LAND USE MIX AND DAILY MOBILITY
THE CASE OF BORDEAUX

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Résumé

La problématique de l'interaction entre forme urbaine et mobilité quotidienne a connu récemment un renouveau. Le modèle de Ville Compacte vise à accroître les densités pour restreindre l'usage de l'automobile. Cependant l'interaction densité-mobilité n'est valable que dans le modèle monocentrique. L'émergence de centres d'emploi périphériques produit des déplacements atypiques, tels que les trajets périphériques et les pérégrinations. En même temps, la localisation conjointe des actifs et des emplois est facilitée dans la Ville Polycentrique. C'est pourquoi la réflexion sur l'interaction forme urbaine – mobilité a glissé des attributs quantitatifs de celle-ci (la densité) à ses attributs qualitatifs : la diversité des usages du sol. L'idée est qu'un usage mixte du sol rapproche origines et destinations du déplacement.

Nous distinguons dans cet article deux types de diversité utilisés dans la littérature : la diversité fonctionnelle (i.e. un partage équilibré entre activités et résidences) ; la diversité économique ou d'activités. Chacun est censé influencer la mobilité quotidienne. Ce questionnement est appliqué à l'aire urbaine de Bordeaux. Dans une première étape est testé un modèle général de forme urbaine, où nous notons que le *degré* de diversité des usages du sol a une influence significative sur les comportements de mobilité. Dès lors, la deuxième étape consiste à tester l'influence du *type* de spécialisation sur les modalités de déplacement. Nous relions ces influences aux comportements de localisation des firmes suivant leur activité.

Mots-clés : forme urbaine, mobilité, diversité fonctionnelle, spécialisation économique

Classification JEL : R12, R14, R41

Abstract

The question of the urban form-daily mobility interaction was recently renewed. The model of the Compact City aims at increasing densities to decrease the use of the automobile. However, the density-mobility interaction is questioned in the polycentric city : on one's hand, suburban employment centers produce original kinds of travel, such as cross-commuting or multi-prupose travelling ; on the other hand, they facilitate co-location of jobs and housing. That's why the reflexion on the urban form-mobility interaction goes through the quantitative aspects of urban form (density) to qualitative ones : the diversity of land use. The idea is that land use mix brings the origin and the destination of the trips closer.

In this paper, we make a distinction between two types of diversity : the functional one (i.e. the jobs-housing balance) and the economic one. Both may have an impact on daily mobility. We apply this question to the case of the metropolitan area of Bordeaux. In a first step, we test a general urban form model : we notice a significant impact of the *degree* of diversity on travel behaviour. Thus we are led to question about the influence of the *type* of diversity on travel patterns. We comment these results thanks to the location behaviour of the firms according to their activity.

Keywords : urban form, travel patterns, functional diversity, economic specialization

JEL Classification : R12, R14, R41

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Introduction

Sustainable development constitutes a normative framework for thinking as much as for action (Hart, 2002), which sets the necessity for a control of the negative externalities of economic growth. As such, the question of daily travel proves to be crucial. The objective of « sustainable mobility » consists in protecting both environment and health without decreasing the need for travel[2]. If cities stand as a pertinent scale for the application of sustainable policies (Camagni *et alii*, 1998), reaching the goal of « sustainable mobility » supposes that the share of the automobile in daily travel is reduced.

Beyond measures intending to reduce emissions or trafic, like car-sharing or incentives to use « soft » travel modes (walking or transit), an overall thought emerges, based on the interaction between urban form and travel patterns. In the french city of Bordeaux, the P.D.U.[3] seeks to « *act on the evolution of the urban morphology [to] limit automobile use and its foreseeable growth* » (C.U.B, 2001, 31)[4]. The main goal is to control for *urban sprawl*, as it is supposed an interaction between automobile use and low-density settlement patterns (*Ibid*., 12).

On one's hand, automobile use has allowed to push back the boundaries of the city. The so-called *Zahavi Law*, which enounces that travel times are constant over time (Zahavi & Ryan, 1980 ; Gordon, Richardson & Jun, 1991 ; Levinson & Kumar, 1997), can be interpreted as follow : speed gains linked to automobile use were traded against an increase of the amount of liveable space through a more peripheric location (Dupuy, 1999 ; Gordon & Richardson, 1997). An *Automobile City* is shaped, which not only extends the urbanized area, but also fills in the empty spaces produced by the Transit City and its « fingerglove » structure (Newman & Kenworthy, 1998).

