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High-capacity transport, floor area ratio and its relationship with urbanization of metropolitan areas

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ABSTRACT

Most of the world's population lives in urban areas (54%). Near 42% of the global urban population live in cities with more than 1 million inhabitants, where problems associated with urban sprawl such as informal settlement, social-economic changes, environmental degradation and deficient high-capacity transport (HCT) systems are common. Meanwhile, urbanization and its associated transportation infrastructure define the relationship between city and countryside, between the city's inner core and the periphery, between the citizen and his right to move.

This article discusses and presents an overview about the relationship between the planning and extension of HCT systems and urban planning, (in the figure of the floor-area ratio - FAR- prescribed in regulations). The methodological approach consists of drawing a conceptual framework and studying 33 different cities of metropolitan areas on five continents.

It's noticed that areas in cities with a high construction potential but with an insufficient HCT negatively influence in urban mobility and hence the right to the city. We consider right to the city the various social and fundamental rights that, among others, includes the right to public transportation. Therefore there's a real need of an integrated approach of community participation, FAR distribution, urban planning and transportation planning and so that urbanization, inevitable these days, takes place in a fair and harmonious way.

1. INTRODUCTION

The term "urbanization" was coined by Ildefonso Cerdà in 1867. He understood that it was the urbanization task to "[…] expand infrastructure as much as possible in order to settle human habitat beyond the symbolic frame of the city". His expansion plan of Barcelona, 1859, is a paradigm regarding the successful implementation of an urban planning. Its

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strength is the application of a scientific method relating planned population density, routes, modes of transportation, services, markets, so that there is an equitable distribution and a compact city without large displacements.

Generally, the current process of urbanization has separately addressed the different spheres that act in the process of occupation and connection of the territories, particularly in dependent capitalist countries. The urban planning (zoning, floor area ratio –FAR-, land use regulations) on one hand and planning of high-capacity transport (HCT) infrastructure, on the other, are not conceived together, as a whole, not recognizing that the action of one influence in the development of other.

Thus, this article aims to better understand the relationship between the planning and extension of HCT systems and the FAR prescribed in regulations. The methodological approach consists of drawing a conceptual framework and studying 33 different cities of metropolitan areas on five continents.

2. METHODOLOGY

This discusses and presents a conceptual framework on the definition of HCT, the main aspects related to its implementation and expansion and FAR. It’s adopted the systematic review method, composed of investigation on indexing databases of research and on primary sources (official journals, i.e.).

At the same time, we performed a standard research, by email, in 33 cities of metropolitan areas in five continents, namely: Bangkok, Barcelona, Berlin, Bogota, Brisbane, Cairo, Cape Town, Caracas, Chicago, Durban, Hamburg, Hong Kong, Houston, Johannesburg, Kiev, Lima, Los Angeles, Madrid, Melbourne, Mexico City, Milan, Munich, New York, Paris, Philadelphia, Rio de Janeiro, Rome, Santiago, Saint Petersburg, Singapore, Sydney, Turin and Vienna. These cities were chosen based on the following criteria:

a. belong to a metropolitan area;
b. have similar population density or total population to the city of Rio de Janeiro (base city).

In the email we requested information about “[…] the relation between HCT systems and construction density (FAR)” in order to identify whether the city's “[…] transport system is planned also considering urban density forecasted on building regulations”. In other words, we intend to identify if there is a “conversation” between the transportation planning and the urban planning, in the figure of FAR.

3. CONCEPTUAL FRAMEWORK

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3.1. High-capacity transport (HCT)

According to the Washington State Legislature (2015) HCT is a system of public transportation services operating principally on exclusive rights-of-way, and the supporting services and facilities necessary to implement such a system, including interim express services and high occupancy vehicle lanes. The main goal of HCT is to provide higher level of passenger capacity, speed, service frequency, convenience and service reliability than traditional public transportation systems operating principally in general purpose roadways. Also, it's characterized by carrying a larger volume of passengers using larger vehicles and/or more frequent service than a standard fixed route bus system.

