified in reference texts for transport policy evaluation.

According to the European Commission (European Commission, 2013a), urban transport systems should seek to "(a.) [be] accessible and meet the basic mobility needs of all users; […] meet the requirements of sustainability, balancing the need for economic viability, social equity, health and environmental quality". Hence, the sufficiency of the urban transport system accessibility *vis-à-vis* of the needs of users appears to be a priority in European policy guidelines. We have adopted it as a central perspective in this paper.

In France, the social and territorial components of equity are specified in reference texts (for example in CGSP, 2013). One of the proposed indicators for appraising equity is the ratio between the total surplus created by a transport project in the zone (ex. time gains, pollutions cost savings, etc.) and the total income of users in this particular zone of impact. To deal with fairness, a special attention is recommended to be paid to the initial rent situation of individuals, for instance when the transport network is structurally servicing more certain categories of individuals than others.

At the frontier between the manifold dimensions of equity and theories of justice to evaluate transport policy, we lead our analysis under the theoretical framework of Martens (2011). Indeed, according to the author, if the good at focus is 'socially distinct' it is worth carrying the equity appraisal under a specific 'sphere of justice'. Following his approach, we try to answer to three questions to appraise equity in transport policy: "1. Which 'goods and bads' or benefits and costs should be at the focus of the equity analysis? 2. How should the 'members of society' be conceptualized, i.e. which population groups should be distinguished? and 3. What constitutes a 'morally proper distribution', i.e. which yardstick rule or distributive principle should be used to determine whether a particular distribution is fair?".

To apply this framework, we consider the urban community of Lille metropole, in the Northern part of France. This territory is interesting to appraise equity effects in transport policy since it presents the particularity to have a multipolar form and rather heterogeneous characteristics of its population.

The remainder of this paper is organized as follows. In section 2, we justify our choice to retain the accessibility to work by public transport (PT) as the 'good' at focus, and the sufficiency approach as the 'yardstick rule' to judge about the fairness of its distribution among the different categories of commuters (the 'members of society'). We also illustrate how those questions are usually apprehended

in empirical studies. Then, we construct an indicator of the accessibility to work by PT in the metropolitan area of Lille. Background information on the case study, description of the data and methodology are presented in section 3. Results are shown and analyzed in section 4. Section 5 discusses ideas for further researches and Section 6 concludes.

2. Potential accessibility to jobs by public transport: the 'socially distinct good' to redistribute among the 'members of the society'

2.1. What means public transport accessibility to jobs and to which extent can we talk about a 'socially distinct good'?

2.1.1. What is public transport accessibility to jobs and what it is not?

Hansen (1959) belongs to the first authors who defined public transport accessibility as the amount of *potential* attractive opportunities that can be reached at desired destinations, such as shopping, school, or work thanks to the design and quality of the public transit system. His indicator (see in equation 1 below) is one of the most popular metrics in empirical studies on PT accessibility. The contribution of gravity-based models (e.g. Harris, 1964; Erlander, 1980) consisted then in adding to these positive factors of potential interaction between two places the negative one of travel impedance (Liu and Zhu, 2004). In equation 1 below, *Ai* denotes the accessibility of the region of origin *i* and *j* represents the regions of destination. Then, $f(C_{ij})$ materializes this impedance function and is generally specified with an exponential or power term to give a higher cost or time weight to far out opportunities Oj. The impedance function will for example count as one an opportunity at zero distance (when C_{ij} is lower than "x") and as zero, a very distant one (when C_{ij} is higher than "x"). When such a time or cost threshold "x" is introduced in the formula, the accessibility equation encompasses an *isochronal* definition[1].

$$Ai = \sum_j Oj \,.\, f(Cij) \qquad (1)$$

If those accessibility indicators may appear rather empirical, cases-specific and difficult to generalize for policymaking on equity, Koenig (1980) draws attention on their solid welfare economics

[1]According to Hansen (1959), isochronal measures give the number of opportunities that could be reached within a given time.

fundaments. That the first part of the equation[2], Oj, provides a measure of the activity participation to key out-of-home activities allowed by the transport network is another sign of theoretical roots of the metric. In this regard, Martens (2014) states that measuring the degree of activity participation to e.g. jobs, health services and education allowed by the transport system's accessibility (ex. the number of locations a person can reach within a particular time) is a good proxy for equity appraisal.

Conceptually speaking, accessibility is to be distinguished from the notion of *availability* that is a simple measure of the distribution of the supply and demand for the services; and *mobility*, i.e. the ability of movement between different places (Morris *et al.*, 1979; in Foth *et al.*, 2013). Accessibility can also be declined into several dimensions: *revealed* versus *potential* accessibility, respectively referring to the case of an actual/probable future use of the services; and *spatial* versus *a-spatial* accessibility, the former highlighting the importance of the 'distance' variable (as a barrier or a facilitator), whereas the latter stresses nongeographic barriers or facilitators (such as social class, income, ethnicity, age, sex, etc.).

Moreover, *access* to the PT network refers to the opportunity of using the services (e.g. proximity to nearest stops) and also differs from accessibility (Murray, 1998). *Affordability* specifically concerns the cost of using transport services and is to relate to individual budgets. On the latter, Jansson (1993) and Olvera *et al*. (2003) talk about an a-spatial component of PT accessibility.

