Light Electric Freight Vehicles for Last-Mile Delivery

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Summary:

A recent development in the postal sector is the use of light electric freight vehicles (LEFV) in urban and suburban areas as a sustainable and cheaper solution for last-mile delivery. Limited research has been performed regarding the impact of LEFV on distribution cost and network design. This thesis introduces a two-echelon location routing model for postal operators (POs) to determine the optimal network configuration for mail and parcel delivery in order to minimize total distribution costs using LEFV in their vehicle portfolio.

Before coming to MIT, Ronald worked as head of cluster distribution for the Dutch postal operator PostNL. In this role he is leading the team responsible for the development and implementation of a new distribution strategy. He holds a MSc in Business Administration and a MSc in Technology Management from the University of Groningen in the Netherlands.

KEY INSIGHTS

1. Across all tested scenarios, the introduction of LEFV into vehicle fleet leads to significant distribution cost savings.
2. LEFV are specifically suited for delivery in geographic areas with a high density.
3. LEFV enable synergy between the mail and parcel delivery networks but require hubs in local proximity to the delivery area (i.e., shorter linehaul)

Introduction

In previous decades the postal sector has experienced drastic changes. The big change started at the end of 2010 when the introduction of a new international Postal Directive (i.e., law) brought an end to the monopoly status the national Postal Operators (POs) held up till then. The full liberalization of the postal market immediately resulted in new competitors entering the profitable national mail markets, trying to take over niche products in the profitable regions of a country. The introduction of a Universal Service Obligation (USO) ensured by law that each inhabitant had access to mail 5 days a week, limiting POs in their efforts to downsize their distribution network. Furthermore, the usage of electronic communication methods (e.g., email) caused high substitution levels in POs letter segment resulting in a continuous yearly volume decline of 5 to 10%. On the contrary POs are strong players in the growing e-commerce market. Retail e-commerce sales worldwide are showing solid gains in 2017, rising 23.2% to $2.290 trillion, resulting in a strong growth of demand for parcel delivery. To cope with these ongoing market developments POs, need to rigorously restructure their delivery networks more frequently than other industries, in order to reduce transportation cost and search for synergy opportunities between the mail and parcel distribution networks.

Furthermore, a recent development in the sector is the use of light electric freight vehicles (LEFV) in urban and suburban areas as a sustainable and cheap solution for postal delivery. After the introduction of LEFV by Danish Post (Postal and Parcel Technology International Award winner 2012), other European POs quickly followed.

Figure 1 – Delivery by a postal worker via LEFV source: PostNL

Typically, a LEFV is an electrically supported bicycle, with a payload between 0.5 and 3.0 cubic meters, used to transport freight. An example LEFV is shown in Figure 1. The electrical support system puts less physical strain on postal workers compared to traditional bicycles. This enables postal workers to work longer shifts. Moreover, it is a sustainable and cheap alternative to car delivery in dense areas. Another advantage is that LEFV's payload allows postal workers, historically using bikes in (sub)urban areas, to deliver mail items together with small parcels seizing synergy opportunities between the parcel and mail networks.

Research regarding the actual cost benefits of LEFV on a large scale is severely limited. Moreover, using LEFV necessitates a redesign of the hub and spokes structure. The LEFV have to be stored in the facilities and will require hubs in close proximity to their delivery area. This research presents a model for POs to determine the optimal network configuration for mail and parcel delivery in order to minimize total distribution costs using LEFV in their vehicle portfolio. This research includes a real-world application at the Dutch PO PostNL. PostNL has a fully separated mail and parcel network and has performed several successful pilots with LEFV. This model can therefore support their strategic decision regarding a possible merger of the distribution networks and the expansion of their vehicle fleet.

Methodology

The presented mixed integer linear programming (MILP) model is a *two-echelon location routing model* (2E-LRP), aiming to minimize the total distribution cost in the postal network. The supply chain network includes three types of nodes: depots (i.e. postal sorting centers), satellites (i.e., postal pickup points) and customer segments (i.e., set of customers in a region). The mixed multi-tier delivery system distinguishes between a tier for the delivery of mail directly from the depot to the customer segments and a tier enabling indirect delivery through the satellites to the customer segments. The 2E-LRP allows tours to deliver mail or parcels separately or perform combined delivery of mail and parcels to a customer segment. This allows the model to determine in which customer segments it is feasible to integrate the parcel and mail delivery network (see Figure 2).

The tier feeding satellites with mail and parcels from the depots is modeled by a multi-depot VRP. A set of binary decision variables show respectively the actual tours of the trucks feeding the satellites from the depot, satellites allocated to a specific depot, and the active depot locations. The tier performing the delivery from depots or satellites directly to the final customer segments is modeled using continuous approximation (CA) methods in order to estimate the cost of serving a customer segment. CA methods applied to LRP enable the estimation of the expected distance of a delivery route, without determining the actual routing sequence throughout the points of delivery (POD). Since the aim of the LRP is strategic by nature, the actual routing sequence can be ignored. A second set of binary decision variables show which satellites to activate and which customer segments to serve from which satellite or depot. Moreover, it shows the optimal vehicle for the tour and the optimal network type (i.e. separate or combined delivery).

