Note on Transportation and Urban Spatial Structure

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The physical components of urban transport and urban utilities are constituted by spatial networks. These networks collect and distribute people, water, sewerage, storm water and solid waste across metropolitan areas. Engineers can optimize the design of networks to maximize their efficiency. However, in the course of optimizing urban network it is necessary to define the type of urban land use that will allow the optimum network. For instance, for a given target water consumption, water engineers can calculate the optimum population density that would minimize the input costs of the network. Urban transport engineers have more difficulties in optimizing their network because of the various potential mix of transport mode. However, if they define a dominant mode, a bus network for instance, they can also define, for a given level of service, the type of land use and street pattern that would allow to minimize capital and operation cost.

In practice, land use, or more generally an urban spatial structure, is the product of the interaction between land markets and regulations. Economists would normally assume that land is better allocated by markets than by transport engineers. Besides, the real estate market would normally reflects the various network costs (it should be noted that optimizing a water network would result in a type of land use significantly different from the one obtained by optimizing a bus network). Network specialists feel justified in recommending an optimum land use that would by-pass market signals because the cost of a primary infrastructure networks is practically never directly related to the price of land as its financing comes either from general taxation or from a financial pool generated by tariffs. The fact that the land market fails to integrate the cost of primary networks appears to demonstrate an obvious market failure which then justifies a heavy dose of regulatory intervention.

Increasingly, urban transport is considered one of the major unresolved problems in large cities because of the pollution and congestion it generates. In Europe and in North America there is an increasing demand for what has been called "Transit Oriented Development" (TOD). TOD is nothing but a partial administrative allocation of land through regulations. This allocation would allow an optimization of transit networks and as a consequence a significant decrease in both congestions and air pollution. To make land use more compatible with an efficient transit network, TOD advocates are proposing regulatory measures which would significantly alter the spatial fabric of existing cities. The main features of TOD are the creation of high density transport corridors, and the setting of urban growth boundaries. Urban growth boundaries would limit the supply of land available for development and therefore force higher densities and more contiguous development easier to service with transit. Two cities in the world are at the forefront of the crusade for TOD: Curitiba in Brazil, a precursor, as the TOD concept was implemented in this city in the eighties much before the terms even existed; Portland (Oregon), which implemented and maintained an urban growth boundary and several corridors along light rail lines.

The TOD approach raises a number of questions: While acknowledging that land markets are imperfect, is it realistic or even desirable to by-pass markets in allocating land between various uses, even for the desirable goal of decreasing air pollution and traffic congestion? If transport corridors are so efficient, why don't land values reflect this efficiency along existing transit routes and create spontaneously these high density corridors without regulatory interventions?

I will use a few concrete examples to show that:

- o urban structures are very resilient and are not easily altered,
- Some cities with already existing high density transport corridors show a number of negative side effects.
- Some cities have already acquired a spatial structure which is incompatible with transit and this structure is probably irreversible.

Before discussing concrete examples, I will briefly review the two most important features which characterize urban spatial structures:

- 1. the pattern of daily trips in monocentric and polycentric cities and
- 2. the average densities in built-up areas.

Monocentric/ polycentric structures: pattern of daily trips



Traditionally, the monocentric city has been the model most widely used to analyze the spatial organization of cities. The works of Alonso (1964), Muth (1069), and Mills (1972) on density gradients in metropolitan areas are based on the hypothesis of a monocentric city. It has become obvious over the years that the structure of many cities departed from the mono-centric model and that many tripgenerating activities were spread in clusters over a wide area outside the traditional CBD. Consequently, many have questioned whether the study of density gradients, which measures density variations from a central point located in the CBD, has any relevance in cities where the CBD is the destination of only a small fraction of metropolitan trips.

As they grow in size, the original monocentric structure of large metropolises tends with time to dissolve progressively into a polycentric structure. The CBD loose its primacy, and clusters of activities generating trips are spreading within the built-up area. Large cities are not born polycentric; they may evolve in that direction. Monocentric and polycentric cities are animals from the same specie

observed at a different time during their evolutionary process.

