Grouping moving people in order to provide an efficiency and thrifty public transportation supply

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SUMMARY
This contribution involves the transport modelling. We tried to understand what are the logics which lead to spatio-temporal concentrated flows in a given territory, those being more favorable for public transportation systems.

So the pattern of the flows appears to depend on three different logics:
• the individual rationality which leads people to live grouped
• the carrier rationality which intends to group people in vehicles in order to minimize the cost
• the structure and the topology of the road network which tend intrinsically to concentrate more or less flows on particular sections

We present and illustrate these logics and we identify the possible leverages suited to provide coherent and massive flows.

KEYWORDS: Flows, transport modeling, Demand Responsive Transport (DRT), urban planning.

INTRODUCTION
According to the decline of the population density in the urban areas, to the dispersion of the urban polarities in peripheral areas such as offices, shopping centers, leisure facilities which were previously exclusively located in town centers, and according to the distension of the link between housing, workplaces and leisure places, the transportation flows are less and less concentrated and the traveled distances are increasing. This new urban organization and way of life makes it difficult to design and implement an efficient public transportation system which is competitive only for massive and stable flows of users (e.g. home-work flows: centre to periphery and vice versa). Moreover, with the increasing spatial and temporal complexity of transportation flows, it seems more difficult to adapt transportation system to the user needs and practices (Montulet&Kaufman, 2004) in an efficient and financially sustainable manner. So the urban sprawl, inducing multipolar urban structures (Chalas&Dubois-Taine, 1997) tends to automobile dependency.

In this context, one can wonder if there are territories which are more suitable for generating favourable flows for public transportation, that’s to say territories which intrinsically lead to spatio-temporal concentrated transportation flows. A flow corresponds to a quantity of individuals, grouped or not in vehicles per unity of time, measured on a given section of the road network (Dupuy, 1991).

Thus, the question is: what are the leverages which imparts to these territories the capacity to provide coherent and massive flows?

In this paper, we identify three logics which cause an un-randomly dispersion of the transportation flows to group moving people in space. The first one involves the individual rationality (homo economicus) which encourages people to live grouped in order to maximize the possible interactions and to minimize the transportation duration. The second is the rationality of the public carrier who tries to group people in vehicles through the design of transportation lines constrained by the commercial supply. The third comes under the structure of the roads network, which tends to intrinsically concentrate more or less strongly the flows.
THE INDIVIDUAL RATIONALITY LEADS TO PEOPLE TO BE GROUPED

The urban areas in industrialized countries are subjected to opposite tendencies of concentration and dispersion:

- **Concentration**: the principle of agglomeration maximizes the interactions while saving the most possible of energy and time (for transportation, facilities, working).
- **Dispersion**: people want to live close to nature, in spacious houses, even if it is an artificial nature with a private garden. Although some of them may seek exclusion form of living and isolation, others maintain rather intensive professional, social and cultural ties with the city. This behaviour and the property market (lower prices available outside the dense areas) tends to spread populations and activities in urban outskirts.

For a long time, due to public transport non efficiency, the concentration prevailed. But nowadays, with massive access to automobile, the towns sprawl can occur. Nevertheless, this sprawl has a limit. While the traveled distances increase, the daily travel duration remains stable for about 30 years (one hour a day), thanks to the increase in the transportation speed (Zahavi Law). Thus, the new settlements follow the map of accessibility “mobility draw the town” (Wiel, 2002). The figure 1 illustrates the process of population spreading according to commuting flows.

![Figure 1: Rural communal densities and corresponding commuting flows in 1999 (territory of the 'Doubs Central', France).](image)

According to the Zahavi law and to a good access to facilities, people choose their places of live aiming to save time. On the figure 2, we compare the real flows of commuters and theoretical flows, computed using generalized shortest time paths within a GIS, that corresponds to all possible travels between all the centers of the communes. We can see that the traveled distances are not so important that the network would allow. Although it would take about 25 minutes or kilometers to go everywhere in the territory, the commuters spend half this time or distance to go to work or to school. So, the distribution of the flows in terms of range and frequency depends on the facilities distribution and on the individual choice linked to transportation conditions and its capacity to support massive flows and to provide frequent types of journeys.
To improve the concentration of the population and activities to generate more concentrated flows, it is first necessary to restore the economic logic to live in dense areas as a rational economic good choice. Two main leverages are suited to do that: (i) increase in the cost of use and decrease of the accessibility provided by car (restriction of free parking possibilities, change of the network hierarchical structure to reduce the efficiency of car due to speed), (ii) housing policy in favor of property for a large range of households in dense areas. Moreover, a good cooperation between urban and transportation planning should provide a coherent location of the traffic generators according to the public transportation supply to avoid the network to chase after a dispersed town.

THE CARRIER ECONOMIC RATIONALITY: GROUPING PEOPLE IN VEHICLES

The capacity of grouping that the flexible transport systems can propose has a direct impact on the environment safety, because it saves vehicles use. In figure 3, we represent 4 different scenarios of demand increasing and their effect on grouping. The scenarios simulate travelers coming randomly from a large territory and going to the same destination, using a DRT which optimises the paths and the lines (Fink, 2002), according on a maximum time loss accepted by the client (simulation based on the DRT 'Evolis-gare' in Besançon, France). The scenario 1 involves about 2 clients, the second 5, the third 10 and the last one, 20 clients. We can see the DRT efficiency of grouping (measured by a rate of occupancy) and its economic impact. In this case, we didn't take into account some price modifications due to spontaneous grouping. The price for clients is unique but the cost is varying strongly, according to the scenarios.