Thus, by measuring the *potential accessibility to work by PT* we seek to analyze the suitability of the public transport network to get individuals from their system entry point to their desired system exit locations in a reasonable amount of time.

2.1.2. Public transport accessibility as a 'socially distinct good to redistribute'

Firstly, modal shift and in particular the increase of the PT patronage generally belongs to the top priorities of urban mobility plans of French agglomerations (Didier and Prud'homme, 2007) for reducing negative externalities from car use. Besides, PT use generally accounts for the largest modal share at the urban mobility scale[3]. Hence it makes sense to appraise equity at the stage of public transport.

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[2] The accessible opportunities at destination, Oj, will be at the numerator of the accessibility indicator if the function $f(C_{ij})$ in the equation 1 presented before has a negative exponent. In that case, the opportunity cost or time to reach those opportunities at destination, C_{ij}, would be at the denominator of the accessibility indicator.

[3] For instance PT use is twice as high as car use in Paris region in 2008 in terms of number of trips (CGDD, 2010).

Then, as claimed by Macario (2014), two essential values can be recognized to PT accessibility: an economic value (land value capture); and a social/equity value (social integration factor). On the latter, by servicing precarious workers who do not have access to reliable private cars, the PT system notably participates in the reduction of poverty, unemployment[4] or can at least address an uneven access to the job market. Besides, the ability of the PT system to move people from their origin points to their preferred destinations makes it an essential urban utility:

"Accessibility measures are capable of assessing feedback effects between transport infrastructure and services, urban form and the spatial distribution of activities. It is thus inevitable that accessibility is used as a measure of quality of living […] due to its impact on social activities" (Macario, 2014).

To measure this capacity of the PT system to meet people's needs in terms of attractive activities at preferred destinations and hence to give an indication on its accessibility degree (Foth *et al.*, 2013), empirical studies usually consider: the number of jobs (desirable or attainable according to different individual-based criteria; Foth *et al.*, 2013), health care services (Luo and Wang, 2003), social activities (Allard, 2004; Talen, 1997 for parks; Talen and Anselin, 1998 for playgrounds), and other urban opportunities (Kwan, 1999)[5].

The potential accessibility to work by PT having been defined as 'the good to distribute', the next questions to appraise equity deal with its social distribution – that is to say, among which population segments to distribute it? And according to which allocation rule?

2.2. Social distribution of the potential accessibility to work by PT

2.2.1. Most commonly encountered social differences to access to the job market

To begin with gender differences, it is recognized that "transport and availability of social services are not equal for men and women. As a consequence, there are inequalities in access to the job market and limitations to women's participation in economic growth" in the report from the European Commission (European Commission, 2014). Therefore, it seems that women might express, a priori, a higher need for accessibility to jobs by PT than men.

Social differences and their implications for transport equity are also observable at the stage of the

[4] It is important to underline here that physical mobility is also a condition to job access, before PT quality of service of PT.

[5] In Delmelle and Casas (2012).

educational level and the socio-professional status. For example, the American report of Brookings (Brookings, 2012) identifies important geographical skills mismatches in several metropolitan areas in the USA, characterized by regions where both the unemployment rate but also the share of skilled individuals is high and persistent; and on the contrary, by regions where the unemployment rate is low but coexists with large shortages of educated workers relatively to employers demand. The authors conclude that these "education gaps" could be partly due to a low public transport availability and efficiency in those regions, which hampers the mobility of e.g. educated people towards high-skilled employment centers. A case study conducted in Hungary (OECD, 2014) reveals similar results for Europe, with significant labor market mismatches and insufficient mobility levels of the high- and low-skilled workers via the transport system, which penalize employment and productivity in certain domains.

Then, dealing with ethnics and social gaps between immigrants and non-immigrants population, the European Commission (2013b) finds evidence that immigrants face discrimination on the labor market in Europe: "immigrants are less likely to be hired even when their qualifications are similar to non-immigrants […] and immigrant students are less likely to be referred to higher track education even when their grades are similar to the performance of non-immigrants. […] In addition, immigrants are overrepresented in low-skilled sectors such as construction, accommodation and food services and under-represented in high-skill jobs including the public sector". On the top of that, the competition effect and hence the higher skill-demanding conditions for immigrants on the labor market have led to increase the risk of over qualification for highly-qualified immigrants. Similarly, Ihlanfeldt and Sjoquist (1998) highlight the problem of a worse access to jobs for the black population than for the whites in American cities. Analyzing further the role of transport system in such mismatch on the jobs market, the authors state that "*the problem isn't space*[6]*. It is race*".

At last, at the stage of the household type, recent research papers show that single mothers for instance commute over short distances to their jobs than single fathers (ITS Berkeley, 2002). Hence, they could be (hastily) considered as the most beneficiary recipients from the welfare distribution of public transport services. However, this result might be the consequence of constraints imposed to women. Indeed, single mothers opt for workplaces the closest to residence and for car use, in order to avoid long reverse commutes by bus because of childcare and household responsibilities (ITS Berkeley, 2002). Therefore, new policy programs that more fully incorporate the particular travel needs of women with children should be developed, such as transport on demand services (European Commission, 2014).