For Vuchic (2005) the high-performance transit modes are the light rail rapid transit, the metro and the regional rail. They have between 100 and 2,500 spaces in the transit unit and the line capacity (sps/h) between 10,000 and 70,000.

3.2. Floor Area Ratio (FAR)

In general is called like this in cities such as Madrid, Seattle, Philadelphia, New York. It is also known as: a) Floor Space Ratio (F.S.R.) in cities like Vancouver, Australia, Berlin; b) Floor Space Index (F.S.I) in cities like Hamburg, most of South Korean cities; Floor Lot Ratio (F.L.R.): Miami; Land Utilization Index (L.U.I.): Rio de Janeiro, Sao Paulo.

The FAR is a number that, multiplied by the lot area, indicates the maximum area that can be built in an lot, including all floors areas, measured from the exterior face of exterior walls, or from the center line of walls separating two buildings. Depending on the regulations of each city, certain built-up areas such as balconies, parking, machinery spaces, uncovered areas, etc., are not included in the FAR. It can be either expressed as a percentage or as a dimensionless number, as a result from the division of the maximum buildable area allowed by the lot area (Equation 1), being established as a maximum or maximum and minimum value. The use of the maximum and minimum value concomitantly has the aim of eliminating the underutilization of certain territories.

$$\text{F.A.R} = (\text{maximum buildable area}) / (\text{lot area}) \qquad (1)$$

The FAR alone does not predict the volumes of the buildings or the lot coverage rate (LCR)[2]. In practice, a FAR expresses the construction density of a lot. A FAR of 1.0 means that the floor area may equal the lot area while a FAR of 3.0 means that the floor area may be up to three times as large as the lot area, as showed in Figure 1.

[2] Lot coverage is that portion of a lot which, when viewed from above, is covered by a building.

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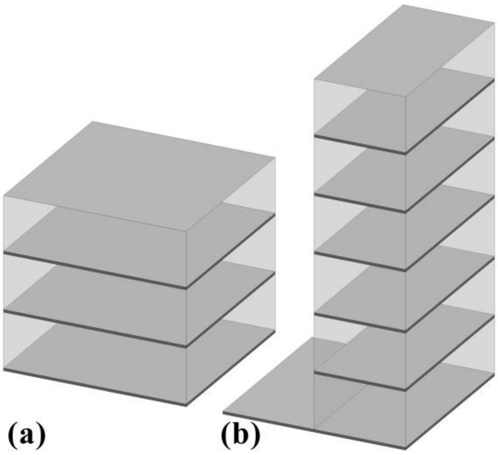

Figure 1: Drawing F.A.R. with different lot coverage rates (a) FAR = 3, LCR = 100% and height = 3 floors (b) FAR = 3, LCR = 50% and height = 6 floors

In the context of urban planning, F.A.R. must be employed with bulk regulations as lot area, lot area per dwelling unit, lot frontage, lot width, height, required yards, courts, usable open space, spacing between buildings on a single lot, and length of buildings in a row, setback and zoning (ASPO, 1958), it is possible:

c. determine the maximum size and placement of a building on a zoning lot;
d. require the bulk and scale of future buildings to have regard to heritage sites and their settings,
e. to reinforce and respect the existing character and scale of certain neighborhoods;
f. provide a transition in built form and land use intensity;
g. prevent the inclusion in the site area of an area that has no significant development being carried out on it;
h. promote high quality walkable spaces and pedestrian traffic;
i. regulate density of development and generation of transportation demand.

This article discusses this last item, the planning of high capacity associated with urban planning.

3.3. Main aspects related to HCT implementation and expansion

There are many aspects that influence HCT implementation and expansion as well as its operation and type. These generally include income, gender, auto availability, auto operating costs, parking availability and cost, transit service availability (Chesler, 2015, p. 1), population and employment density (these last two are a major or even the primary driver of transit demand). Primary indicators for auto-oriented cities like Los Angeles and Phoenix (Chesler, 2015, p. 1) and parts of Rio de Janeiro city (Barra da Tijuca) appear to be auto availability, income, transit availability and service frequency.