The test set was based on the geographic zone of Utrecht, the Netherlands. The total delivery area serves 8,000 POD, and has a variety of density characteristics. Three scenarios were tested. First, the impact of LEFV on the standalone mail network. Second the impact of LEFV on the standalone parcel network. Third, the impact combining the networks without LEFV. Fourth, the impact of LEFV on a combined delivery network.

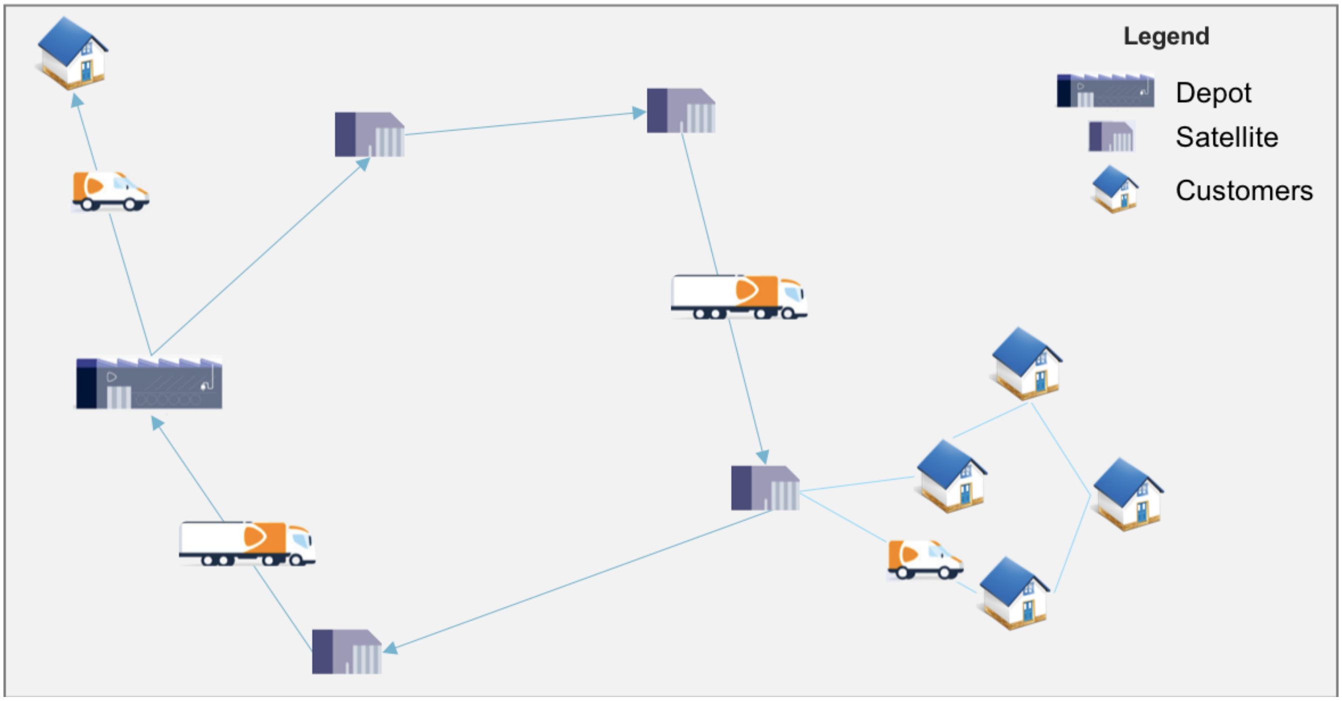

Figure 2 – 2E-LRP applied to PostNL

Results

As presented in Figure 2 our findings show that the introduction of LEFV in the mail distribution network leads to significant cost savings. The advantages of LEFV - increased maximum service time and higher speed - result in a 3% reduction of distribution cost. There is substitution of bicycles with LEFV, while the number of scooters remain at a constant level. Scooters are more useful in areas with a lower density and consequently a larger intra-stop distance. Even when the market volumes will drop according to the forecast, investing in LEFV still results in a significant cost saving. A reduction of volume leads to longer intra-stop distances resulting in more benefits as a result of the LEFV's higher intra-stop speed in comparison to bicycles. Payload does not play a major role in the mail network, since the maximum service time is the limiting factor.

In the separate parcel network, the introduction of LEFV also leads to a reduction of +/- 3%. Vans in dense customer areas are substituted by LEFV which have lower operating cost, while still reaching a similar intra-stop speed as a consequence of the high customer density. A second echelon is created with satellite locations in close proximity to the LEFV served customer areas, minimizing the linehaul distance to compensate for the slower linehaul speed of LEFV compared to vans. Selecting a LEFV with a payload between two and three cubic meters is essential in order to use these vehicles efficiently. Smaller payloads do not lead to a substitution of vans. An increase of future parcel volumes results in a higher customer density. This will lead to more cost savings when LEFV are used. This brings the total distribution cost saving to 5.5%, making it a robust model for the future.

