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Locational dynamics of logistics facilities: Evidence from Tokyo

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ABSTRACT

This study uses data from a large-scale freight survey conducted in the Tokyo Metropolitan Area to jointly analyze the spatial distribution of logistics facilities and their proximities to the locations of shipment origins and destinations. The aim of the study is to examine in detail the argument that logistics sprawls increase truck trip distances, and thus would incur negative impacts to the society. We found that between 1980 and 2003, logistics facilities in the Tokyo Metropolitan Area have migrated outward, albeit in a much smaller scale than the cases documented in some U.S. and European cities. Our analysis of the shipment data confirms that logistics sprawl increases truck travel. Furthermore, we found that, regardless of their age, logistics facilities tend to increase shipping distances as their distances to the urban center increase, due to the spatial mismatch between the locations of the facilities and the shipment origins and destinations. The findings underscore the importance of comprehensive efforts to coordinate land use, not only for logistics facilities but also other businesses that generate freight movements.

1. Introduction

Logistics-related infrastructure systems in metropolitan areas around the world have gone through significant transformations over the last several decades promoted by the growth of the logistics industry, the evolution of global supply chain management practices, and technological innovations in logistics. In the U.S., the number of establishments and employment in the warehousing and storage sector increased by 111% and 451%, respectively, between 1998 and 2011 (U.S. Census Bureau, 2014). In England and Wales, warehousing space increased by 22% during the 1998–2008 time period (Allen et al., 2012). While flourishing warehousing and logistics industries are often coveted by local governments for their economic development potentials, the concern over the negative impacts caused by freight traffic is increasing. Negative impacts associated with truck traffic, including carbon emissions, energy use, congestion and infrastructure damage, are considered to be especially problematic when the development of logistics facilities occurs in an uncoordinated manner. Logistics sprawl is defined by Dablanc et al. (2014) as "the movement of logistics facilities away from urban centers" (Dablanc et al., 2014, p. 105). While outward migrations of logistics facilities reflect rational business decisions by firms in many cases, their impacts on the society are one of the emerging issues of concern for transportation researchers and practitioners alike. While the need for analyzing the impacts of the rapid shifts in logistics distribution using empirical data is recognized (e.g. Cidell, 2010; Hesse and Rodrigue, 2004), the dearth of freight facility and shipping data has prevented researchers to examine in detail some of the key issues concerning the logistics sprawl.

With the leadership of the Transport Planning Commission of the Tokyo Metropolitan Region in Japan, detailed freight surveys with a large sample of business establishments, Tokyo Metropolitan Freight Surveys (TMFS), are carried out in the Tokyo Metropolitan Area (TMA) roughly every 10 years. The data from the 2003 survey, which is the latest available as of July 2014, includes the responses from around 30,000 establishments and covers standard freight activity measures as well as facility and business information. The survey is arguably the most comprehensive of its kind. We derive insights into some key issues concerning logistics sprawl by analyzing the 2003 TMFS data.

Specifically, this paper discusses the changes in the spatial distribution of logistics facilities and their implications on the social impacts of goods distribution in the TMA through two main threads of investigations including, (1) analysis of the spatial distribution of logistics facilities in relation to the population and shipment demands, and (2) comparison of the proximities of the logistics facilities to origins of inbound shipments and destinations of outbound shipments with respect to the location and age of the logistics facilities. The paper tries to answer the questions such as how the spatial distribution of logistics facilities changed over time

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and whether their locations in relation to the urban center enhance or mitigate social impacts of trucking in urban areas.

This study introduces two proximity measures that can be used with freight survey data. The first measure is the average shipment distances based on the Euclidean distance between the coordinates of the facilities and the origins and destinations. The second measure is the difference between the actual and optimized (or minimized) shipment distances, where the latter is estimated by solving a simple optimization problem to find the median center of shipment origins and destinations. Although travel distance, for which proximity measures represent, does not always correspond to the level of negative social impact, the use of vehicle travel distance as the indicator of social disutility is quite common (Richardson, 2005).

To our knowledge, all existing literature on logistics sprawl examine cities in Europe or the U.S. We believe a study using the data from Tokyo, a megacity in Asia which is considered the largest metropolitan area in the world (United Nations, 2014), will provide a novel reference for understanding logistics sprawl and its implications.

The rest of the paper consists of the following contents; in Section 2 the literature concerning spatial distribution of logistics facilities are reviewed and discussed; in Section 3, the data and the analysis methodology are presented; in Section 4, the analyses of the geography of the logistics facilities through above-mentioned threads of investigations are provided; the final section summarizes the findings and puts forward recommendations for further research.