Studies have been able to relate the implementation of high and medium transport system

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capacity with the rent value of properties next to the systems such as Denny (2015), PTI (2015), Cervero (2011), Pan (2008). Mohammad (2013) conducts a meta-analysis on empirical estimates from 23 studies (102 observations) that analyzed the impact of rail on land/property value changes and shows that, in general, there are higher real estate values as the properties get closer to HCT stations.

Some works like Denny (2015), Senatsverwaltung für Stadtentwicklung (2009), Bertaud (2010), Grubbauer (2011), Lee (2011), Guerton (2012), South Dublin (2010, p. 76) and Crawford (2009) study specific areas of a city subjected to urban renewal projects and, in this context, calculate the average F.A.R. of the area. However, disregarding works such as Eberle (2014), OECD (2012) e Lainton (2011) there are few studies dealing with F.A.R. of a city as a whole.

Even less are studies that work with the relationship between transport and urban planning, in the figure of F.A.R. Given this situation, we have given priority to studies that relate population densities (which generally increase as F.A.R. increases) and ridership of HCT. Los Angeles Metropolitan Transportation Authority (2015, p. 29) works with minimum demand for each mode and characteristics of the operations, as follows:

- Heavy Rail (Subway): 2,500 boardings per route mile or more than 50,000 boardings per day;
- Light Rail: 1,000 boardings per route mile or more than 25,000 boardings per day;
- Express Routes: 300 or more boardings during peakhour and in peak direction of travel;
- BRT: 300 or more boardings during peakhour and in peak direction of travel or daily average of more than 500 boardings per route mile or more than 10,000 total daily boardings;
- Local, Limited and Shuttle Routes: 80 or more passengers during peakhour and in a single direction of travel and total daily boardings greater than 2,000.

Brisbane transport planning considers existing and planned activity centers and recommends the incorporation of higher density residential uses in transit oriented development precincts to increase vitality and provide more convenient access to services and transport. It uses baseline density guidelines (Queensland, 2009, p. 102) of dwellings per hectare to identify city locations capable of receiving different modes of HCT, as follows:

- activity centers: 40–120 dwellings per hectare (net) or greater;
- suburban and neighborhood locations: 30–80 dwellings per hectare (net) or greater;
- priority transit corridors: 40 dwellings per hectare (net) or greater.

The study from Cervero (2011) works with inhabitants and commercial densities. It states that light-rail systems need around 30 people/gross acre (7,413 people/ km^2) around stations and heavy rail systems need 45 people/ gross acre (11,120 people/ km^2) to place them in the top one-quarter of cost-effective rail investments in the U.S. The ridership gains from such increases would be substantial, especially when jobs are concentrated within ¼ mile (400 meters) of a station and housing within a half mile (800 meters). Increasing the

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number of jobs around stations, in particular, appears to have a stronger impact on ridership than increasing population.

Pushkarev and Zupan (1977) quantify the required levels of urban density to support transit. It's based on three factors: non-residential CBD floorspace, minimum residential units per net acre, and distance to the CBD. These factors are quantified for each one of the eight modes of public transportation analyzed: taxicab, dial-a-bus, local bus, express bus, light rail, light guideway transit, rapid transit and commuter rail. Using regression models, it was estimated travel demand (in terms of one-way trips per square mile) and passenger operating costs, at various service frequencies.

Guerra (2010, p. 7) studies minimum densities should municipalities zone for around existing or planned stations in different settings or for different types of investments. It concludes that for investments to pay off, there must be an unwavering local commitment to substantially raise population and employment densities along transit corridors.