[6]Indeed, young workers are sufficiently fluid in their commuting patterns to overcome "space" factors, i.e. any problems arising from an absence of nearby jobs or from inefficiencies in the PT network.

Led by these general observations, we retain gender, educational background, socio-professional category, immigration status and household type for classifying the groups of commuters. In the next paragraph, to judge about the fairness of the distribution of the potential accessibility to work by PT between the classes of commuters, we go beyond the most frequently used utilitarian framework and we explore the sufficiency approach.

2.2.2. An extension of the sufficiency rule to allocate the potential accessibility to work by PT among the commuters groups

Egalitarism finds its origin in the theory of social choice (Arrow, 1951)[7] and is in the wake of horizontal equity: it assumes that a uniform distribution of transport services over distances, densities, customer types, etc. should prevail and that differences in people's well-being should be annihilated. The egalitarian approach, beyond being more costly (everyone should be equally well-off, regardless of their initial situation), seems to offer narrow conclusions for evaluating transport systems equity. Indeed, as cities naturally develop centers and peripheries, it is unavoidable that residents will have unequal access to opportunities (Martens, 2012).

Then, the *Utilitarian theorem* developed by the Marginalist school (e.g. Harsanyi, 1982) is the allocation rule the most commonly used in policy evaluation. It stipulates that the scarcest goods should be allocated to the individuals who contribute the most to the welfare maximization.

But what constitutes a 'morally proper distribution' of the public good can also be approached by other frameworks, such as these of the *sufficiency* approach (Meyer and Roser, 2009; Rock *et al*., 2014) and the *capability-centered* approach (see Sen (1982) for a first contribution on this topic and Baujard and Gilardone (2014) for a review). The former can be assimilated to vertical equity[8] and consists in supplying demanders with transport services "decently", i.e. accordingly to their social advantages or disadvantages. The latter aims for a situation in which "all people [are] equally assured of the basic capability (real or effective freedom) [to a "good enough" level] to function in important valuable ways" (Sen, 1982).

This way, a mix between the sufficiency and the capability approaches appears as a better candidate than utilitarism to capture the wider values of transport for the society. Retaining this enlarged sufficiency rule in the next section, we construct an indicator of the potential accessibility to work by

[7] In Wistrom (2002).

[8] According to Musgrave (1990), "*vertical equity calls for an appropriate differentiation among unequals*".

PT per category of commuters. We simulate shorter commuting times to work by PT from the regions of the territory the least served, and we verify whether this policy scenario does benefit the most to the vulnerable categories of commuters.

3. Method and data

In this section, we present the study area, methodology and data used to measure the potential accessibility to work by PT in the metropolitan area of Lille on the one hand; and to simulate shorter connecting times to work by PT from some specific parts of the territory, with the lowest accessibility levels, on the other hand.

3.1. Study area

The Urban Community of Lille Metropole (*LMCU* in French), in the Northern part of France near the Belgian border, is the fourth largest city. LMCU counts 85 districts for a total area of 611.45 km^2 and a total population of 1,107,861 inhabitants in 2006. It has a multipolar structure with two main urban poles, Lille and Roubaix-Tourcoing. The area at focus is characterized by a share of diesel vehicles lower than the national average (due to the slower pace of the vehicle fleet renewal and therefore the delayed arrival of diesel cars), but which has significantly increased over the last two decades (see for example Hivert, 2013). The financial situation of LMCU residents is rather heterogeneous, with an average of €15,000 per year at the observation period at focus. The gross disposable income in the Nord-Pas-de-Calais region is the lowest of France, and coexists with a tiny share of very wealthy population (Ministère de l'Economie et des Finances, 2013).

The design of the public transport system in 2006 reveals axes of the territory that are less covered by tramways, metros or buses stops, notably at the south-west, south-east and north-west of the LMCU (see Figure 1).

If spatial gaps seem to exist in terms of transport accessibility to urban centers, equity goals have accompanied the development of the network since 2000. Indeed, beyond the general objectives of "promoting alternative modes to car" and "strengthening the public transport supply", among other environmental and social policy targets (LMCU, 2000), the policy targets we focus on (accessibility and equity) are listed in the fourth part of the urban mobility plan of June 2000 called "the synergy evolution of urban activities and the transport system". This part notably includes the planned development of new urban activities nearer to the available integrated public transport facilities (i.e.

main metro, light rail and rapid transit lines), the re-qualification of derelict districts notably thanks to improvements on the metro lines, the creation of bus lines with rapid transit (BRT development over a 60km-lengh network), and the reform of the public transit system pricing (with cheaper tickets and specific to small trips).

3.2. Methodology: construction of our accessibility indicator and simulation of policy scenario

3.2.1. Computing an indicator of the potential accessibility to work by PT

Inspired by the equation of Hansen (1959) presented in the previous section, herein we give a measure of the "jobs per minute" that are accessible by PT from the different municipalities of the LMCU. Besides, to focus on the sum of jobs at destination – representing the numerator of our accessibility indicator – comes from the fact that the labor market policy is a hot topic in the political agenda of our study area (see the report of CETE-NP (2013)). At the denominator of our accessibility indicator, we calculate the potential generalized times by PT (i.e. the connecting travel times, waiting and walking time to nearest PT stops, etc.) to reach those jobs, as done in Delmelle and Casas (2012). For this, we reconstruct the travel times by PT between the origin and destination nodes of the observed commutes using the shortest path calculator Musliw developed by CETE-Nord Picardie (CETE-NP, 2011).