2. Spatial distribution of logistics facilities: literature review

2.1. Changes in logistics facility requirements

The recent changes in the roles and functions of logistics facilities are well-acknowledged phenomena. The elimination of barriers separating economies, in the forms of deregulation and liberalization, widened the scope of supply chain management, and the evolution in logistics integration transformed the way in which supply chain is actually managed (Hesse and Rodrigue, 2004). Using several different data sets, mainly from the U.K., McKinnon (2009) identifies the factors that influence logistics land requirements as the off-shoring of manufacturing, rebalancing of logistics cost trade-offs and advances of warehouse technology among others. Similarly, Cidell (2011) argues that containerization, the globalization of production, and the prevalence of just-in-time (JIT) production model have enhanced the need for high through-put facilities. In addition, the changes in retail business practices, such as the rise of electronic commerce (Dablanc et al., 2011), have increased the importance of the capacity of handling flows compared to the capacity of storage (Hesse, 2004). The need for centralized logistics facilities, which are desired to be larger and expandable, has emerged with the evolution of logistics practices and supply chain management. Several researches discuss the suburbanization or decentralization of logistics facilities, promoted by the availability of larger lands and cheaper land price in suburban locations and undesirable traffic conditions in core urban areas (Bowen, 2008; McKinnon, 2009; Hesse, 2004; Hesse and Rodrigue, 2004; Mueller and Mueller, 2007).

2.2. Studies of logistics facility distribution

Spatial decentralization of logistics facilities in metropolitan areas, which is often called "logistics sprawl", is the interest of several recent studies. The studies of U.S. cities typically use the Census Bureau's County Business Patterns data. Examples include a work by Dablanc and Ross (2012) for the Atlanta Piedmont Megaregion, Dablanc et al.'s study of Los Angeles and Seattle (2014) and Cidell's study of U.S. metropolitan areas (2010). Dablanc and Ross (2012) show that, between 1998 and 2008, the average distance to the barycenter of warehousing establishments increased by 2.8 miles (4.5 km) while the average for all business establishments increased by only 1.3 miles (2 km). They termed this phenomenon "relative logistics sprawl" in which logistics facilities move farther away than the businesses they serve for pick-ups and deliveries. Dablanc and Rakotonarivo (2010) compare locations of large parcel and express transport companies in Paris, France, using databases of establishments and building permits as well as the yellow pages of the French postal companies. They found that the average distance of terminals to their barycenter increased from 6 km in 1974 to 16 km in 2008. Meanwhile, logistics sprawl is not necessarily a consistent phenomenon in all metropolitan areas; in Seattle, the increase of warehousing establishments during 1998–2009 is mainly in the Puget Sound region, near the weighted geographic center and, therefore, sprawl has not occurred (Dablanc et al., 2014).

Some studies have examined spatial distribution of logistics facilities at national scale. Cidell (2010) applies indicators such as the number of establishments per population and Gini coefficients of logistics establishment's distribution for measuring the concentration of logistics activities in the U.S., while Rivera et al. (2014) apply Horizontal Cluster Location Quotient and Logistics Establishments Participation index for the same purpose.

While these studies often point out that logistics sprawls are likely to generate negative impacts due to increased shipment and truck travel distances, because of data limitations, they do not analyze in detail actual changes in shipment patterns that may accompany logistics sprawls. As noted above, since logistics sprawls have been partly driven by the changes in supply chain strategies, it is a legitimate possibility that the newer facilities are not used in the same way as older ones. As such, actual impacts of logistics sprawl, at least the ones that are related to truck vehicle kilometers traveled (VKT) or frequency of trips (e.g. congestion, energy use, infrastructure damages, and greenhouse gas emissions) may be greater or less than those implied by the spatial distribution of the facilities.

2.3. Locational decision making of logistics-related entities

The research on location decisions for logistics facilities is relatively scarce in comparison to the studies of general business establishments. Woudsma et al. (2008) analyze the performance of accessibility indicators for estimating the locations of logistics land use developments using spatial-autoregressive modeling techniques. The analysis, conducted using the data from Calgary, Canada, finds that accessibility measure based on travel time is a statistically significant predictor of logistics land use developments. They also find that congestion has even stronger influence on logistics land use. Furthermore, the study identifies 5–10 year lag between accessibility and its influence on land use developments. Van den Heuvel et al. (2013) examine the spatial concentration of logistics establishments during the period 1996–2009 using the data from North Brabant in the Netherlands. Their analysis identifies agglomeration as well as the knowledge of local areas influence the location choices for logistics establishments.

TMFS data have been used to study locational choices. Nguyen and Sano (2010) develop a location choice model (discrete choice model) for logistics firms that considers spatial effects using the 2003 TMFS data. They estimate models for retailers, product wholesalers and other manufacturers applying zonal population, number of zonal employees, land price, number of employees and floor area of a firm as predictors. Hagino and Endo (2007) also