While benefits of combining delivery of parcels and mail with the current vehicle fleet seem severely limited (i.e., cost saving less than 1%), the merger of networks with LEFV in the vehicle fleet does lead to additional savings up to 5%. Cheaper vehicles with similar speed characteristics on short intra-stop distances in dense areas are favorable over vans. Similarly, to the standalone parcel network scenario a second echelon is created. The increase of indirect delivery and the opening of multiple satellites ensures that linehaul distances are minimized.

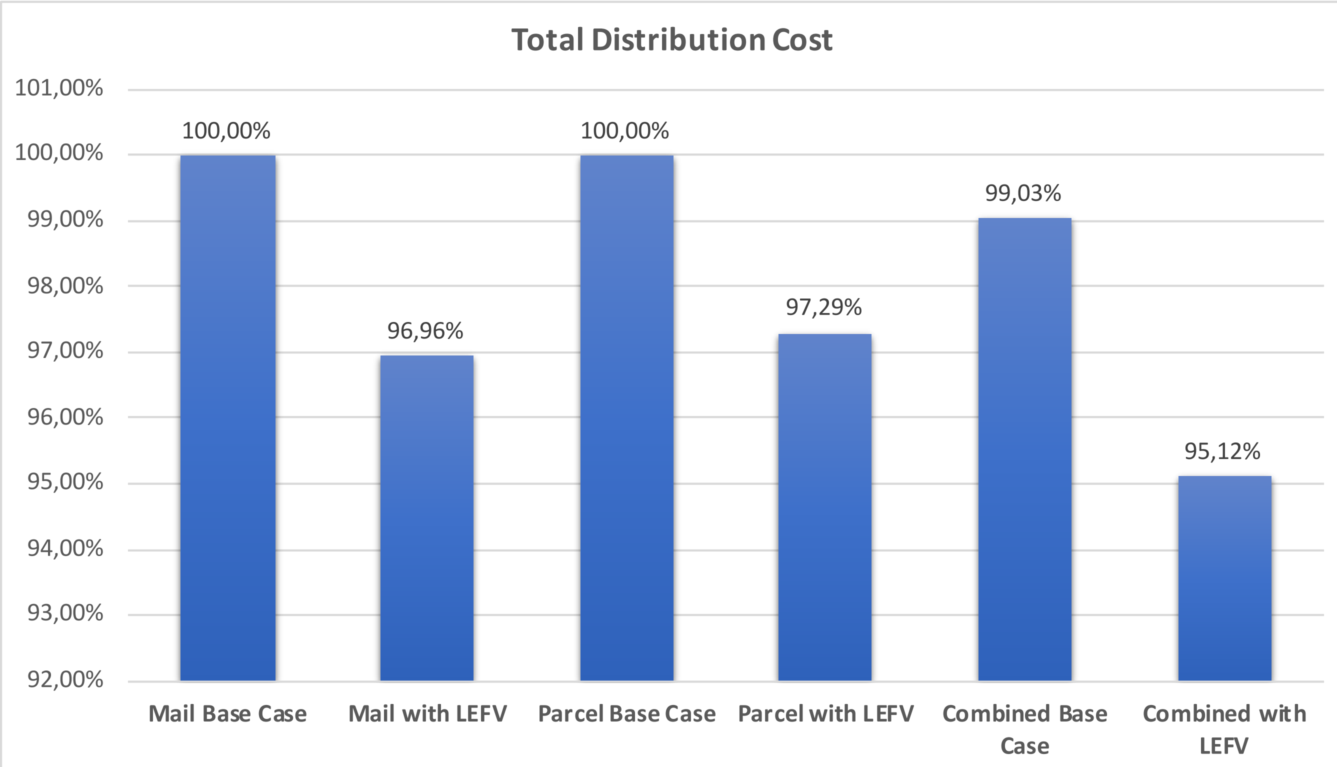

Figure 3 – Total Distribution Cost

Conclusions

The proposed model and findings in this research can support PostNL in its decision-making process regarding a possible merger of the distribution networks in the future. Our research shows that the introduction of LEFV in last-mile delivery results in significant distribution cost savings between 3-5% in this specific area. LEFV are a worthy alternative to vans in dense city areas, due to their high speed on short distances and their maneuverability in city areas. Moreover, they offer a longer maximum service time (MST) due to less physical strain on the deliverer and higher payloads than bicycles.

Our model suggests that traditional bicycle routes in the mail network can be substituted by LEFV. The additional operating and storage cost are more than compensated by the faster speeds on the intra-stop and line haul distances. Moreover, in the parcel network LEFV with a minimum payload of 2 cubic meters will substitute traditional vans. LEFV reach similar speeds as vans in dense city areas. To overcome the lower linehaul speed, the model suggests creating a second echelon network opening satellite locations in close proximity to dense city areas. A combination of the mail and parcel network seems infeasible with the current vehicle fleet mix due to limited savings. Bicycles and scooters are not suited for delivery of parcels due to their limited payload, while at the same time migrating letters to the parcel network served with vans would lead to higher operational and labor cost. The inclusion of LEFV in the fleet would allow PostNL to start combining delivery with distribution cost savings up to 5.5%. Sensitivity analysis following the market volume developments show that the cost benefits remain for the coming years.