On the other hand, the dispersed and low density urban form, which is a characteristic of the Automobile City, creates low levels of accessibility, and thus favours automobile use. Some authors talk about *automobile dependence*, stating that « *the use of an automobile became not so much a choice but a necessity in the Auto City* » (Newman & Kenworthy, 1998, 31). Thus automobile use has increased sprawl, as much as sprawl has expanded automobile use. That is why urban planification is oriented towards a control of urban sprawl, by means of bringing up to date urban revitalization (Breheny, 1995), or adopting « urban growth boudaries » measures (Dawkins & Nelson, 2002). The underlying model is the one of the « Compact City ».

The model of the Compact City is based on empirical results. The well-known Newman and Kenworthy's curve sets up, for thirty-two global cities, an inverse relationship between gasoline consumption per capita and net urban density (Newman & Kenworthy,

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[2] This formulation stems from a french national law, the LAURE of 1996, an equivalent of the american Clean Air Act.

[3] *Plan des Déplacements Urbains*, a forecast planning document which focuses on the 5-years evolution of individual mobility and tries to plan it.

[4] Translations are made by the author.

1989). Numerous studies confirm such a relationship, at an inter-urban scale (Naess, 1996 ; Cameron *et alii*, 2003) as much as at an intra-urban scale (Fouchier, 1997 ; Hivert, 1998). High densities produce lower distances travelled and modal shares in defavour of the car.

The link between urban density and travel patterns is an obvious fact in the Monocentric City. The negative rent gradient, which stems from the concurrence for the accessibility to the CBD, produces a negative density gradient (Mills, 1972, chap. 5). If every job is located in the CBD, then every home-work travel is from the periphery to the center. For such a radial trip, the distance travelled *is* the distance to the centrer. A decrease of densities caused by urban sprawl implies an increase of the distance to the center, which provokes in turn an increase in distances travelled and a modal split towards the automobile. Thus urban sprawl causes mecanically an increase of energy consumtion for travel. In the Monocentric City, the link between density and mobility is a truism.

If we give up the hypothesis of a central location of jobs, the density-mobility interaction is challenged. Suburbanization of jobs brings original kinds of travel, such as circumlinear travels (cross-commuting) and multi-purpose trips. They are usually made on greater distances than traditional radial trips, and the automobile is the predilection mode. In the non-monocentric city, the strict correspondance between urban density and travel behaviour is broken. The litterature on « wasteful travelling » (Hamilton, 1982, 1989 ; White, 1988 ; Small & Song, 1992 ; Giuliano & Small, 1993) tries to measure the theoretical amount of « excess » travel due to the shifting from a monocentric structure to a polycentric or dispersed structure.

Nevertheless, « *the relations between sub-centtring and commuting are complex* » (Cervero & Wu, 1998, 1073) : the emergence of peripheral job centers facilitates the co-location of jobs and people. That's the way P. Gordon *et al*. (1991) try to explain their « commuting paradox » : for nine out of twenty great amercian cities, travel times have decreased when sprawl has increased. For D. Levinson and A. Kumar, individuals carry out « *periodic relocations to face changing needs* » (1994, 320). Y. Rollier and M. Wiel (1993) bring the hypothesis of *sectorization* : the households whom workplace is far away from the CBD would locate their home in the same geographical sector.

Then we are led to modify our questionment. The question is the one of the urban form – mobility interaction. Beyond the quantitative measure of urban form, that is density, and its influence on travel patterns, researchers question the qualitative dimension of urban form, that is land use, or the way a parcel of land is used.

This new problematic has bring to the fore the very importance of land use mix in the urban form - travel patterns interaction. It is argued that in a given community, various land uses allow an easier access to convenience and amenities (Cervero & Kockelman, 1997) as well as to adapted jobs (Wiel, 2001). A better accessibility allows shorter distances travelled, hence a modal shift towards non automobile travel modes, and a lower individual energy consumption. What's more, land use mix produce « *well-defined commutersheds wherein local neighboorhoud traffic is segregated from regional through-traffic* » (Cervero, 1989,

137) : thus freeway congestion, which is an important cause of wasteful energy consumption, is reduced.

For these reasons, land use mix is seen as an efficent way to reduce individual gasoline consumption. As long as daily mobility is concerned, a « sustainable » city is a combination of high densities and mixed land-use patterns (Breheny, 1993, 142). For J. Levy (1998), « *the 'dense diversity' is less expensive (…) in terms of respect of the environment* ». Thus mixed use land patterns, combined with high densities, becomes an important objective for planification authorities. The New Urbanism movement, founded in the late 1980's by E. Plater-Zyberk and A. Duany, sets out in a charter the new principles for building urban form : « *Neighborhoods should be compact, pedestrian-friendly and mixed-use* » (CNU, 2001). The objective is to raise the « autonomy » of the neighborhoods so as to favour local mobility and « *to create human-scale, walking communities (…) : at the edge of the neighborhood, there are shops and offices of sufficiently varied types to supply the weekly needs (sic) of a household* » (Steuteville, 2000). What's more, the building up of compact, mixed-use centers in the periphery of an agglomeration might allow the supply of a better transit service : it is the principle of the well-known « Transit-Oriented Development » (Laliberté, 2002).