Several studies have linked land use and urban space structure along rail transit like Chorus (2016) e Xiong (2014) proving that higher development intensity and more capital-intensive land uses occur in more accessible areas near train stations. This shows that a HCT corridor can be a convenient spatial and institutional unit to integrate transport and land use developments.

The Viennese Urban Mobility Plan (2015) sets out ambitious goals for implementing a viable transport system of the future for the city of Vienna, Austria, and it describes the steps to be taken in the next ten years so these goals can be reached. It is not just a simple expansion of infrastructure but a real integration between transport and urban planning, between urban expansion, public transportation availability, access to infrastructure and the right to the city. We consider right to the city the various social and fundamental rights that make up a system composed of a bundle of rights including the right to housing, to education, work, health, public services, leisure, information, security, heritage preservation and public transportation (Cavallazzi, 2008).

Also, in Sydney, Australia, the New South Wales (NSW) Government has a policy to integrate land use and transport planning to ensure the best outcomes for projects and to support the forecast growth of the state, working closely with the Department of Planning & Environment. This aims to ensure that all projects, including mass transit, take into account not only travel forecast but also demographic changes as a result of zoning regulations and new urban plans (considering floor area ratio and building height controls).

4. DILEMMAS IN STUDYING THE TRANSPORT-FAR LINK

In compact and high density cities, like London or Paris, the main aspects related to transport

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planning implementation and expansion are existing and future demand. Demand is a factor of the number of people, jobs, or other attractors within zones that are used in the assessment process. Through modeling, it is forecasts of these demand factors that generate forecasts of usage. It is the relatively large population growth forecasts, together with a continuing shift away from the private car that is driving much of compact's cities public transport growth. Increasing density and FAR is a factor of this growth, but the impact of density itself is currently a marginal factor. So, for this type of cities, there is no strict or direct relationship with urban density. As density increases there is generally a shift away from private car trips. This shift can be to walk/cycle, and/or to public transport (Transport for London, 2015). There can also be a slight change in the propensity to make trips as density changes, although this is more a result of car ownership (which in itself may be influenced by density of development).

FAR is deficient as a control of density and as a predictive device. (ASPO, 1958). Although it determines the maximum area that can be built, it is not necessarily related to the population density of a certain region. For example, in areas of a city where the real estate market demand larger residential units for wealthy buyers, there will be a smaller population density in relation to the FAR. In office building districts, it offers a way of predicting the ratio of persons to a unit of land of high land use intensity (ASPO, 1958) and means of regulating the generation of traffic, demand and of predicting future needs. Its best used when employed together with the number of units (residential and / or commercial and / or number of employees) per area, helping predict the flow of people (demand), the need for transportation and its type.

However, in cities with urban sprawl, with a not comprehensive or deficient public transport, especially in underdeveloped countries, the FAR, along with zoning regulations and housing density, are important factors that can promote densification in specific locations, avoid congestion, support transport planning decisions and ensure access to public transportation.

5. CASE STUDIES

Aiming to understand the relation between HCT systems and construction density (FAR) and its influence in the transport planning system we conducted a survey, by email, with 33 cities of metropolitan regions in 5 continents. After 05 weeks that all of the contacts were made through e-mail, we got responses from cities listed in Table 1, along with the following comments.

City(Country)	Comments on how HCT is planned and expanded
Los Angeles (U.S.A.)	Uses a Travel Demand Model based on the population and employment forecasts for the Horizon, typically 25-30 years into the future. The forecasts provide population, employment and retail employment by travel analysis zone. Also uses boardings per route mile or boardings per

