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# Calculating the net cost of home delivery

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## 1. Introduction

A number of universal service providers (USPs) see their yearly mail volumes declining; some have even been experiencing sharp declines in consumer demand. Against this background, it appears likely that USPs may require compensation for universal service obligations (USO) that would have to be provided by government funds or through a cost sharing mechanism. Under the current EC regulatory framework, USO compensation requires calculating the “net cost” of the USO. There is a consensus among economists that the net cost is to be calculated based on the profitability cost approach presented by Panzar (2000) and Cremer et al. (2000), i.e. as the difference in USP profits with and without the USO.<sup>4</sup>

One essential element of the USO and hence of USO net cost calculation consists in the obligation of home delivery, which entails two major USO requirements: (1) Frequency: Daily delivery (2) Coverage: Nationwide home delivery. In regulatory practice, claims made by USPs that frequency of delivery constitutes a net cost seem to be accepted to a certain extent, in particular if national requirements include six delivery days. USP net cost claims of not serving entire remote areas have often been rejected, e.g. in Denmark, based on the belief that foregone revenue would be larger than avoided cost.

With no USO on delivery in place, the USP may be able to increase profits by optimizing delivery. In this paper, three potential approaches to optimization are analyzed. With respect to frequency, the USP might (1) *adjust the number of weekly delivery days*, e.g. from six to five and even to three or one day(s) in selected remote areas. With respect to coverage, the USP could (2a) *stop delivery services to certain areas*. As a result, all costs associated with providing services to the area in question would be saved. Equally all revenues would be lost. Alternatively, the

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<sup>4</sup> For a discussion on consistent regulation assumptions in the scenario without the USO cf. Jaag, Trinkner and Uotila (2013)

USP could (2b) *adapt the place of delivery* of households that are particularly costly to serve. In this case, households would continue to be served while the mail would be delivered to delivery points that exhibit lower cost such as road-crossings or P.O. boxes.

In this paper, the net costs related to the three potential optimizations introduced above are analyzed using the bottom-up delivery model presented in Trinkner et al. (2012). The delivery costs for the different counterfactual scenarios are simulated in a bottom-up model. The cost effects for the rest of the postal value chain are calculated based on empirical cost elasticities. The estimated costs savings are contrasted with potential foregone revenues to identify the potential for net costs. Special attention is paid to the demand effects that arise from modifying delivery services.

The paper is structured as follows. Section 2 introduces the delivery cost components that are potentially affected from the three modified delivery schedules. Section 3 presents the bottom-up model and calibrations. Section 4 applies the model to calculate the effects of adaptations in coverage and frequency. Section 5 concludes.

## **2. A bottom-up approach to calculate net costs of home delivery**

Once a given quantity of mail is sorted to the route level, the main cost drivers for delivery can be broken down into *route*, *access*, and *load* time as applied by Cohen and Chu (1997). Additional fixed costs arise from running the delivery office (if operated independently from the post office)<sup>5</sup>.

Taking the delivery of a particular street as an illustration, route time represents the time needed to travel along the street and access time is the time required to reach individual mailboxes from the street, Load time consists of the time needed to feed each mailbox. While load time is essentially variable with respect to the number of mail items delivered, access and route times are quasi-fixed costs. For a given delivery point, access time is variable with the first mail item, afterwards it is fixed. For a given (independent) route section, route time is variable with the first mail item for that section, afterwards it is fixed up to the most remote

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<sup>5</sup> In the quantitative part of the paper it is assumed that delivery centers are operated in different locations than post offices. This is increasingly the case in Europe and simplifies the exercise, as interdependencies between different USO dimensions do not have to be accounted for. See Jaag, Koller and Trinkner (2009) for a discussion on the need of a global approach to calculate the net costs of the USO to account for interdependencies between the various USO dimensions.

delivery point receiving mail. In countries with high volumes per capita, route times can be considered as effectively constant, and access times as mostly constant.

Compared to the status quo, the three delivery modifications presented above have the following direct impact on route, access and load time.

(1) Reducing the frequency of delivery saves the entire route and access time on days when delivery services are no longer offered, while load time is shifted to the next delivery day. The fixed cost of maintaining a delivery office persists. On the remaining days, the probability of serving a particular household increases if the effect of the new delivery schedule on consumer demand is limited. As a result, route times may increase in regions with very low volumes per delivery point, and access times may increase slightly even in regions with high volumes per delivery point.