Once the accessibility indicators computed at the municipal scale, those are aggregated by travelers groups, in order to obtain an indication of the "jobs per minute" specifically for men and women (as in Geurs and Wee (2004)), for high and low professional and educational levels (as in Moos and Skaburskis (2010)) for immigrants/non-immigrants (see Omer (2005) for a similar sorting) and for different types of household structure of the commuter (as done in Foth *et al*. (2013)).

For the policy simulation in the next paragraph, we come back to the accessibility indicators detailed at the municipality stage. At this scale, the software Musliw models the commuting times by PT to access the jobs in any municipalities of work from any municipalities of residence. For this, starting from the employment data described at the scale of the municipalities of work, we sum the jobs per municipality. We weigh the average commuting times to access the municipalities of work by the jobs existing in the municipalities, in order to account for the real distribution of jobs over the territory, and we obtain a mean commuting time of 77 minutes on the LMCU.

Now within this time threshold of 77 minutes, we cumulate the number of jobs that can be reached

from any particular points of the territory: we obtain 249,361 jobs[9] "potentially accessible". This is what we call the *average potential job market*. It corresponds to the mean size of the employment center that is theoretically reached on average among the simulated commuting trips in the LMCU. We retain it as the threshold to set. We look then into the matrix of cumulated jobs per threshold of time of 10 minutes[10], and for each municipality of residence, from which travel time the jobs threshold of 249,361 is met. By linear approximation, we obtain a new table with the corrected average commuting times. The average corrected commuting time, among all the municipalities of residence from the LMCU, is of 82 minutes (to meet the 249,361 jobs).

The 37 municipalities of residence for which the corrected commuting time is superior to this average of 82 minutes are: Armentières, La Bassée, Beaucamps-Ligny, Bousbecque, La Chappelle d'Armentières, Comines, Deulémont, Emmerin, Ennetières-en-Weppes, Erquinghem-le-Sec, Erquinghem-le-Lys, Escobecques, Fournes en Weppes, Frelinghien, Fretin, Gruson, Hallennes-Lèz-Haubourdin, Halluin, Hantay, Herlies, Houplines, Illies, Leers, Marquillies, Neuville-en-Ferrain, Péronne-en-Mélantois, Premesques, Quesnoy-sur-Deule, Sainghin-en-Weppes, Salomé, Santes, Vandeville, Warneton, Wavrin, Wervicq-Sud, Wicres and Don. They are circled in red in the Figure 2 and the "needed time adjustments" in percentage to catch up with the average of 82 minutes is also indicated.

The policy simulation in the next paragraph concerns those municipalities as their travel time to reach the *average potential job market* is higher than the average.

3.2.2. Simulating shorter travel time to work by PT from the municipalities with the lowest accessibility indicator

The municipalities the "most in need" having been identified above, we simulate a reduction of the PT travel time from those, of 20% and then (independently) 40%. The drawing of this policy scenario results from discussions with Lille Metropole and could take the form of the creation of transport-on-demand services, BRT with reserved lines, or of an extension of one of the metro lines for instance in practice.

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[9] More precisely, 249,361 jobs are reached if we do the arithmetic mean of the jobs accessible at less than 77 minutes and at more than 77 minutes.

[10] Travel times are usually analyzed by thresholds of 5 or 10 minutes in accessibility analyses.

Simulation results are then analyzed at the aggregated scale of the pre-identified social groups of commuters, in order to verify whether the categories that have benefited the most from the measure in terms of accessible "jobs per minute" gained (expressed in percentage changes) were also the most vulnerable ones – hence respecting the sufficiency approach.

3.3. Description of the working population

Geo-referenced data on employment come from the national Census of 2010. From the preliminary descriptive statistics analysis, we observe that high-skilled jobs are more numerous than low-skill jobs on average on the territory (more than 75% of the jobs in the LMCU are high-qualified jobs), and that the male-occupied jobs are almost equal to female-occupied jobs. We can expect from this distribution that the gap between men and women in terms of accessibility to work by PT will be mostly explained by the denominator of the ratio, i.e. the connecting time to work by PT.

Among the professional trips censed at the departmental level[11], we select the commutes departing to and from the communes belonging to the LMCU, which are 385,792 trips collected in 2006. We draw up in what follows the socio-demographic characteristics of the trip-makers.

Gender parity is respected in the sample. Contrarily to women, men are mostly located at the fringe of the LMCU, particularly to the North and North-West of the territory. Employees are dominating in our sample, representing a third of the respondents, and are rather equally "distributed" over the territory. Both upper and lower socio-professional categories are over-represented in our sample compared to national average at the time of the observation. The commuters with the highest diploma, i.e. with a second and third cycle university degree representing the main part (20%) of our sample. This time, high qualified commuters are over represented in our sample whereas low qualified commuters are under-represented compared to national average. We notice that those possessing French Baccalaureate ("Bac") or higher diploma are mostly concentrated in central communes and prized residential areas contrarily to their counterparts. Immigrant commuters represent less than 8% of the surveyed population, which is pretty much the same share as their proportion at the national scale. At last, working parent commuters are overrepresented compared to national average, making more than the half of the sample; whereas lone parents and single commuters are much lesser represented.