This paper tries to bring a contribution to this question. Its objective is to examine the link between travel behaviours and diversity of land use. We first examine main previous results of the literature about the land-use mix – travel patterns interaction. Then we propose an empirical application of this question to the metropolitan area of Bordeaux.

I – Diversity of land use and travel patterns : some previous results

The study of the link between land use and daily mobility has been the subject of more than fifty empirical studies in 2001 (Ewing & Cervero, 2001). The examination of this literature leads us to ditinguish between two types of diversity : the functional and the economic diversity.

1. The functional diversity

Functional diversity of land use is the degree to which jobs and housing are balanced. It can be measured by jobs-housing ratios. Balancing jobs and housing is a necesary (but not sufficient) condition to bring workplaces and houses closer. If jobs and housing are imbalanced, « *there is an insufficient supply of available housing to meet the needs of the local work force* » (Cervero, 1989, 137). At the contrary, single-use land patterns may create « tunnel effects » that increase distances travelled (OCDE, 1994). The expected benefits are a reduction of the distances travelled and a possible modal shift towards non-automobile modes, hence a decrease in individual energy consumption.

Of course, jobs-housing ratios only indicate the *potential* for a good balance, not the degree to which this potential is realized. Empirical studies don't agree about the influence of functional diversity on daily mobility. In a study of the metropolitan area of Milan (Italy), R. Camagni *et al*. note a negative correlation between the jobs-housing ratio and the ecological impact of mobility, which means, they note, « *a growing impact with (…) the reinforcement of the residential content of the districts* » (2002, p. 126). Inversely, for the 42 largest suburban employment centers of the San Francisco Bay Area, R. Cervero (1989) picks out a negative impact of the jobs-housing ratio on the use of non-automobile modes as well as on the level of service on main freeways.

The jobs-housing ratio is habitually used to detect employment centers (Standback, 1991). They constitute « travel generators », which, for a same density, receive more travels. For example, R. Cervero and K.-L. Wu (1998) note that in San Francisco, the highest increase of VMT (Vehicle-miles travelled) has occured in the most remote and the most recent suburban employment centers.

2. The economic (sectoral) diversity

Travel behaviours may not be the same according to the purpose of the trip : home-work trips are usually distinguished from commercial or leisure trips. As a consequence, some studies make a difference between retail and others jobs ; then, the measure of diversity is based on the sectoral distribution of jobs. For example, D. Chatman (2003) uses the american NPTS (National Personal Travel Survey) of 1995 and tries to explain mileage traveled for commercial purpose by the proportion of retail jobs in the area, but he does not find any significant relationship. M. G. Boarnett and S. Sarmiento (1998) make a joint test of retail jobs density and service jobs density to explain non-work trips. They don't obtain any significant result.

More generally, the question is the one of the influence of the degree of economic specialization of urban space on daily mobility.

The economic specialization can be measured through a synthetic variable. L. D. Frank and G. Pivo (1994) use an entropy index and show that the more specialized an area is, the less people walk to their workplace. R. Cervero and K. Kockelman (1997) use a « dissimilarity index » : for each spatial unit, it measures the proportion of adjacent unit whose use is different (according to the « queen » rule). With an elasticity of 0.11, the dissimilarity index is positively associated with the car-sharing rate.

The question of the influence of the degree of economic specialization of urban space is a very complex one. There seems to be no consensus about it, because of (1) the different specifications of diversity that are used in empirical studies, and (2) contradictory or weakly significant results of these studies. We propose in the continuation of this article an empirical application of this question to the metropolitan area of Bordeaux.

<u>II –Methodological approach and empirical application to the metropolitan area of Bordeaux</u>

1. Data and Methodology

Bordeaux is one of the greatest french cities, with 801,309 inhabitants. The data used here is from the 1998 Household Travel Study (HTS), a survey about the travel behaviour of a sample of 4,329 households (INSEE DR Aquitaine, 1998). The study area was divided in 66 zones of different size. Land use data was added to it, stemming from the National French Institute of Statistics : among others, we had at disposal the spatialized sectoral distribution of the firms in the metropolitan area of Bordeaux (36 economic sectors).