(2a) Refraining from serving entire areas implies that all corresponding route, access and load times as well as the costs of delivery offices other than post offices can be avoided. At the same time, however, 100% of revenues associated with the area are forgone, and the people who had been served in those areas no longer get mail.

(2b) Adapting the place of delivery from one or several delivery points, e.g. from the doorstep to the road crossing, reduces route and/or access times. If the distance to the road crossing is acceptable for the recipients, the mailbox will still be emptied and hence no revenues are lost and load time remains constant.

The calculation of the net cost associated with delivery schedules (1) and (2b) hence requires the consideration of changes in quasi-fixed cost components (route and access times) that depend on the effects on daily delivery quantities and the specific spatial distribution of delivery points. A bottom-up model taking into account location-specific cost elements is well suited to estimate the effects of changes in delivery on route and access times. Econometric cost analysis would need very detailed data for reliable estimations which is not readily available. Moreover, it would not be able to take into account effects between routes (i.e. the optimality of one route) depends on neighboring routes).

In the remainder of the paper we present a bottom-up model that can be used to simulate the cost effects of alternate delivery models for different demand scenarios (high volume vs. low

volume country; high negative impact of new delivery schedule vs. no impact) and show simulation results calibrated to Switzerland. Thereby, the distinction between route and access time is not necessary. Route and access time are therefore referred to together as “street time”.

### **3. Model and Calibration**

#### **3.1 The bottom-up model**

To calculate the costs effects of different modes of home delivery, the bottom-up model introduced in Trinkner et al. (2012) is used and calibrated to real street times of Swiss Post. In this model, the location of the delivery center is fixed whereas the number of delivery days, the coverage of delivery or the places of delivery can be varied. To determine the street time costs (costs of route and access times) as a function of the spatial distribution of the households around the delivery center, the delivery process is treated as a routing problem (minimizing the street time to deliver all the mail) and solved with numerical methods.<sup>6</sup> To keep the model tractable, it is assumed that the carrier can move freely in the area.

This bottom-up approach does not deliver street times directly. Instead, it computes linear distances, which can serve as proxies for the real street times. The model therefore requires calibration to effective street times of the local postal service to determine effective route costs. Below this is achieved by comparing actual street times with simulated street distances for the entire delivery network of Switzerland. The analysis reveals that the model is capable of accurately describing the effective street times. Once calibrated, the model allows comparisons of delivery costs across various USO definitions and letter volumes.

#### **3.2 Calibration**

For 810 delivery offices in Switzerland delivery routes are simulated and the model’s predictions are compared to actual street times.

Regressing simulated distances on real street times for every of the 67 delivery regions, consisting of the 810 delivery offices and about 8000 routes, leads to an average  $R^2$  of 95.37%. Hence over 95% of all variation in Swiss Post’s street times can be statistically explained by

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<sup>6</sup> To relate to the previous section the model simulates route and access times together, i.e. no distinction is made between the two and both are estimated together. Load times are assumed to remain constant in all scenarios (i.e. 100% variable).

the model, meaning that the model approximates actual street times very well. The fit could be further increased by introducing dummies to describe the delivery technology (car, e-bike, foot, etc.).

It is, however, unclear whether the model also constitutes a reasonable and unbiased estimate of street times in scenarios with adapted places of delivery. This cannot be tested directly. Adapting places of delivery means that households or routes with extreme characteristics are being dropped. The cost of the newly organized and remaining routes can well be estimated based on the data from all routes since they conform to the characteristics of the typical routes with full coverage. Hence, cost estimates on new routes are in-sample in terms of their characteristics. A series of qualitative considerations of arbitrary delivery situations suggest that situations in which the model overestimates reductions in street times are equally likely as situations in which the model underestimates the reductions. In addition, a systematic error in the model's predictions can occur only if a substantial fraction of households that would no longer be served feature some relevant characteristic outside the model that affects delivery times.

#### **4. Results**

The calculation of the net cost of home delivery is illustrated for a series of counterfactual scenarios that reflect options (1), (2a) and (2b), i.e. reductions in delivery days and two possible adaptations of coverage. Below, the model's predictions are presented for two frequency of delivery scenarios and for four coverage scenarios.