[11] Commutes from the Department Nord (59) are available in the database MobPro 2006 from Insee.

4. Results

4.1. Reference situation: higher potential accessibility to work by PT for the "socially most served"

The disaggregated accessibility indicators presented in Table 1 give a measure of the "jobs per minute" accessible by PT per type of commuters. Depending on the category of travelers at focus (men or women, single men or single women, lone father or lone mother, etc.), the column 'average number of jobs' alternatively reports the average of the total number of jobs censed in the municipalities of work, the average of the high/low-qualified jobs (ex. high qualified for senior executives) or the average of the male/female-occupied jobs (ex. female-occupied jobs for lone-mothers) in the municipalities of work.

We conclude that the highest accessibility indicators, as an effect of having the highest mean jobs accessible or the lowest mean commuting time by PT, are observed for the "socially most served":

The highest score of all categories to the accessibility indicator is observed for the commuters possessing the 'French Certificate of general education (brevet)', with 1,068 "jobs per minute" (jobs/min). They are followed by 'Working parents' (926 jobs/min), 'Non-immigrants' (925 jobs/min), 'Employees' (872 jobs/min) and 'Women' (517 jobs/min). Hence, those categories are also the most 'served' socially.

More precisely, to start with the gendered accessibility indicators, women demonstrate both the highest number of jobs accessible and the lowest commuting times to go the work compared to men. The former can be simply attributable to a higher proportion of female-occupied jobs in the municipalities of work that are the most frequented by female commuters. The latter confirm previous findings from the literature according to which women tend to travel shorter distances for professional trips (Predali, 2004), and to dwell closer to workplaces, due to a more complex mobility patterns than men in general (notably due to the accompaniment of children, trip-chaining and shopping purposes, less flexible working hours, etc.). Yet, a higher accessibility indicator for women is not necessarily synonymous of a good response of the PT system to their specific needs.

Then looking at the breakdown by SPC, intermediate professions correspond to the class with the highest number of qualified jobs available, and craftsmen and employees to the professional occupations with the lowest commuting time. The former is probably to relate to a size effect of the intermediate professions that are more numerous as such in the studied municipalities of work. The latter can be explained by the fact that craftsmen and employees generally live closer to their workplaces and commute over shorter distances than senior executives for instance.

Compared to the rest of their category, commuters possessing professional diplomas have the highest number of jobs available; and the 'No schooling' group has the lowest commuting time on average to go to work. The former can be explained by the fact that a high educational status leads to a higher chance to access to the labor market. However, those having a two-years university/professional diploma undergoing a lower competition level than their counterparts (the ones graduated of a 2nd or 3rd cycle university degree), they benefit from the highest number of jobs in the studied municipalities of work. Out-of-school travelers tend to occupy menial and precarious jobs that are generally closer to where those people live (in particular if those vulnerable class has no car), or in places well-served by the PT network (city-centers).

The fact that non-immigrants can access to a higher number of jobs can reflect some cases of job discrimination on the labor market.

Even though working parents have the highest commuting times to go to work, they can access, by far, to the highest number of jobs in their municipalities of work. Hence, the best accessibility indicator is observed for them (with 925 jobs/min). At the opposite, lone fathers get the lowest accessibility indicator of their category (lower than for lone mothers), even though they demonstrate the lowest commuting times on average. If no clear conclusions can be derived from the former, the latter might reflect the fact that lone fathers can relatively less easily opt for workplaces where the work density is more developed (less jobs) compared to lone mothers. Indeed, they benefit from less fiscal advantages than lone mothers to relocate in city-centers where the employment market is more diversified.

4.2. After policy simulation: more accessible jobs gained for the least served

After a subsequent decrease of 20% and 40% of the potential travel time to work by PT, the indicators are respectively improving the most for the group of travelers the least served in terms of accessibility. Percentage changes from initial disaggregated accessibility results are expressed in Table 2.

This is the case for the gender classification (respectively +7% and +20% of additional "jobs per minutes" for men) and SCP breakdown (+8% and +21% for blue collars). Hence, for those classes who seem to be doubly "penalized", both spatially (tend to live in remote areas, where the PT supply along with the labor market is not so important) and socially (tend to occupy precarious jobs, to be alone with children at home, etc.). Our simulation suggests that reinforcing the PT capacity in remote areas sensibly adjusts this accessibility gap in favor of the most vulnerable.

However, for the rest of the categories – i.e. non-immigrants, working parents and high educational

level groups – the commuters who were already the best-off in terms of accessibility (before the change PT policy) see their ratios increasing the most. Indeed, after the two scenarios of commuting time improvements, a respective increase of +7% and +20% is observed for the non-immigrants population and of +8% and +20% for the family with working parents. Likewise, regarding the qualification levels of commuters, the accessibility indicators increase the most for the 2-years university/professional diploma or 'DUT/BTS' graduated class (with +8% and +21% under the two scenarios of commuting time improvements), as long as for 'brevet' (with +8% and +20% under the two scenarios); the latter already corresponding to the highest accessibility ratio under the reference situation. Hence, in these cases, accessibility to work is increasing proportionally more for the individuals who already were 'socially best-off' (working parents, high-qualified and non-immigrants) and the sufficiency rule for equity is no longer respected.

