Modelling Spatial Diffusion of Carsharing Membership

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Carsharing developed rapidly during the past decades (Katzev, 2003). First introduced in Western Europe (Switzerland in 1987 and Germany in 1988), it is now widespread in North American cities, in both Canada (19 organizations, 61,900 members, 2,140 vehicles as of January 2010) and the USA (27 organizations, 388,000 members, 7,580 vehicles; Shaheen et al., 2010). It provides access to cars on a pay-per-use basis, thus potentially reducing car ownership among subscriber households living in neighbourhoods where it is offered. An individual's lower investment in car ownership probably leads to a more diversified set of transportation modes used for travel to activity locations, thanks to low general transportation fixed costs, motivating carsharing users to compare various settings of destinations/transportation modes when planning each trip or tour to activities (e.g. walking to a nearby shop, riding a bus to a shopping centre or driving to a big box). In contrast, car owners likely overuse their vehicle because they are willing to cushion fixed costs. These peculiarities in cost structures likely imply differences in behaviour between car owners and carsharing users, leading in theory, to a higher use of public and active transportation modes among the last group, thus motivating interest for such an emergent behaviour. This could also mean that carsharing potential is related to the urban form, restricting diffusion to higher density neighbourhoods with good accessibility to everyday services and work places (Stillwater et al., 2010). Moreover, since access to car pools implies walking to fixed-location parking lots, one can expect a somewhat "oil stain" diffusion process on membership because cars are locally allocated on a proportional basis (e.g. 1 car per 20 members around a pool). This is the subject of this paper which combines 3D (density, diversity, design) and 5D (+ distance to transit, destination accessibility) models (Cervero and Kockelman, 1997) for assessing travel demand potential with Hägerstrand's (1953) diffusion of innovation concepts. It aims at modelling spatial diffusion of carsharing in Quebec City, from 1996 (2 years after opening) to 2008.

In 1994, a carsharing service was initiated by Communauto in Quebec City. It is the oldest still-operating business of its kind in North America, years before City CarShare in San Francisco (March 2001; Cervero et al., 2007). At the end of 2008, Communauto was operating in the Montreal, Sherbrooke and Ottawa regions having more than 16,000 subscribers; 2,985 of them were living in Quebec City. This urban region provides several benefits for testing hypotheses about relationships between the urban form and spatial diffusion of carsharing memberships: (1) It is the oldest city in Canada still having a large European-style centre built before the introduction of cars (before 1920; high density urban fabric, narrow streets and mixed land use), older neighbourhoods developed during car diffusion (1920-1960; mid density, large streets and mixed land use) and new suburbs which are the result of urban sprawl following car domination (after 1960; low density, highways network and segregated land uses). Fourteen years after its opening, Communauto is well installed in the first two types of neighbourhoods and is now extending its services in suburbs. (2) Excluding its historic centre, Quebec City is a rather typical Canadian City, thus providing a relevant test region for assessing potential of carsharing development in Canada. (3) An efficient bus service is operated by a public transit company (RTC); it is a requisite for carsharing development. Finally, there is a strong demand for enhanced knowledge linking mobility strategies and urban planning for sustainable development.

We got access to a full listing of Communauto's membership from 1994 to 2008, disclosing, for 4,764 actual and previous members living in Quebec City: joining date, age,

gender, residential postal code and, eventually, withdrawal date. Using Canadian postal codes, we located members to their home places using geocoding procedures (up to urban block sides). Using a network made of regular grid cells (2040 hexagons with 250 metres radius), we computed the total number of active members (before eventual withdrawal) on a yearly basis from centre to the outskirts of the city. Using spatial interaction relationships among neighbouring cells, we estimated the incidence rate of membership (carsharing members per 10,000 driving licence holders - 21 years old or more) for successive radii of distance (500, 1000, 1500, 2000 metres). Then, each tuple of year-grid cell, was associated with carsharing membership of the previous year in the neighbouring cells. This provides data to build a zero-inflated Poisson regression model of spatial diffusion linking number of carsharing members in each cell, considering potential (car drivers) at time t and membership rates in neighbouring cells at time $t-1$. In the next step, indicators of urban form computed using OD surveys (1996, 2001 and 2006) and municipal assessment roles are included for each cell in order to assess the 5D effects on marginal probability of increasing number of carsharing members at each location in space and time (23,103 year-grid cells with car drivers). Examples of such 5D indicators are residential density, accessibility to work places using buses or active transportation means, ratio of commercial versus residential land uses (or building values), number of bus stops, etc. Finally, socio-economic factors are controlled for using indicators like proportions of non-motorised and partly motorised (cars < drivers) households, modal shares of active and public transportation modes, household income (census of 1996, 2001, 2006), family structure, etc.

GIS was used at every step of the modelling procedure, in particular to build indices pertaining to land use, spatial diffusion, accessibility, diversity, distances and mobility behaviour, yielding a comprehensive spatio-temporal database needed for mapping the diffusion process and for statistical modelling of linkages between carsharing development and the urban form, controlling for spatial diffusion constrains (access to car pools) and imitation (increasing visibility), as well as socio-economic determinants of decision to join. The poster presents maps of this evolution along with results of the regression model.

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