The objective is to link travel behaviour and land use patterns. The explained variables are : distances travelled in automobile per capita (for the origin zone) or per job (for the destination zone), which proxy the individual energy consumption (van Diepen and Voogd, 2001) ; trip length ; modal shares ; and the number of trips per capita. The first variable is the outcome of the three others, which means we may explain its variation by the variations of the other ones.

The two first variables were distinguished according to the purpose of the trip : professional (home-work trips), and non professional (commercial, leisure and others). Technically, we used OLS regressions[5], except for modal shares, for wich the appropriate model is a multinomial logit one, as modal shares are the result of a choice (de Palma & Thisse, 1987).

A first result can be mentioned : the coefficients of the regressions on the number of trips per capita were rarely significative. In fact, the number of trips per capita and per day is very stable (around 3.75, with a standard error of only .459). Our hypothesis is that the number of trips per capita is not dependent from land use patterns. That’s why this variable wasn’t included in the tables of results.

This empirical study is divided in two parts. In the first one, we try to explain travel behaviours with a general model of urban form, which includes (among others) measures of functional and economic diversities. These results suggest that the influence of the *degree* of land use mix on travels is significant. As a consequence, we are led in the second part to question the influence of the *type* of economic specialization on travel patterns.

2. The urban form model : the influence of the degree of specialization on daily travels

In a first step, we specify a general urban form model, which includes quantitative dimension (density and distribution of densities) as well as qualitative dimension (functional

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[5] We used the White Correction to avoid heteroscedasticity problems, as they may produce biases in the estimation of the coefficients. The White Correction gives a robust estimation of the variance-covariance matrix without being forced to know the source of the heteroscedasticity (Greene, 2000, 506-507).

and economic specialization[6]) of land use. We verified the good specification of this model (that is, the absence of multicolinearity, which is a frequent problem with cross-section data) thanks to the non significativity at a level of 5% of the Pearson correlation coefficient. Results are presented in Table 1 and Table 2.

Table 1. Distances travelled and the general urban form model (OLS regression)

General urban form model (origin of the trip)	Distances travelled in automobile per capita		Trip length (at the origin)	
	1st purpose*	2nd purpose	1st purpose	2nd purpose
Intercept	**3,574**	**12,185**	**9,938**	**7,404**
	5,929	*9,488*	*13,564*	*13,015*
Residential density	**-0,029**	**-0,055**	**-0,031**	**-0,023**
	-6,407	*-4,147*	*-3,616*	*-3,513*
Normalized standard error of res. densities	-0,006	**-0,042**	-0,013	**-0,021**
	-0,818	*-2,062*	*-1,305*	*-2,383*
Jobs/workers ratio	**1,431**	**2,319**	-0,119	-0,077
	5,799	*3,604*	*-0,860*	*-0,753*
Sectoral specialization khi-square index	**7,259**	3,825	2,412	**3,525**
	3,845	*1,147*	*1,022*	*2,069*
Adjusted R2	0,645	0,532	0,200	0,252
N	*66*	*66*	*66*	*66*

General urban form model (destination of the trip)	Distances travelled in automobile per job		Trip length (at the destination)	
	1st purpose	2nd purpose	1st purpose	2nd purpose
Intercept	**3,234**	**11,927**	**9,553**	**7,188**
	5,661	*7,892*	*13,159*	*12,782*
Job density	**-0,199**	-0,032	**-0,096**	**-0,083**
	-5,979	*-0,284*	*-1,993*	*-3,299*
Normalized standard error of res. densities	-0,016	**-0,078**	**-0,027**	**-0,032**
	-1,887	*-3,103*	*-2,225*	*-3,019*
Jobs/workers ratio	**1,614**	**2,764**	0,122	0,142
	9,087	*7,395*	*0,679*	*1,466*
Sectoral specialization khi-square index	**6,225**	0,352	1,578	2,498
	3,436	*0,075*	*0,696*	*1,587*
Adjusted R2	0,665	0,508	0,197	0,171
N	*66*	*66*	*66*	*66*

Note : t-ratios are in italic ; significant coefficients are in bold.