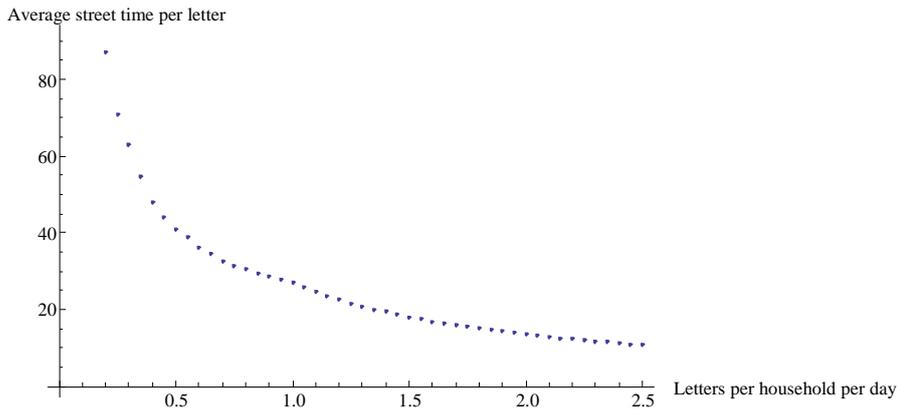
##### **4.1 Reduction of delivery days**

A reduction of the delivery days directly reduces street time on the one hand. On the other hand, it will - *ceteris paribus* - give rise to a decline of mail volumes as the speed of delivery and therefore the quality of the service is reduced. The total effect on profits as well as on costs per letter is therefore not a priori certain. For the processes other than street delivery, the effects are calculated based on cost allocations and elasticities from NERA (2004) and Trinkner (2009).

If mail volumes decline, two opposing delivery-related effects are at play. Firstly, street times per letter increase (direct effect). Secondly, street times decline as fewer households need to be served daily (indirect effect). Theoretically, it is not possible a priori to state which effect

dominates, Therefore, the sign of the change of street time per letter in response to volume changes is ambiguous. Model simulations show that in the relevant domain of the demand curve, the direct effect clearly dominates.<sup>7</sup> The relationship between mail volumes and street time per letter is illustrated in Figure 1.<sup>8</sup>

**Figure 1: Effect of mail volumes on street time per letter.**



The change in street time costs has to be contrasted with foregone revenues and changes in other costs that arise from the reduction of delivery days. The profit function of a postal operator can be expressed as a function of the average mail volume  $E$ :

$$\pi = p E - C(E) - V(E) - F \quad (1)$$

where  $p$  stands for the price of a letter (assumed fixed),  $C(E)$  are the quasi-fixed street time costs,  $V(E)$  are the variable costs up- and downstream, for example load time.  $F$  represents up- and downstream stream fixed costs. Equation (1) is then normalized for the price calibrated according to NERA (2004) and Trinkner (2009). It is further assumed that there are upstream fixed costs that are independent of mail volume. Hence, using  $\Delta E = k E$ , a reduction of the delivery days is profitable if

$$\Delta\pi = -\Delta E + 0.17\Delta C(\Delta E) + 0.6\Delta V(\Delta E) > 0. \quad (2)$$

Evaluating (2) requires simulating delivery costs for various mail volumes. This is computationally not feasible for the whole of Switzerland. The following results are therefore based on model simulations for artificial cities as reported in Trinkner et al. (2012). In these artificial cities distances from the delivery center to households are lognormal distributed and cardinal

<sup>7</sup> This is consistent with Kenny (2005) and other empirical estimates

<sup>8</sup> The curve shows the average of 20 simulations. More simulations would make the curve smoother.

directions in which households are located (from the viewpoint of the delivery center) are uniformly distributed. Statistical tests indicated that this distribution provides a reasonable approximation to Swiss data. The calculations are based on a baseline volume scenario of 1.5 letters per household per day.

Table 1 shows the break-even volume decline  $k$  for different population densities and delivery days per week such that the reduction of delivery days is still profitable, i.e. (2) is still fulfilled and hence the obligation of six delivery days constitutes a net cost. For example, a reduction to 3 delivery days per week is still profitable in very remote areas if mail volumes decline by less than 40%.