5. Discussions

5.1. Including challenges from the job market in the analysis

All through this paper, our analysis solely considered one side of the labor market's challenges for adjusting the gaps in accessibility to work. Indeed, only the jobs reachable from the demanders' side (i.e. the existing or potential commuters) were described and studied. However, one can also consider the other way around and start first from the needs of the employers in terms of human resources to hire. The two perspectives do not follow the same rational and, rightly or wrongly, high skilled workforce is sometimes brought over from more distant cities than from the local labor market. In this regard, the report analyzing the dynamics of employment centers within the LMCU (CETE-NP, 2013) provides the following highlights. The growth of 14% of the external professional trips (coming from outside of the Metropole) heading to Lille, confirms the longer distances trend of the commuting trips. If the half of the workforce in 2010 does live in the LMCU, the additional workers mostly come from nearby urban communities. Some also come from further, e.g. from Ile de France or Belgium. This phenomenon can be explained by large improvements on the transport system (e.g. the 'TGV' and 'TRGV') that renders realizable longer distances commuting (a bit more than one and a half hour to do Paris Gare du Nord-Lille Flandes) and leads to an extended polarization of the jobs centers.

In addition, introducing competition effects in the labor market would be of high interest for completing our work. A first step would be to make corresponding the jobs count with their sectoral

activity, using the SIRENE database[12]. A second step would be to describe which job is vacant and which one is not. A third step would be to simulate the strengthening of the public transit accessibility to work specifically for the intra-peripheral trips. This way, we would have "forced" the servicing of the municipalities of work with the highest proportion of low-qualified jobs at first in the simulations. This would have allowed to favor the socially disadvantaged groups and to counter the labor competition pressure since a wider scope of trips than 'remote municipalities-to-Lille' trips only would have been 'covered' by the policy. However, this assumption was difficult to test from a technical point of view. For each step, sensitivity analyses could then be carried out to account for labor competition effects on the accessibility indexes previously calculated. In addition, considering this element may lead to controversial conclusions. Indeed, an increase of the accessibility index means more chances for all (including for the commuters coming from outside of the LMCU) to apply for and obtain a job in a given municipality of work of the LMCU. Thus because it attracts proportionally more qualified workforce from further, due to the mechanical competition effect, improving the PT accessibility could turn out to be prejudicial from an equity perspective.

5.2. Representation of the specific needs of travelers in terms of accessible jobs

If city-centers concentrate most of the potential jobs due to a simple size effect, commuting choices can be rendered more complex when it comes to e.g. home-based works, personal services and jobs of that kind that follow a less structured pattern. Kawabata (2003) shows for instance that working hours are different and jobs locations are more scattered on the territory when it comes to the commute patterns of low-skilled auto-less workers in US metropolitan areas. However, such information on the travelers' needs in terms of jobs characteristics was not available in our dataset.

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6. Conclusions

If social exclusion factors already exist on the territory, due to e.g. skill/job mismatch, racial

[12] The SIRENE database (*Système Informatique pour le Répertoire des Entreprises et de leurs Établissements* – in French) is a repertory of the records of all companies, associations, public sector organizations and institutions registered on a territory, available on the Insee website. Using those data could be of interest for relating the number of jobs available in a given area to the industrial sector they belong and hence to provide information on the type of the jobs.

discrimination reasons, or the position of the individual in the household preventing a fair access to work by public transport (forming the a-spatial component of the gaps in accessibility to work by PT), the spatial characteristics of the PT network such as the coverage, length, frequency, etc. can either reinforce this poverty or help to address it (Lucas, 2012). But appraising the fairness of transport policy is challenging because the notion of equity itself is multi-faceted. After investigating the most suitable definitions together with the proxy indicators (as reviewed from empirical researches) of transport equity, an indicator of the potential accessibility to work by public transit is calculated.

Once detailed by categories of individuals, the key findings from our empirical analysis are that: the socio-professional occupation is the variable the most discriminating of the accessibility distribution among the commuters in LMCU (employees getting for example 737 more "jobs per minute"[13] thanks to the PT system than blue collars on average), followed by the household structure (working parents having access to 536 more jobs per minute than lone fathers), the level of qualification (commuters possessing the 'brevet' diploma getting 404 more jobs per minute than the non-schooled sampled individuals), the gender (100 more jobs per minute accessible by PT for women compared to men) and immigration status (23 more jobs/min for the non-immigrants).

Our main insight for policy making is that infrastructural investments are not the panacea to solve transport equity issues. Since the majority of the trips are realized at the outskirts of the LMCU (only 14% occurring within the city Lille and a large majority of them by car), strengthening the PT network in peripheral areas[14] may appear at first as beneficial for the population living in peripheral areas. However, this is an overstatement of the value of infrastructural investments, since servicing more those with the highest accessibility 'defaults' in the metropolitan area does not necessarily means targeting those with the greatest accessibility 'needs'. In fact, this is often other barriers that seem to block accessibility to work. For instance, lone mothers will not use more the PT system if it is e.g. their private schedule and/or role in the household that constrain and restrict most their trips to car use (children accompaniment, shopping, etc.). For them, we observed complex mobility behaviors to which it is difficult to provide a straightforward answer only via the PT system. Similarly, unschooled individual will not better access to jobs after the improvements on the PT network if their diploma level is not high enough anyhow to meet the conditions of the nearest labor market.

