Authors	Sergio R. Jara-Diaz
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Abstract

Optimal transit route structures for varying proportions of trips towards CBD and periphery.

Sergio Jara-Díaz, Antonio Gschwender and Claudia Bravo
Universidad de Chile

ABSTRACT

Starting with the seminal papers by Mohring (1972) and Jansson (1980) most of the microeconomic analysis of public transport design has been focused on the optimal levels of frequency and vehicle size on an isolated line. Kocur and Hendrickson (1982) and Chang and Shonfeld (1991) departed from this to introduce the spatial dimension by adding the spacing between parallel lines as a third design variable to optimize. Later on, the choice of a transit lines structure on a network has been discussed in the literature from various viewpoints. In recent years a series of papers on optimal lines structure emerged, dealing with the choice between services with and without transfers (Jara-Diaz and Gschwender, 2003; Jara-Diaz et al, 2012, 2013; Gschwender et al, 2014). The discussion on the appropriate lines structure has also expanded to real systems, as in the analysis of the impact of the implementation of direct lines crossing the city of Monterrey, Mexico (El-Hifnawi, 2002) or in the study by Sandoval (2010) who argued in favor of the introduction of direct lines in addition to feeder-trunk systems in several developing cities. These types of questions fall within the generic area of the Transit Route Network Design Problem (TRNDP) that has been studied mostly with the help of heuristics when dealing with real size transit systems. Within this view the analytical approach is seen as a potentially useful tool to provide a starting point for a detailed design (Kepaptsoglou and Karlaftis, 2009).

The study of simple networks using analytical models is helpful both for the strategic design of real transit networks and for policy analyses (Cedar, 2001). This has been our intention during the last decade, through the study of the optimal lines structure on simple but representative stylized networks (cross or Y shaped) under various forms of demand representation. In this paper we want to highlight two aspects of the problem. One is an urban network where local streets and main ones or avenues coexist. A second aspect is the presence of a demand pattern that is quite common in Latin American capital cities in the morning peak, namely the presence of large amounts of people traveling from the peripheral residential zones not only towards the CBD (where services, business, government and retail locate) but also crossing the CBD towards other peripheral zones to work mostly at local retail, private houses and labor intensive construction sites; these latter are long trips that cross the city to many disperse destinations.

In previous studies we have shown that total patronage and the way this total flow distributes in space (which we have named imbalance) do matter when analyzing an optimal lines structure. In this paper we will work over an

extension of the cross-shaped network presented in Jara-Diaz and Gschwender (2003), including two shorter links in all four extremes (local streets). Over this network a parametrically given demand *Y* originates in four adjacent peripheral points with destination at the center of the cross (short trips) and at the remaining four peripheral points (long trips); a parameter α represents the split (imbalance) of the *Y* origin-destination flows into long (periphery-periphery) and short (periphery-center) trips. Within this framework we will analyze three families of lines structures: mostly direct (DIR, periphery-periphery), hub and spoke (HS) and feeder-trunk (FT). For each structure fleet and vehicle sizes are optimized, considering both users' and operators' costs. The best structure is found parametrically in total passenger volume, the proportion of long trips and the value of the transfer penalty. The advantages of each dominating structure are explained in terms of factors like idle capacity, waiting or in-vehicle times and number of transfers.

Results show that transfer cost is a key parameter. In the base case (no transfer costs) the HS structure dominates nearly over all the (α, *Y*) space essentially because fleets adapt to demand and there is no idle capacity. When walking at transfers and disruption costs (which are found to vary up to 10 times in the literature) are considered, some DIR structures emerge as optimal alternatives. For synthesis, HS is the best structure for low proportions of long trips over all the range of demand (*Y*) for high transfer costs. The dominance of the DIR family for high proportions of long trips is essentially due to lower users' cost, as under those conditions users' cost is the determinant factor, because operators' cost of the HS structure become similar to the corresponding of the DIR family; in that case HS has more passengers boarding and alighting (more transfers) yielding larger cycle times and higher operating costs.

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