* 1st purpose :: professional ; 2nd purpose : non professional (commercial, leisure, others)

Table 2. Modal shares and the general urban form model (multinomial logit)

Urban form Model	1st purpose (professional)				2nd purpose (comercial, leisure, others)			
	Walking		Transit		Walking		Transit	
Intercept	**-0,685**	*-6,141*	**-1,321**	*-11,349*	**-0,781**	*-7,680*	**-1,922**	*-9,118*
Human density*	**0,002**	*2,743*	**0,001**	*2,121*	**0,001**	*2,313*	**0,001**	*2,308*
Normalized standard error of res. densities	-0,004	*-1,774*	-0,003	*-1,376*	0,000	*-0,046*	-0,003	*-0,752*
Jobs/workers ratio	**-0,407**	*-6,625*	**-0,117**	*-3,014*	**-0,318**	*-6,648*	**-0,470**	*-3,561*
Sectoral specialization khi-square index	**-0,929**	*-2,592*	-0,466	*-1,233*	**-0,856**	*-2,599*	**-1,458**	*-2,101*
McFadden-R2 (B.I.C)	0,028 (2.270,87)				0,023 (5.154, 513)			
N	*66*				*66*			

Note : t-ratios are in italic ; significant coefficients are in bold.

Note : the reference category is the share of automobile trips

* Human density is the sum of residential density and job density

[6] This last one is measured through a synthetic khi-square index of economic specialization : the higher it is, the more economically specialized a zone is, compared to the economic structure of the whole metropolitan area (Lajugie *et al.*, 1985, 699-700).

The general urban form model allows us to confirm the traditional role attributed to **densities** as far as travel patterns are concerned. Residential density (for trips measured at the origin) as well as job density (for trips measured at the destination) are negatively correlated with distances travelled in automobile per capita and per job, whatever the purpose of the trip is. Our results confirm not only the negative empirical relationship between density and individual energy consumption, but also its theoretical justifications : density is negatively associated with trip length as well as with the share of the automobile in the total of the trips (the coefficients of the use of alternative modes are positive).

Our results show a significant influence of the intra-zonal **distribution of densities** : in a given zone, the more heterogenally distributed densities are, the lower distances travelled in automobile per capita or per job are. Here again, this influence can be explained by shorter trip lengths and by lower automobile use. We must qualify this assertion by noticing that the coefficients are significant only for non home-work travels. These results seem to confirm the advantages of a polycentric development on a dispersed one (Camagni & Gibelli, 1997) : the concentration of residential development allows, for example, to provide a better transit supply, as in the model of the Transit-Oriented Development seen above.

The **jobs-workers ratio**[7] has a significant positive influence on distances travelled in automobile per capita or per job. This result is conform to R. Cervero's ones, but it is not consistent with R. Camagni *et al*.'s ones. It may be explained by a higher use of non automobile modes.

At last, we can state that the **specialization index** is positively correlated with the distances travelled in automobile per capita (for home-work travels only). Here again, the explanation lies on a modal sharing in favour of non automobile modes rather than on shorter trip lengths.

Thus, we can confirm the influence of land use mix on travel patterns through the significance of the variables of functional and economic specialization. We can link these two results to each other : the more numerous compared to population jobs are and the more specialized an area is, the higher distances travelled in automobile per capita or per job are. This kind of situation correspounds to the emerging suburban employment centers, situated around the *rocade* (a circular expressway surrounding Bordeaux). Not only these subcenters are characterized by high jobs-workers ratios, but they are also more and more economically specialized compared to the CBD as well as compared to each other, as was demonstrated by the empirical study of F. Gaschet (2001, chap. 6)[8].

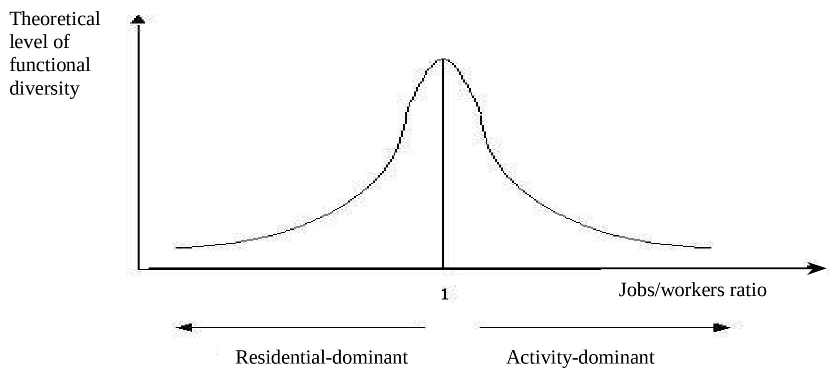
Nevertheless, the use of the jobs-workers ratio as a measure of functional diversity is ambiguous. It is an indicator of the sharing between workplaces and housing in a given zone, but it is not linearly linked with functional diversity. A « perfect » diversity is theoretically

[7] In this study, we use jobs-workers ratios instead of traditional jobs-housing ratios.