Therefore, other accompanying measures should be developed instead to solve accessibility issues, in concert of the public transport infrastructural investments. We can think about schedule management

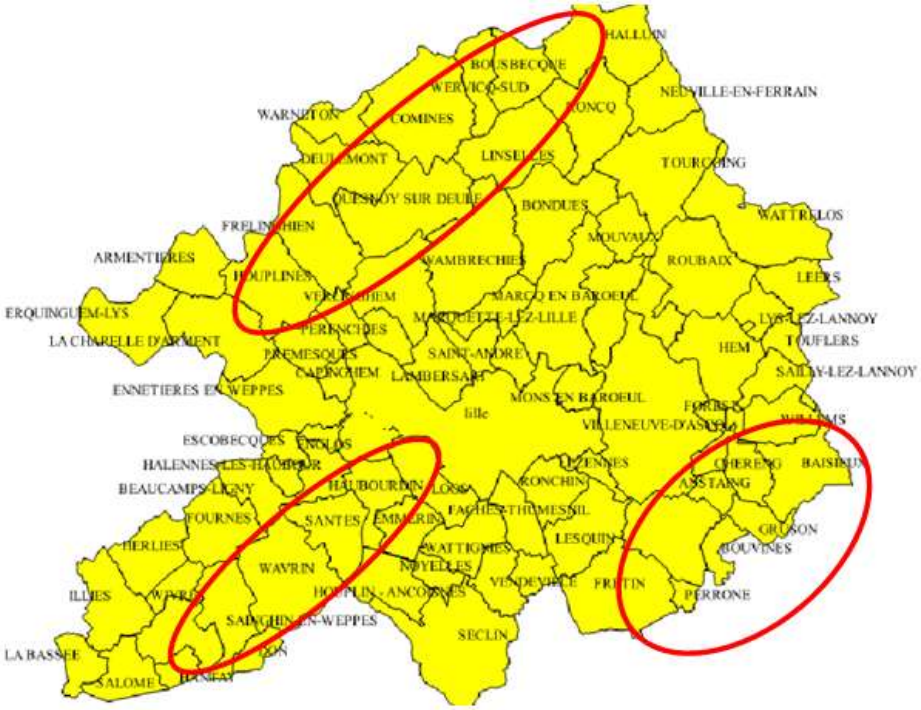
[13] 737 more "jobs per minute" comes from the difference between the indicators 871.75 ('Employees') and 135.04 ('Blue collars') in Table 1.

[14] After reconsidering and then cancelling the project of building new subway lines, the urban mobility plan of Lille Métropole led to the vote in 2000 of the development of a BHLS network for 2008 doted of new bus lines called "Lianes" aimed at extending PT network services.

policies (e.g. the postponing of the opening hours of the schools or providing daycare services later in the evening) labor policies (special accompaniment services to jobs for precarious population) or land use policies (with the relocation of activities and especially jobs centers on the territory) provided by local decision-makers from other sectors than transport. To control for the structural un-accessibility factors, such as the sample selection biases and endogenous residential sorting (see Di Paolo et al., 2014), that do not depend on the transport system but on the dwelling prices (that creates a centrifugation effect of the population towards the periphery) for instance would be necessary in the latter case.

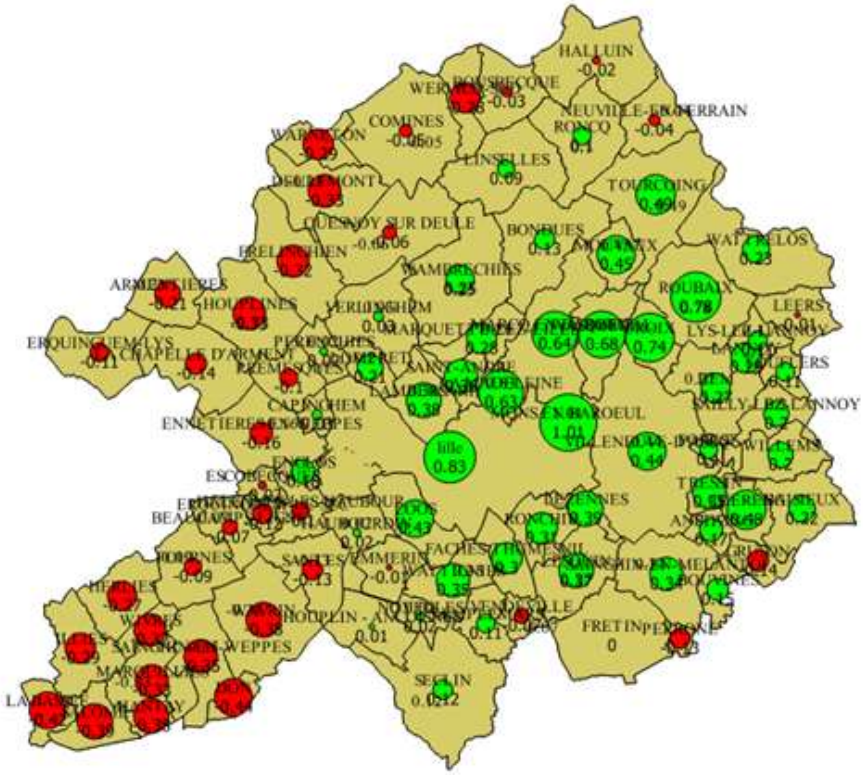
Figure captions

Figure 1 Municipalities from the urban community of Lille Metropole and areas the least served by public transport (circled in red)



Author's representation. Output from QGIS 2.2.0

Figure 2 Representation of the needed adjustments (in %) of the corrected commuting time to reach the average potential job market



Positive (in green) and negative (in red) growth rates in percentage to reach the average potential job market. Author's computation. Output from QGIS 2.2.0.

