Transport Policy 50 (2016) 115–125

Contents lists available at ScienceDirect

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

An effects analysis of logistics collaboration in last-mile networks for CEP delivery services

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ARTICLE INFO

Article history:
Received 16 March 2015
Received in revised form
18 March 2016
Accepted 10 May 2016
Available online 24 May 2016

Keywords:
CEP delivery service
Logistics collaboration
Last-mile network
Horizontal delivery
Vertical delivery
Spatial clustering

ABSTRACT

Rapid increases in courier, express, and parcel (CEP) delivery demand have made environment- and traffic-related issues important in metropolitan areas. This study analytically formulates CEP delivery behaviors in last-mile networks to estimate the effects of logistics collaboration for apartment complexes. Reflecting courier delivery behavior, the CEP delivery problem was divided into horizontal and vertical routing problems. Optimization methodologies commonly utilized in the operations research area were employed for the analytical modeling of these two routing behaviors. The proposed methodologies were applied to apartment complexes in Seoul, Korea. It was found that the financial feasibility of CEP collaboration is guaranteed when the number of households in an apartment complex exceeds about 900. From the financial perspective, CEP collaboration is applicable to 9.1–19.4% of the apartment households in Seoul. In addition, CEP collaboration was analyzed to provide a meaningful amount of social cost savings, implying its economic feasibility. The public sector's roles in stimulating CEP collaboration are discussed from financial and legislative perspectives.

1. Introduction

With the spread of new technologies and in response to economic and social changes, the courier, express, and parcel (CEP) industry has experienced considerable global growth and has prospered as a door-to-door, same- or next-day delivery service (Kim et al., 2014). This process has increased CEP volumes, especially for home delivery (Hesse, 2002; Esser and Kurte, 2005; Weltevreden and Rotem-Mindali, 2007). Thus, CEP actors are increasingly confronted with the “last-mile” issue, and firms and stores have modified their urban supply chains, increasing the frequency of just-in-time and small, divided deliveries (Gevaers et al., 2011; Menge and Hebes, 2011). At the same time, urban goods distribution has become an important issue for cities (Patier and Routhier, 2008).

Services offered in a competitive service-oriented market must be reliable, effective, and cost-efficient. Responding to many physical and operational limitations, CEP companies have adopted highly mobile and accessible light trucks to provide fast and efficient service. This has significantly increased commercial vehicle movements in urban areas, which has strongly impacted urban issues such as transport infrastructure repairs, accidents, and pollution costs. In particular, the rise in commercial vehicle movements in apartment complexes, an efficient type of residence for densely populated areas, has created problems such as traffic congestion and accidents. Another issue related with last-mile CEP service is crime. There are 20 CEP companies in Seoul, Korea, and therefore at least 20 different service people visit apartment complexes to provide delivery service. The apartment complexes' residents do not recognize them well, and thus many crimes have been committed by people pretending to be service people (Kim et al., 2014).

Delivery efficiency must be improved, especially the CEP-sector delivery service networks, which are beset by rising energy costs and fierce competition among carriers (Schwind et al., 2010). In addition, consumers demand higher standards of ecological sustainability management from the transportation business sector (Leonardi and Baumgartner, 2004). Collaboration among CEP carriers is one possible solution for city logistics problems. Solutions through CEP logistics collaboration are increasingly focused on the optimization of last-mile delivery networks in inner city regions to solve the problems caused by the increase in commercial vehicle movements (Fusco et al., 2003; Taniguchi et al., 2003).

Seoul, the capital of Korea, has a quarter of the nation's population and has the highest population density among OECD capital cities. Its high population concentration during the 1970s and 1980s led to a serious housing shortage. The government initiated a housing supply policy that triggered the construction of large apartment complexes. This trend has continued, and much of

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http://dx.doi.org/10.1016/j.tranpol.2016.05.009
0967-070X/

Seoul's housing consists of densely populated high-rise apartment complexes. The city's trunk line transportation strategies are diversified in accordance with the characteristics of each individual CEP company, but no similar strategies are found in the city's last-mile networks, whose urban structure is quite differentiated. This creates several socioeconomic problems for the residential and transportation environments.

Introducing logistics collaboration to the CEP delivery system in last-mile networks could produce several benefits, especially for apartment complexes (Seo and Lee, 2014). For example, the R apartment complex in Seoul, which has approximately 26 buildings, 2400 households, and 1000 delivery demands per day, has recently adopted a collaborative delivery system. The new CEP delivery agency has contracts with nine CEP delivery companies and offers an integrated delivery service. This agency has a collaborative delivery center, comprising an office, a restroom, and facilities (e.g., cold storage, conveyor belts, pallets) installed in an underground parking lot. The agency draws a commission on the delivery of each order from the individual companies and pays a fee for renting the center to the R apartment office. The collaborative delivery system increases delivery efficiency in last-mile networks, reduces delivery truck traffic, and prevents access by criminals impersonating delivery service people. The change has produced residential, environmental, and social benefits such as savings in vehicle operation, travel time, accident, and pollution costs. Seoul's S apartment complex also introduced a collaborative delivery system. However, complex officials treated logistics collaboration as a profit-making business, and the operation failed to take root. Meanwhile, the Unified Government Building in Gwacheon, where delivery service people were not allowed to enter for security reasons, began applying logistics collaboration in September 2011. Although this system has reduced parking lot congestion and improved delivery efficiency, it has been difficult to achieve financial sustainability owing to the limited number of packages it handles.