[8] Theoretical justifications of the economic specialization of suburban subcenters are mainly : the demand of spatial interaction which is differenciated according to the sector (Ota & Fujita, 1993), and the supply of activity centers from the « macro-agents » (Henderson & Mitra, 1996).

obtained for a value of 1 : one job for each worker. Beyond this threshold, the zone is « activity-dominant », and the functional diversity decreases ; but for values inferior to one, the zone is « residential-dominant » and the functional diversity decreases too. As a consequence, the relation between the jobs-workers (or jobs-housing) ratio and functional diversity is not monoton, but bell-shaped (cf. Figure 1).

Figure 1. The relationship between jobs-workers ratio and functional diversity



Then, it is difficult to interpret significant relationships between jobs-workers ratios and travel patterns, as we don't know if this relationship is due to, for example, a weak residential content or a strong jobs content. A study of Z.-R. Peng (1997) illusrates this ambiguousness : the relationship between jobs-housing ratio and the total VMT per capita is U-shaped (instead of an expected L-shape).

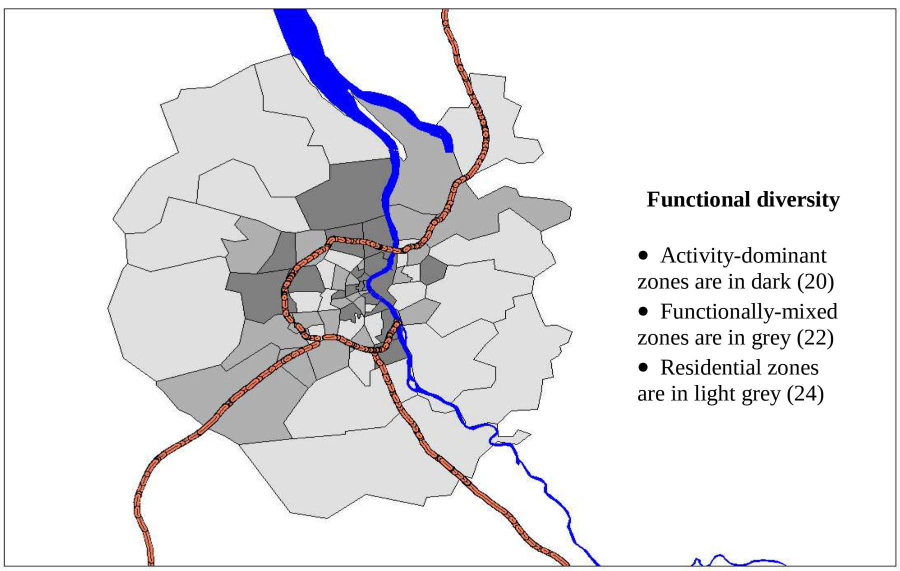
The first step of this empirical study has been dedicated to the influence of general urban form variables on mobility variables. We have noted a significant impact of the *degree* of functional as well as economic specialization on travel patterns. Such an analysis leads to go further into the question of the interaction between land use mix and daily mobility. The question is now : does the *type* of specialization have an effect on travel patterns ? The second step of this empirical study is devoted to an attempt to answer to this question, thanks to a model where the synthetic index of economic specialization has been replaced by a set of location coefficients.

3. The type of specialization and travel patterns

To build the khi-square index of economic specialization, we used the NES 36, a standard division in 36 sectors defined by the INSEE (French National Institute of Statistics). To take in account the *type* of specialization in our analysis, we can replace this synthetic index by a set of location coefficients[9]. However, it seems to be difficult to test jointly 36 coefficients with a sample of only 66 observations. Thanks to a method of automatic classification and the analysis of the significativity of the Pearson correlation coefficient, we have grouped together the most similar activities, so as to obtain 6 great economic sectors : 1. Industry and building industry 2. Retail Trade 3. Transports 4. Finance and Real Estate 5. Wholesale trade and Collective services 6. Individual services. We added the density of jobs to this set of location coefficients to specify a model of type of specialization.

We have seen above how much ambiguous is the integration of jobs-workers ratios in the model. Thus the question is how to take in account the functional diversity in the model ? We argue it is possible to use it as a control variable. From the values taken by the jobs-workers ratio, we have distinguished between residential zones (low values), functionally mixed zones (values around one), and activity zones (high values), as it is represented on the Figure 2.

Figure 2. The distribution of the global sample in three subsamples according to the criterion of jobs-workers ratios



Thus we obtain three subsamples, built on the criterion of jobs-workers ratios. The objective is to make a regression for each subsample, then to compare the results ; it correspounds to a generalization of the R. Cervero (1989)'s approach, who had built a sample only composed of employment subcenters, with jobs-housing ratios beyond 1.5.