**Table 1: Break-even volume decline**

Population density [r/km2]	Delivery days per week				
	5	4	3	2	1
10000	$k < 1.83\%$	$k < 3.65\%$	$k < 5.48\%$	$k < 7.31\%$	$k < 9.14\%$
5000	$k < 2.63\%$	$k < 5.26\%$	$k < 7.90\%$	$k < 10.53\%$	$k < 13.16\%$
2000	$k < 4.05\%$	$k < 8.10\%$	$k < 12.16\%$	$k < 16.21\%$	$k < 20.26\%$
1000	$k < 5.45\%$	$k < 10.91\%$	$k < 16.36\%$	$k < 21.82\%$	$k < 27.27\%$
500	$k < 6.57\%$	$k < 13.14\%$	$k < 19.71\%$	$k < 26.28\%$	$k < 32.85\%$
50	$k < 13.33\%$	$k < 26.67\%$	$k < 40.00\%$	$k < 53.34\%$	$k < 66.67\%$

Table 2 shows the potential profit differentials from a reduction of the number of delivery days from 6 to 3 delivery days per week for different initial demand configurations (100%, 80% and 50% of status quo) under the assumption that the new delivery schedule reduces mail volumes by 10 %.<sup>9</sup>

**Table 2: Net costs of a reduction to 3 delivery days assuming an induced volume decline of -10%**

Initial mail volumes	Population density (residents per km2)					
	10'000	5'000	2'000	1'000	500	50
100%	-15.1%	-7.0%	7.2%	21.2%	32.4%	100.0%
80%	-8.7%	-0.8%	13.1%	26.9%	37.8%	104.2%
50%	-0.8%	7.2%	19.0%	32.1%	40.8%	102.9%

<sup>9</sup> This corresponds to the share of priority mail on total mail volume in Switzerland

These model calculations show that a reduction of the delivery days leads to negative consequences for profitability in highly dense areas as in dense areas the foregone revenues are much larger compared to the saved street and variable costs. The opposite might be true however for countries with very low ratios of letters per capita, as then foregone revenues are small compared to the cost avoided. In less dense areas, a reduction of delivery days is profitable, as avoided street time costs are sufficiently large to compensate for foregone revenues. Avoided costs increase with lower population densities because absolute street time costs are higher with lower population density.

The results in Table 2 reveal a non-monotone relation between mail volumes and cost savings. First, cost savings increase when mail volumes decline. At some point however, cost savings decrease again. This is first revealed in areas with very low population density and is best seen for volume scenarios far below 50% (results not reported in Table 2). Intuitively, a decline in mail volume provokes two effects. On the one hand, foregone revenues become smaller which tends to make the reduction more profitable. On the other hand, a decrease in mail volume also implies smaller street time costs which make the reduction of delivery days less attractive. Whereas the first effect dominates with relatively high volumes, the second effect starts to dominate with lower volumes.

#### **4.2 Adapting coverage**

Coverage may be adapted by different strategies. Below, two options are analyzed in detail:

*(2a) Closing delivery offices:* Either entire routes, areas or regions are no longer served with home delivery, a practical example can be found in Copenhagen Economics (2008) for the case of Denmark. In analogy it is assumed that the respective delivery offices are closed and the corresponding fixed (and variable) costs are saved.

*(2b) Adapting delivery places:* Throughout the country, the place of delivery is adapted for households that meet certain criteria (thereafter distance to next neighbor).

#### 4.2.1 Direct Cost effects: Avoided street time

First, street time savings are estimated and compared for Switzerland for four coverage levels. Indirect cost and revenue effects are accounted for further below. The coverage levels are 70%, 90-95%, 95-97.5%, and 97.5-100%. The exact coverage levels cannot be disclosed.

To determine the street time savings of option (2a) “closing delivery offices” for a given coverage level, first the average street time per household is calculated for each of the 810 delivery offices in Switzerland. Then delivery offices are closed one after another in decreasing order of average street time per household until the desired national coverage is reached. Note that customers that had been served by these offices would no longer get mail.

In option (2b) “adapting delivery places”, the x% most remote households on the national level are no longer served to the doorstep, instead receiving delivery at a location on the new route or a P.O. box, thereby not causing any incremental street times, but still being served. The new routes and street times are calculated in the model presented above. The measure for remoteness is the distance to the next neighbor. A given coverage can hence be translated into a maximum distance to the next neighbor.

