17 The Economics of Transportation Network Growth

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17.1 Introduction

A number of factors influence the efficiency, productivity, and welfare of transportation networks. Travel demand, user costs, and facility supply costs equilibrate on various time scales under a set of pricing (taxes and tolls), investment and ownership policies. Two types of equilibria exist in a transportation network, short-run traffic equilibrium and long-run supply-demand equilibrium. The phenomenon of traffic equilibrium is explored with a fixed transportation network where the capacity of links is given. Even though investment- and ownership-related policies are not of major concern for studies of traffic equilibrium, it is still a complex problem due to network congestion effects, variations of pricing rules, and multidimensionality of user choices. In order to understand the long-run supply-demand equilibrium in a transportation network, one has to consider all of the above-mentioned factors in a coherent analytical framework. We refer to this research problem as the transportation network growth problem, because the network evolves and link capacity is not fixed in the long run.

The growth (and decline) of transportation networks obviously affects the social and economic activities that a region can support, yet the dynamics of how such growth occurs is one of the least understood areas in transportation, geography, urban economics, and regional science. The growth of the transportation network is determined by the total amount of investment and the investment rule, both of which could change over time. What has become known as the network design problem in the transportation literature simplifies the network growth problem in three aspects: (1) investment decisions are considered independent of pricing rules and ownership structures; (2) only the optimal investment rule is considered; (3) inter-dependencies of sequential investment decisions are ignored. In
reality, the budget is typically determined by the revenue generated from the pricing policy and inter-agency negotiations. Various practical investment rules have been adopted by public or private decision-makers with different goals in mind, that are not necessarily socially optimal. Historical dependency is also an important property of network growth. Economic studies on transportation network growth should recognize these facts. A salient feature of the network growth problem, defined in this chapter, is that it considers the growth of transportation networks as endogenous, in contrast with current transportation planning practice that strives to exogenously direct that growth. In other words, transportation network growth is not entirely an artifact of design, but driven by various market forces present in the network.

Today’s decisions both depend on expectations of tomorrow, and constrain tomorrow’s choices. Understanding how markets and policies translate into facilities on the ground is essential for both scientific understanding and improving forecasting, planning, policy-making, and evaluation. An improved understanding of long-term network dynamics should lead to better planning and design of transportation networks to exploit network economies and externalities. The challenge for solving the network growth problem is that travel demand, cost structures, and all relevant policies must be modeled with accuracy and sensitivity. This chapter is therefore exploratory in nature, investigating these modeling needs and possible solutions. Another purpose of this chapter is to demonstrate how a network growth model can improve transportation planning in ways short-run network models cannot achieve.

Most previous studies have considered network pricing, investment, and ownership structures separately, which are reviewed in the following section. The next section considers choices of prices, capacity, and ownership simultaneously on small parallel, serial, and parallel-serial networks, and develops an analytical network model. Section 17.4 of this chapter discusses properties of long-run network equilibria with different network layouts and ownership regimes, and the implications on network efficiency. Section 17.5 concludes the chapter with some critiques on the analytical model and suggestions for future research.

17.2 Literature Review

Transportation economists have long been investigating various road pricing policies for optimal allocation of scarce road resources, primarily from a theoretical framework (Dupuit 1844, Pigou 1920, Knight 1924, Mohring and Harwitz 1962, Vickery 1963, Walters 1968, Small 1992, Arnott et al. 1993, Button and Verhoef 1998, Gomez-Ibanez 1999, de Palma and Lindsey 2002, Verhoef 2002). The economic theory also suggests that the optimal level of road investment is to expand a road to the point that the cost of one additional unit of capacity just equals the benefits it brings. An important finding, due to Mohring and Harwitz (1962), states that the revenue generated from the optimal pricing scheme is just sufficient to finance the optimal level of capacity under certain conditions. A series of stud-