We use the technique of the *typological regressions* to control for functional diversity. The principle is to regress the same model on each subsample, then to test the hypothesis of

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[9] The location coefficient of an activity *a* in a zone *z* is given by $L_{az}= (J_{az}/J_z)/(J_a/J)$ where J is the number of jobs (here the number of firms). A value beyond 1 means that the given activity is over-represented in the given zone, compared to the productive structure of the metropolitan area (Lajugie *et al*., 1985, 689-696).

the equality of the coefficients (adapted from a « Chow » test, but in a spatial way)[10]. Thus it is possible to know if the effect of a given variable is the same for each subsample. What's more, it is possible to compare the results of each subsample with the results obtained in the global sample (i.e. before the division in subsamples).

The results of the typological regressions are presented in Table 3[11]. We can comment these results in the following way :

- **Density of jobs** has an expected negative impact on distances travelled in automobile per job, as well as on trip length, whatever the purpose of the trip is. This correlation is only significant for residential zones : in a given zone, the interaction between density of jobs and the distances travelled weakens with the increase of the number of jobs.
- In the global sample, the specialization in **wholesale trade and collective services** has a positive influence on distances travelled in automobile per job, as well as on trip length, whatever the purpose of the trip is. The division in subsamples makes this influence disappear, which means that such an influence may interact with functional diversity. In fact, the firms of this sector are mainly located in places that are far away from the CBD ; what's more, they tend to avoid peripheral subcenters. It can be explained by the fact these firms need a lot of space. We can suppose that it is for land price reasons they locate in distant and residential zones.
- We invoke the same causal interpretation to explain the positive correlation between the **industry and building industry** sectors and trip length for professional purpose : it is positive in the global sample, but it is only significant for residential zones.
- In the global sample, the location coefficients of **finance and real estate** are negatively correlated to the distances travelled in automobile per job. However, it cannot be explained by shorter trip lengths, as the regression coefficient is not significant. What's more, the division in subsamples makes this correlation unsignificant. Thus we can explain such a correlation by the preferential location of these sectors in zones with a high content of jobs. Moreover, the influence of the location coefficients of finance and real estate on trip length is only significant in the activity zones. This explanation seems plausible, as these sectors are attracted by high concentrations of jobs.
- The specialization in **individual services** is positively linked to the distances travelled in automobile per job as well as on trip length. What's more, the coefficients are the same whatever the functional specialization of the zone is. This result is

[10] This can be done with the specification of a contrained model (under the hypothesis of the equality of the coefficients) and a non constrained model. The hypothesis of equality of the coefficients is tested with a F-statistic, which tests the significance of the restrictions imposed to the constrained model. We develop with more details and justify the use of the technique of the *typological regression* in a previous paper (Pouyanne, 2005 ; available in an english version on demand to the author).
[11] We didn't include modal shares in the analysis, as they are not measured at the destination of the trip.

astonishing, as individual services are preferently located in the CBD. Thus it can be explained by a mismatch between housing and jobs for this sector.

Conclusion

The long-time question of the interaction between urban form and daily mobility has been renewed under the influence of sustainable development : the objective is to know how to act on urban form to shorten trip lengths and to decrease the use of the car. After having focused on urban density through the debate on the Compact City, the research has been interested in the question of the interaction between land use mix and travel patterns. Indeed, the emergence of suburban employment centers questions the density-mobility linkages. Some empirical studies try to lighten the interaction between travel behaviour and functional as well as economic specialization.

We try to apply this question to the metropolitan area of Bordeaux. In a first step, we test a general urban form model, including quantitative measures (density and distribution of densities) as well as qualitative measures (functional and economic specialization) of urban form. We show that the degree of functional and economic specialization have a significant influence on travel patterns.

In a second step, we try to explain these patterns by the type of economic specialization. Because of its ambiguity, functional diversity measured through the jobs-workers ratio is used as a control variable. We use the technique of typological regressions, which allows to produce different subsamples according to the functional specialization of the zones. The results we have obtained can be interpreted through location behaviour of the firms according to their activity, which has in turn an influence on the travel behaviour of their employees.