Figure 2: Distributions of the traveled distances and times: comparison between the theoretical potential of flows and the real practice of commuting in 1999.
Figure 3: The relation between the mean travel cost and the occupancy rate of the vehicles

For a traditional carrier, the aim is to meet the transportation need of the population with the minimum possible costs and to maximize the number of users per vehicle. So the transport lines are designed in order to catch the more people as possible. Moreover, the transportation supply is temporally limited: the frequency of the bus should be weak to maximize the number of passengers per bus and be high enough to encourage people to take the public system. Here we can see that the carrier rationality isn’t so close to the passenger rationality. Indeed, due to economic efficiency, the transportation supply remains limited and generated a loss of time, access and comfort.

Here appears a leverage to encourage the grouping to revitalize the public transportation supply with new systems more flexible as fit-to-demand transport (as Demand Responsive Transport, Ambrosino & Nelson, 2004) and innovation concerning the price setting. In such systems, the price can be indexed to the occupancy rate of the vehicle. So it encourages people to travel together. People grouped on recurrent journeys will accept more easily the necessary detours made to maximize the occupancy rate. In compensation for the grouping and time lost, people will save money. A recent inquiry we provided (sample of 1000 people) reveals that more than one person on two would accept some uncertainty on a transport service if it is more flexible (timetable paths or conditions of reservation may change depending on the client wishes). Among those, more than 70% of questioned persons who already used a Demand Responsive Transport agree to try a more elaborated and flexible service. This means the transport supply and innovation can generate a new demand from the population, and might be modeled for rather fruitful assessment (De Dios Ortúzar & Willumsen, 2001).

In the Central Doubs’ (France), local authorities encourage people to decide to group before using the service, because:

- people close from each others often use the same facilities and so develop quite similar mobility behaviors,
- living in the same neighborhood, they may wish to travel together.

A client who would book a vehicle for two or more people requiring to travel together will benefit from this effort and will get a reduction for both travelers. It is expected that most of times, the clients will group with their neighbors. The concept of grouping, based on the individual rationality, calls this time a collective strategy, and, why not, the begin of a ‘traveling friendship’?
THE ROAD NETWORK TENDS INTRINSICALLY TO CONCENTRATE THE FLOWS

The first paragraph shows that the pattern of the flows is partially determined by the location of the traffic generators. Although the mobilities infer oriented flows, the functional network structure plays a crucial role on concentrating more or less the flows.

The question we asked in the following experience was: how important is the structure of a road network on the flows? In other terms, does a given portion of the road have a particular capacity to carry flows depending on its topological situation on the network? To answer to this question, we handled the road network of the town of Besançon (France) and compared the counted flows during one year with the quantity of expected flows assuming the location of the road sections would define their occurrence. To simulate these theoretical flows, we dropped split nodes separated by equal distances (using the GIS ArcInfo) over the complete network and processed the minimum time paths between all nodes considered as origin and destination points (Genre-Grandpierre, 2000, figure 4). Then we summed and normalized per each road section the quantity of expected flows (i.e. we considered a person goes from a given node to another given node, add the value of 1 on each road section his path uses).

<table>
<thead>
<tr>
<th>Simulated rate of flows</th>
<th>Daily rate of flows (mean number of vehicles counted per day during a year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>very high</td>
<td>&gt; 20000</td>
</tr>
<tr>
<td>high</td>
<td>de 15000 à 20000</td>
</tr>
<tr>
<td>medium</td>
<td>de 8000 à 15000</td>
</tr>
<tr>
<td>weak</td>
<td>de de 5 à 8000</td>
</tr>
<tr>
<td>very weak</td>
<td>&lt; 5000</td>
</tr>
</tbody>
</table>

Figure 4: Comparison between the counted flows in Besançon and the intrinsic theoretical capacity of the topological network to group flows.

Using this method, we considered that individuals were regularly spread along the network. We didn’t take into account the population locations, densities and strategies, factors that we mentioned in the first section. Secondly, we didn’t incorporate the transport public services, very well developed on Besançon and having a significant effect on the urban mobility. We only simulated flows corresponding to potential personal car use. Despite our method doesn’t cover the whole set of factors, the results, presented in the figure 4, show that a non negligible part of the flows can simply be explained by the topological structure of the network and that a certain rationality exist for people using the shortest time paths.
CONCLUSION
As the paper showed, there are at least 3 identified leverages to manage flows on a territory:

- the households planning, for the population to be located close to each others, due to individual rationality and facilities access,
- the commercial supply and innovation to minimize the cost for carriers and local authorities, by proposing incentive prices for users moving together,
- the road network structure, that implies more or less concentrated flows on parts of the network.

These three components can be possibly combined to provide coherent and massive flows. It can help the local authorities to assess and to develop an efficient and sustainable management of their territories. But there are still lots of work to do to measure how much the territorial organization can explain the flows. We propose in our further research to mix the three identified leverages to try to reach a level of general and sufficient explanation, by:

- computing flows according to the demand quantity and location,
- simulating the motion carried by the transport local supply,
- incorporating the conditions of mobility due to individual rationality.

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