Beyond several theoretical approaches and practical cases, no analysis of how the issues raised by logistics collaboration for CEP service have been undertaken to determine what benefits it generates. This study estimates the effect of logistics collaboration in last-mile networks, focusing on apartment complexes. The study formalizes both individual and collaborative CEP delivery behavior in last-mile networks and estimates their total traveling distance and time. The CEP delivery process in last-mile networks is divided into horizontal and vertical deliveries. The capacitated vehicle routing problem (CVRP) and a four-step experiment are used to describe horizontal and vertical deliveries, respectively.

The remainder of this paper is organized as follows. After a literature review, the mathematical formulations and solution algorithms are presented. Then, the study area, sensitivity analysis, and spatial clustering are described. Next, the numerical results of logistics collaboration are discussed. The final section summarizes the conclusions, policy implications, and extensions of this study.

2. Literature review

Logistics collaboration has been thoroughly studied and discussed by both scholars and practitioners (Caputo and Mininno, 1999; Schmoltzi and Wallenburg, 2012). It has been referred to as a critical factor (Naesens et al., 2009; Lindawati et al., 2014) for logistics competitiveness. Among the cooperative sectors in logistics, the CEP industry remains a neglected topic, and the related literature is in its infancy (Leitner et al., 2011). An important aspect that has not received the attention it deserves is the reluctance of some shippers to participate in urban consolidation centers (UCCs). Two independent surveys (Regan and Golob, 2005; Holguín-Veras et al., 2008) have estimated that carriers' willingness to participate in UCCs is in the range of 16–18%. Urban staging areas (Holguín-Veras et al., 2008) could increase load factors and reduce truck traffic. This concept is appealing in a number of ways. First, it takes advantage of existing infrastructure, which bypasses the need to invest in an entire building, and minimizes ancillary expenses such as security and lighting. Second, it would work well for non-perishable items, which represent a large portion of deliveries. Third, it is scalable, as the space used could be scaled up or down as needed. Fourth, it eliminates shippers' concerns about loss of contact time with customers and brand recognition. The estimates suggest that anywhere between 15% and 19% of carriers would be interested in such a concept (Holguín-Veras et al., 2008; Holguin-Veras and Sanchez-Diaz, 2016).

Logistics collaboration is understood as a tailored business relationship based on mutual trust, openness, shared risk, and shared reward yielding a competitive advantage resulting in business performance greater than firms would achieve individually (Lambert et al., 1999). Studies on urban logistics collaboration can be categorized into three groups (Gonzales-Feliu et al., 2014). The first focuses on computer modeling and simulation. Such methods use operations research methods mainly derived from vehicle routing frameworks (Toth and Vigo, 2002). Two main approaches are taken: a single-tier system in which commodities are directly shipped from urban collaborative distribution centers (UCDCs) and two-tier systems in which new intra-modal transfers are organized between UCDCs and the goods' final destination (Lee and Jeong, 2008; Van Duin et al., 2008; Crainic et al., 2009). The second group includes quantitative evaluation and assessment methods. These studies use quantitative economics and econometrics techniques to evaluate the feasibility of urban logistics collaboration. Once the location has been chosen, the main strategic decisions are made (Van Duin et al., 2008; Ambrosini et al., 2013). The European project CO^3 (2014) presented a set of key performance indicators (KPIs) from logistics horizontal collaboration: (1) higher utilization rate of delivery vehicles (cube and weight fill), (2) lower number of kilometers driven in the transport network (especially empty ones), (3) lower number of receptions at the gate of the Spar Retail warehouse (lower cost of labor), (4) lower inventory levels (higher inventory rotation), (5) higher customer service level (faster deliveries and small drops), and (6) positive impact for society (reduced traffic). Lin. et al. (2014) examined the effectiveness of urban delivery consolidation in terms of monetary logistics cost, energy consumption and $PM_{2.5}$ emissions with respect to a number of operational (e.g., rent cost, customer demand) and policy factors (e. g., commercial vehicle size restriction in city centers). The third group comprises qualitative and discussion studies that assess the suitability and limitations of urban logistics collaboration, based on either literature surveys or case studies (Allen et al., 2012; Arvidsson and Browne, 2013; Janjevic et al., 2013; Ville et al., 2013; Dablanc, 2014).

In seeking a sustainable logistics environment, CEP-centered solutions have been increasingly focused on the optimization of last-mile delivery networks in inner-city regions (Fusco et al., 2003). A two-stage process is often formulated to simplify the CEP network optimization problem (Zäpfel and Wasner, 2002). The most well-known approach for finding the optimal depot location in a CEP delivery network is the location routing problem (LRP), in which a vehicle routing problem (VRP) is integrated into the system to consider the real pickup and delivery tour expenses needed to visit multiple customers (Nagy and Salhi, 2007). The VRP is one of the most thoroughly studied topics among combinatorial optimization problems because of its practical relevance and difficulty. The VRP is concerned with determining the optimal route for a fleet based at one or more depots to serve a number of customers. Many additional requirements and operational constraints are imposed on route construction in practical VRP applications (Sungur et al., 2008). The CVRP is a fundamental issue that considers vehicle capacities in combinatorial optimization, with wide-