Table 3. The type of economic specialization model (typological OLS regressions)

	Distances travelled in automobile per job *1st purpose (professional)*				Distance travelled in automobile per job *2nd purpose (comercial, leisure, others)*				Trip length (at the destination) *1st purpose (professional)*				Trip length (at the destination) *2nd purpose (comercial, leisure, others)*			
	Global sample	Residential zones	Mixed zones	Activity zones	Global sample	Residential zones	Mixed zones	Activity zones	Global sample	Residential zones	Mixed zones	Activity zones	Global sample	Residential zones	Mixed zones	Activity zones
Intercept	**27,668**	40,663	32,091	-23,604	30,988	45,084	40,761	11,421	0,607	2,588	0,561	-1,186	0,147	-2,558	-0,047	3,069
	2,508	*1,660*	*1,739*	*-1,070*	*1,636*	*0,810*	*0,953*	*0,243*	*0,383*	*0,719*	*0,174*	*-0,352*	*0,116*	*-0,702*	*-0,014*	*0,928*
Job density	-0,090	**-3,723**	0,083	0,017	**-0,320**	**-12,644**	**-1,330**	-0,207	0,001	-0,195	0,006	0,014	0,003	**-0,366**	-0,004	0,005
	-1,331	*-3,169*	*0,228*	*0,153*	*-2,079*	*-5,750*	*-2,129*	*-1,120*	*0,176*	*-1,180*	*0,113*	*0,986*	*0,401*	*-2,318*	*-0,091*	*0,451*
Industry/building industry	-13,028	-8,867	**-29,448**	11,536	-24,468	-6,317	-6,317	-6,317	**2,632**	**4,105**	2,607	-1,099	1,995	**3,477**	2,636	-2,840
	-1,481	*-0,684*	*-2,013*	*0,690*	*-1,195*	*-0,361*	*-0,361*	*-0,361*	*2,351*	*2,027*	*1,468*	*-0,484*	*1,886*	*2,030*	*1,747*	*-1,456*
Wholesale trade/coll. services	**24,015**	-3,663	**35,919**	0,496	**62,408**	-5,090	-5,090	-5,090	**1,828**	1,528	1,528	1,528	**1,858**	0,966	0,966	0,966
	3,993	*-0,373*	*2,440*	*0,044*	*3,800*	*-0,358*	*-0,358*	*-0,358*	*2,731*	*1,432*	*1,432*	*1,432*	*3,364*	*1,042*	*1,042*	*1,042*
Retail trade	-4,497	2,730	**-31,428**	-8,393	14,114	18,526	18,526	18,526	0,418	0,462	0,462	0,462	0,137	0,723	0,723	0,723
	-0,674	*0,289*	*-2,882*	*-0,644*	*1,184*	*1,347*	*1,347*	*1,347*	*0,684*	*0,485*	*0,485*	*0,485*	*0,234*	*0,854*	*0,854*	*0,854*
Transports	-2,893	0,342	-10,210	4,883	-11,338	**-37,451**	-0,121	4,403	0,457	0,591	0,591	0,591	0,383	0,504	0,504	0,504
	-0,845	*0,045*	*-1,698*	*0,997*	*-1,513*	*-2,095*	*-0,010*	*0,396*	*1,135*	*1,038*	*1,038*	*1,038*	*0,862*	*1,038*	*1,038*	*1,038*
Finance/Real estate	**-13,495**	0,676	0,676	0,676	**-33,401**	0,841	0,841	0,841	0,239	-2,979	0,025	**4,239**	-0,295	-2,856	-0,375	**2,925**
	-2,344	*0,086*	*0,086*	*0,086*	*-2,254*	*0,050*	*0,050*	*0,050*	*0,213*	*-1,126*	*0,011*	*2,702*	*-0,237*	*-1,268*	*-0,185*	*2,171*
Individual services	5,417	**21,645**	**21,645**	**21,645**	18,024	**134,879**	11,349	0,624	**2,653**	**3,124**	**3,124**	**3,124**	**2,433**	**8,116**	2,320	0,643
	0,836	*2,426*	*2,426*	*2,426*	*1,243*	*3,116*	*0,310*	*0,026*	*2,552*	*2,341*	*2,341*	*2,341*	*2,337*	*3,272*	*1,055*	*0,439*
Adjusted R2 (Akaike criterion)	0,388	0,548 (8,145)			0,394	0,675 (9,723)			0,334	0,416 (4,450)			0,301	0,484 (4,132)		
N	*66*	*20*	*22*	*24*	*66*	*20*	*22*	*24*	*66*	*20*	*22*	*24*	*66*	*20*	*22*	*24*
Restrictions		*G(4,42) = 2,047 ; Pr = 0,105*				*G(8,42) = 0,255 ; Pr = 0,976*				*G(8,42) = 0,525 ; Pr = 0,831*				*G(6,42) = 0,675 ; Pr = 0,986*		

Note : t-ratios are in italic ; Sigificant coefficients (at a 5% level) are in bold.

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