Table captions

Table 1 Mean accessibility indicators *Ai* per categories of commuters

	Number of jobs	**Commuting times (min)**	***Ai***
Gender			
Men	22913.70	61.22	416.93
Women	**26590.55**	**57.98**	**517.15**
SCP			
Farmer	1444.29	8.80	468.54
Craftsmen	6510.73	**39.54**	214.50
Lib. Profession/senior executive	44259.59	66.76	743.14
Intermediate prof.	**45259.38**	66.09	767.50
Employees	42263.19	55.72	**871.75**
Blue collars	7126.39	59.22	135.04
Highest diploma			
No schooling	24289.74	**22.69**	663.99
Primary school or middle school	32532.91	42.10	827.38
High school	36323.16	53.64	780.56
Certificate of Primary Education (CPE)	34389.88	43.55	881.97
French Certificate of general education (brevet)	54088.15	56.94	**1067.63**
Certificate of Professional Aptitude (CAP)	42472.63	54.54	874.25
Diploma of Occupational Studies (BEP)	45204.57	57.86	888.94
High school diploma (Bac)	54176.82	61.32	1021.03
Technical high school diploma (Bac technique)	51563.95	60.59	951.95
2-years university/professional diploma (DUT/BTS)	**55216.84**	65.75	938.92
2nd and 3rd cycle graduated university degree	54607.41	65.71	928.80
Immigration status			
Immigrants	43613.21	**51.55**	901.80
Non-immigrants	**49254.76**	59.68	**924.57**
Households type			
Single men	21037.41	53.35	414.12
Single women	23886.86	53.22	489.91
Cohabitation	42267.61	51.17	877.51
Lone father	19533.44	**44.77**	389.14
Lone mother	22668.37	54.25	480.94

Family with working parents	**50692.44**	61.17	**924.77**
Family with working father only	22023.65	57.72	418.30
Family with working mother only	22846.68	49.98	511.67
Family with unemployed parents	40649.24	51.62	803.08

In bold: figures commented in the text; in green (resp. in red): highest (resp. the lowest) accessibility indicators.
Note that the ratios in the column 'Accessibility indicators' do not strictly equal to the division between numbers from the columns 'Average number of jobs' and 'Average commuting times' due to the rounding off to two decimals at each step of the calculation. To note also that since the 'No ordinary housing' category of commuters represents a 0.62% share of our sample, the accessibility indicator (705.25) was not displayed in the above Table 1.

Table 2 Changes in the accessibility indicators *Ai* per commuter group, after 20% or 40% decrease in the mean commuting time to work by public transport from the least served communes

	Ai	***Ai 20%***	***Ai 40%***
Gender			
Men	416.93	**7.35%**	**19.64%**
Women	**517.15**	7.25%	19.33%
SCP			
Farmer	468.54	2.26%	6.03%
Craftsmen	214.50	5.67%	15.11%
Lib. Profession/senior executive	743.14	7.05%	18.81%
Intermediate prof.	767.50	7.50%	20.01%
Employees	**871.75**	7.17%	19.11%
Blue collars	135.04	**7.69%**	**20.52%**
Highest diploma			
No schooling	663.99	2.37%	6.31%
Primary school or middle school	827.38	7.11%	18.96%
High school	780.56	6.64%	17.71%
Certificate of Primary Education (CPE)	881.97	6.51%	17.37%
French Certificate of general education (brevet)	**1067.63**	7.63%	20.35%
Certificate of Professional Aptitude (CAP)	874.25	7.33%	19.54%
Diploma of Occupational Studies (BEP)	888.94	6.83%	18.21%
High school diploma (Bac)	1021.03	6.99%	18.63%
Technical high school diploma (Bac technique)	951.95	7.40%	19.73%
2-years university/professional diploma (DUT/BTS)	938.92	**7.71%**	**20.57%**
2nd and 3rd cycle graduated university degree	928.80	6.87%	18.32%
Immigration status			
Immigrants	901.80	6.41%	17.10%
Non-immigrants	**924.57**	**7.31%**	**19.50%**
Households type			
Single men	414.12	5.77%	15.39%
Single women	489.91	6.31%	16.83%
Cohabitation	877.51	5.61%	14.95%
Lone father	389.14	3.89%	10.36%
Lone mother	480.94	5.99%	15.97%
Family with working parents	**924.77**	**7.61%**	**20.30%**
Family with working father only	418.30	6.99%	18.64%
Family with working mother only	511.67	6.21%	16.55%
Family with unemployed parents	803.08	4.64%	12.37%

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