Most cities operate in mixed mode. Part of the trips are radials and follow the monocentric model, other have random origins and destinations and follow the polycentric model. A city a monocentric or polycentric by degree only. Some cities are dominantly monocentric other are dominantly polycentric.

Because of the pattern of trips, a dominantly monocentric city is favorable to transit, a dominantly polycentric city is more favorable to individual transport.

Average built up densities

Among major world cities, averages built up densities vary by several order of magnitude between cities. Transport solutions are obviously not the same in low density cities and in high density cities. Empirical data shows that efficient transit is difficult to provide in cities with a density below 30 people per hectare. Densities of very large cities are very resilient and are not likely to change much in the future. The graph below shows that urban densities have a cultural aspect, they are all the most difficult to change in the future in a significant way.





Mumbai: the rail corridor with long trips and low accessibility

MUMBAY (BOMBAY) - Densities in Built-up Areas



The peculiar topography of Mumbai makes the entire city a natural heavy rail transport corridor. The catchment areas of the main stations where trains are formed have an effect on the local density. This is an example where urban transport has influenced the land market and the city structure without regulatory intervention (even probably at odd with regulations).

In spite of its very high density the number of people within 10 km of Mumbai CBD is only 2 million people, less than half of the number of people within 10 km of Paris CBD (Paris density is only 1/5 of Mumbai). This is the inconvenience of transport corridors: They increase trip length. However, if the CBD of Mumbai was moved to Bandra (about 15 km north of the current CBD) 5 million people would become at less than 10 km from the CBD.





Curitiba: the bus corridor with <u>"efficient" long trips</u>

The bus transport system of Curitiba is often given as an example of successful integration of transport and land use. The transport solution selected (bus corridors) has dictated land use. The figure below shows, on the left, Curitiba population density in the built-up areas, and on the right the zoning of residential and commercial areas. The zoning map shows clearly the planners intent: a high density transport corridor running North South with feeders roads. The density map shows



that the reality is not as neat as the concept (to be fair the census tract do not coincide exactly with the zoning areas and therefore they tend to dilute the density effect). The U shape density profile (figure at the top of the page) is showing a higher average density in the periphery than in the center. It confirms the danger of ignoring land markets, even to optimize transit operations. The spatial outcome is a city where trips are much longer than they would have been if land use had been mainly generated by the market. The large high density areas it the periphery, not even directly connected to the transport corridor shows the difficulty in adapting a "command land use" to normal city expansion and changing economic base. The very low densities to the West of the city center decreases the general accessibility of the center and contribute in tilting the center of gravity of the city toward the South, progressively decreasing land values in the traditional CBD.

Atlanta: when the spatial structure is unfavorable (low density,) supply does not create demand

Atlanta is an interesting example of a city making a desperate effort to shift a large number of trips from individual car to transit. A high level of air pollution and chronic traffic congestion are the main incentive to increase the share of transit trips.

However, intentions and investments are not enough. I am convinced that the current spatial structure of Atlanta is completely inadequate to support a share of public transport significantly larger than the current 4% of all trips. Besides, a simple analysis shows that Atlanta spatial structure is irreversible. Atlanta spatial structure has 2 main features which makes transit difficult to operate at a large scale: it average built-up density is very low - 6 people/hectare - and it is dominantly a polycentric city (see below the spatial distribution of population and jobs).

The housing and job market confirm this diagnosis. The trends of the past 10 years show that in Atlanta people and jobs have been moving away from transit served areas not getting closer to it.

Between 1990 and 1999 Atlanta has added nearly 700,000 people to its population and created about 400,000 new jobs. 88% of the new population and 77% of the new jobs have located outside the reach of existing networks of buses and metro.