Table 3 presents the estimated savings in street times for both strategies. For every coverage level, the savings of option (2b) “adapting delivery places” are significantly larger than for option (2a) “closing delivery offices”. For low reductions in coverage, the reduced street times of option (2b) are almost twice as high as with closing delivery offices.

**Table 3: Effect of a reduction in coverage on saved street time**

% Home delivery (instead of 100%)	% Savings street time	
	Option (2a): Closing Delivery Offices	Option (2b): Adapting delivery places
97.5 – 100%	5.35%	9.3%
95 – 97.5%	8.00%	15.4%
90 – 95%	14.66%	25.6%
70.00 %	40.56%	46.7%

For reasonable and identical levels of doorstep delivery the simulation results hence suggest:

$$\text{street time savings option (2a)} < \text{street time savings option (2b)}.$$

#### 4.2.2 Revenue effects

For the calculation of net costs not only the costs are relevant but also the revenues.

The situation is fundamentally different for options (2a) and (2b). Abstaining from delivering to an entire area implies that there is no service available for mail destined to that region. Accordingly, 100% of potentially mailed letters are lost. In the presence of positive network externalities, these losses will rise beyond 100%.

The effect of adapting the place of delivery on mail demand is unclear. The reduction of home delivery coverage has little or no impact on the sender's utility as the letter is still provided to the recipient. The recipient bears additional costs in picking up the letter at the point of delivery (the next road crossing where the carrier passes by). In Switzerland, if at least one of the recipients passes this crossing anyway, additional costs are low or zero. However, based on the study of Felisberto et al. (2006), a maximum of 35% of Swiss recipients with home delivery responded to the effect that they may not collect their mail in P.O. boxes if forced to do so. Because mail boxes at road crossings can be reached with less effort than P.O. boxes at post offices, it can be inferred that the effect on revenues is substantially lower than 35%.

In the following, it is abstracted from estimating the revenue effects directly because this would require detailed information on consumer demand which is not available. As an alternative, the cost reductions and conditions for the existence of net costs are discussed, i.e. situations in which foregone revenue are smaller than avoided costs. These results are then compared with the result from Felisberto et al. (2006).

#### **4.2.3 Net effects**

To calculate the net cost of the USO, the effects of the changes in coverage on profits as a sum of total avoided cost and foregone revenues are of relevance.

In option (2b), customers, which are affected by the change of the delivery place, are either served via a mail box on the adapted new route or by P.O. box delivery. It can be assumed that for both choices, variable costs remain constant as compared to doorstep delivery. Therefore, the reduction in costs stemming from the reduction in home delivery coverage is entirely driven by the savings street time, which can be simulated within the bottom-up model. In absence of any demand effects, the cost reductions correspond to the route cost reductions and equal the net cost. Demand effects influence the revenues and the cost reductions (large

volume declines may change street times). In the following, sufficient conditions for the existence of net costs of option (2b) are derived.

Let there be  $n$  regions, the mail volume flowing to region  $i$  is denoted by  $E_i$ , the street time costs, fixed costs and variable costs in that region are denoted by  $C_i(E_i), F_i(E_i), V_i(E_i)$ . Then the overall profit function of a postal operator is expressed by the following equation:

$$\pi = \sum_{i=1}^n pE_i - \sum_{i=1}^n C_i(E_i) + V_i(E_i) + F_i(E_i), \quad (3)$$

where  $p$  stands for the uniform price of a letter. Assuming that the fixed costs remain constant in option (2b) and the change in mail volumes to region  $i$  are expressed as  $\Delta E_i = k_i E_i$ , the change in profits in this scenario is

$$\Delta\pi_{2b} = -p \sum_{i=1}^n k_i E_i + \sum_{i=1}^n \Delta C_i(E_i) + \nabla V_i(E_i). \quad (4)$$

It is assumed that the volume declines do not have a significant effect on street time savings. That is the street time savings  $\Delta C_i(E_i)$  are equal to the ones calculated in the model for constant mail volumes. This is a lower bound for the actual street costs savings. Assuming that variable costs per letter are approximately 60% of the price per letter (4) becomes

$$\Delta\pi_{2b} = -0.4 p \sum_{i=1}^n k_i E_i + \sum_{i=1}^n \Delta C_i(E_i). \quad (5)$$

Using the cost estimates from the model and information on volumes and prices from Swiss Post in 2012, the break-even average nationwide mail volume decline  $k_{max}$  can be computed such that  $\Delta\pi_{2b} \geq 0$  still holds, i.e. coverage obligations constitute net costs. The results for the four coverage scenarios are reported in Table 4.