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	day or boardings during the peak hour in the peak direction of travel, according to the mode of transportation.
Philadelphia (U.S.A.)	Service expansion and planning takes into account ridership growth opportunities based on a legacy system that was built 100 years ago.
Barcelona (Spain)	Passenger origin-destination flows; the construction of new stations can be made in areas with new residential settlements with significant population density.
London (U.K.)	Uses a Travel Demand Model, based on existing and future demand. It is forecasts of these demand factors that generate forecasts of usage. It is the relatively large population growth forecasts, together with a continuing shift away from the private car that is driving much of London's public transport growth. Increasing density is a factor of this growth, but the impact of density in itself is currently a marginal factor.
Madrid (Spain)	Passenger origin-destination flows; population density.
Vienna (Austria)	New urban developments need to be within easy reach. The dwellers of high population new urban developments should be able to take public transport for granted. Urban expansion will be restricted to those areas where sufficient public transport exists or can be established.
Brisbane (Australia)	Brisbane's transport system is planned considering the number of people, households, jobs and education enrolments rather than floor area. Focus on the highest residential and commercial densities around existing and proposed public transport nodes and corridors. Doesn't get into the scale of local zones. Identifies ideal minimum densities of dwellings per hectare. Forecasts are usually based on outputs from economic models.
Melbourne (Australia)	Network plan takes into account Melbourne's expected population and employment growth over the coming decades as well as where they will occur.
Sydney (Australia)	Integration between land use and transport planning (Department of Planning and Department of Transport) to guarantee the best outcomes for projects and to support the forecast growth of the state, ensuring that all plans consider the forecast demographic changes in projects.
Rio de Janeiro (Brazil)	Demand, current transportation infrastructure and the studies already made for the City, origin-destination flows

Table 1: Comments on how HCT is planned and expanded on the surveyed cities.

In overall the city's HCT are planned and expanded based on forecasts related to the increase in demand as well as expected population and employment growth over the coming years. That is, the main concern is that the increase in urban density alongside with the increase in demand is enough to guarantee the viability of the expansion of the HCT.

It's especially interesting Vienna's Urban Mobility Plan (Urban Development Vienna, 2015). It prescribes that the urban expansion will be restricted to those areas where sufficient public transport exists or can be established in parallel with development. So in this case the public transport is not a vector of metropolitan expansion neither is deficient in many areas, but it is planned concurrently with the urban development of the city.

Also it's worth mentioning New South Wales (NSW) Government plans for an area in south

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Sydney. The Department of Planning and of Transport for NSW recently worked together to prepare a land use and transport planning strategy for Sydenham to Bankstown. The Strategy looked at how to integrate the Sydney Metro extension, increased density around stations and the bus, road, walking and cycling network.

6. CONCLUSIONS

FAR is a supplementary device that does not necessarily replace the traditional means of relating bulk of building to land, to other buildings in the vicinity, and also doesn't directly establishes a relation with HCT. However, it's noticed that areas in cities with high FAR and with insufficient HCT are negatively influenced in urban mobility and hence the right to the city. It's the case of most metropolitan cities in developing countries, like Rio de Janeiro.

Unfortunately we obtained only 30% responses from the cities selected. From the obtained data 20% from North America, 40% from Europe, 30% from Oceania and 10% from South America. Only 20% explained that consider urban and transport planning together. The results must be extended for more cities; however it is clear the necessity to improve this "conversation": the interaction between the transport sector and the urbanization is fundamental to develop an equilibrated city.

It's also necessary rigid government control, to assure all rights to all people, like Vienna planning, that has a strong and dynamic interaction between transport planning and urban planning, clearly demonstrated in their mobility (Urban Development Vienna, 2015) and urban plans (Urban Development Vienna, 2014). An interesting example is the case of the real estate development called Aspern IQ, which was designed as an urban expansion restricted to an area where sufficient public transport existed or could be established in parallel with development. Also, it's important to promote a comprehensive participation from the community and land owners, like the Sydenham to Bankstown Urban Renewal Corridor, in Sydney (NSW Government, 2016). The NSW government receives and analyzes their feedback in order to develop the final plans for the city's transport extension. The right to the city is guaranteed.

There's a real need of an integrated approach of FAR distribution, population densities, urban planning, transportation planning and community participation so that urbanization, inevitable these days, takes place in a fair and harmonious way, and guarantees citizens' right to move, their right to the city.

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