Atlanta - Changes in the population and jobs within walking reach of transit between 1990 and 1999 file:Atlanta Public transport.xls

	1990		1999		population g	rowth 90-99
Total population	2,513,000	100%	3,202,400.0	100%	689,400	100%
Population within 800 from metro:	90,200	4%	102,500.0	3%	12,300	2%
Population within 800 m from a bus line	911,800	36%	999,500.0	31%	87,800	13%
Population without access to public transport	1,511,000	60%	2,100,300.0	66%	589,300	85%
	1990		1998		new jobs bet	ween 90-98
Total number of jobs	1990 1,263,300	100%	1998 1,662,500.0	100%	new jobs bet 399,200	ween 90-98 100%
Total number of jobs Job within 800 from metro stations:	1990 1,263,300 87,400	100% 7%	1998 1,662,500.0 90,500.0	100% 5%	new jobs bet 399,200 3,100	ween 90-98 100% 1%
Total number of jobs Job within 800 from metro stations: Jobs within 800 m from a bus line	1990 1,263,300 87,400 622,200	100% 7% 49%	1998 1,662,500.0 90,500.0 709,700.0	100% 5% 43%	new jobs bet 399,200 3,100 87,500	ween 90-98 100% 1% 22%

Sources: Census data: Atlanta Region Information System, Atlanta Regional Commission and "Order Without Design", Bertaud 2002





The graphs above show how the high degree of polycentricism of Atlanta: in 1990 only about 75,000 jobs or 6% of all jobs were in the CBD (Central Business District).

60 % of the population had no direct access to public transport and 44% of the jobs were not accessible by public transport. One should note that the meaning of a job accessible by public transport on this graph means only that it is possible to use public transport and less than 12 minutes walk at both end of the trip to reach this job, it does not mean that it is practical do to so, because of the time of transport, transfers and walking to destination.



The graphs above suggest that the majority of firms and households do not recognize the value of locating within walking distance from public transport. The number of jobs accessible by public transport decreases between 1990 and 1998 from 66% to 48%. And 88% of the new population and 77% of the new jobs have located outside the reach of the existing networks of buses and metro.

The number of the jobs in the CBD (approximatively within 4 km from the city center) have actually decreased between 1990 and 1998.



Atlanta and Barcelona: why there are transit density thresholds?

The map above shows Atlanta and Barcelona built-up areas at the same scale. Barcelona had a slightly higher population than Atlanta in 1990. (2.8 million vs. 2,5). This graph illustrate the importance of densities in making transit possible. To provide an 12 minutes walk access time to transit stops for all of its population, Atlanta will have to develop and operate 4280 kilometers of transit line while Barcelona could provide the same service with 163 kilometers only. If Atlanta wants to maintain a frequency of 5 minutes between buses during rush hour it would have to use at least 2800 buses while

		Atlanta	Barcelona
area:	km2	4280	162
population (1990)	million people	2.5	2.8
Approximate length of bus lines required to provide	km		
an accessibility of 800 mto every bus stop		4,280	162
people per km of bus line	people/km	584	17,284
density	p/ha	5.84	172.84
Assumption on average speed during rush hour	km/h	18	18
Frequency of buses during rush hour	minutes	5	5
Distance between buses at rush hour	km	1.5	1.5
Minimum number of buses during rush hour		2,853	108

Barcelona could provide the same service with a minimum of 108 buses. In spite of this enormous advantage the % of trips made by public transport in Barcelona is only 30% of total trips, vs. about 4 % for Atlanta.

Conclusions:

- Transport has to be adapted to urban structures not the other way around,
- Urban spatial structures are path dependent, some structures are irreversible;
- Urban structures are dependent on the interaction of the land market with regulations, but ignoring the land market to rely entirely on regulations to "optimize" land use has serious side effects.
- Dominantly monocentric cities and high density cities are more favorable to transit that dominantly polycentric and low density cities.
- Whenever a city is dominantly monocentric and has a high or medium density is it legitimate to try to maintain this spatial structure through an enabling regulation and appropriate infrastructure investments. This will probably contribute to maintain a high level of public transport use.
- When a city current spatial structure is dominantly polycentric and low density, appropriate measure of transport has to be found to decrease pollution and congestion. A shift toward a higher use of transit is probably not among the feasible solutions.

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