**Table 4: Break-even volume decline**

% Home delivery	Break-even overall volume decline for Option (2b)	Upper Estimate based on Felisberto et al. (2006)
97.5 – 100%	$k < 2.88\%$	0.875%
95 – 97.5%	$k < 4.77\%$	1.75%
90 – 95%	$k < 8.05\%$	3.50%
70.00 %	$k < 14.61$	10.50%

Table 4 reveals that demand effects have to be implausibly high such that reducing the coverage of home delivery is no longer profitable for an USP. Specifically, a reduction in home delivery of at most 2.5% (row 1 in Table 4) would require mail volumes to decline by 2.88% or more for coverage obligations not to constitute net costs.

According to Felisberto et al. (2006), a maximum of 35% recipients would not collect their mail if delivered to a P.O. box instead of the doorstep. This constitutes an upper bound as we assume delivery at crossroads which are closer to the recipients. In all coverage scenarios, the break-even mail volume decline is significantly higher than the effect of this upper estimate (column 2 of Table 4). It is therefore very likely that coverage obligations constitute net costs.

In option (2a), not only the street time costs but also quasi-fixed costs and variable costs are saved. Conversely, the entire mail volume to the region in question disappears and therefore also the corresponding revenues. Consequently, only regions which are unprofitable in their entirety should be excluded from service.

Assuming that the entire mail volume to region  $i$  disappears, as well as all costs being saved, when closing the delivery office in region  $i$  the change in profits is

$$\Delta\pi_{2a} = -p \sum_{i=1}^n E_i 1(i)_{\{2a\}} + \sum_{i=1}^n 1(i)_{\{2a\}} \{C_i(E_i) + V_i(E_i) + F_i(E_i)\}, \quad (6)$$

where  $1(i)_{\{2a\}} = \begin{cases} 1 & \text{if region } i \text{ is closed} \\ 0 & \text{else} \end{cases}$  is the indicator function whether the region is no longer served. Not considered in this formulation is the potential indirect decline in mail volume arising from the general reduction in services due to the reduced coverage and that people in regions with closed delivery offices will tend to send fewer letters to other regions. Hence, (6) can be seen as an upper bound for the change in profits.

To evaluate whether (6) is positive, i.e. whether coverage constitutes net costs, would require detailed information on regionally specific variable costs, fixed costs and mail volumes, which are not publicly available. Nevertheless, option (2a) and (2b) can be compared. Option (2b) is more profitable than option (2a) if  $\Delta\pi_{2b} \geq \Delta\pi_{2a}$  which is equivalent to

$$-p \sum_{i=1}^n k_i E_i \geq \sum_{i=1}^n \{1(i)_{\{2a\}} C_i(E_i) - \Delta C_i(E_i)\} + \sum_{i=1}^n 1(i)_{\{2a\}} \{-p E_i + V_i(E_i) + F_i(E_i)\} - \sum_{i=1}^n \Delta V_i(E_i). \quad (7)$$

This equation could be evaluated in detail but this requires detailed information on regional fixed and variable costs, which are private information of postal operators. We therefore make the assumption that

$$\sum_{i=1}^n 1(i)_{\{2a\}} \{-p E_i + V_i(E_i) + F_i(E_i)\} \leq 0. \quad (8)$$

(8) is fulfilled if the price per letter in the regions subject to closure lie above the variable costs plus the fixed costs per letter on average, which can be expected. Furthermore, based on NERA (2004) and Trinkner (2009), it is assumed that the variable costs per letter are on average approximately equal to 60% of the price per letter. That is, the savings in variable costs  $\sum_{i=1}^n \Delta V_i(E_i)$  can be expressed as in Switzerland are reported in  $p \sum_{i=1}^n k_i E_i$ . When willing to accept the above assumptions a sufficient condition for  $\Delta \pi_{2b} \geq \nabla \pi_{2a}$  is

$$-0.4 p \sum_{i=1}^n k_i E_i \geq \sum_{i=1}^n \{1(i)_{\{2a\}} C_i(E_i) - \Delta C_i(E_i)\}. \quad (9)$$

The term on the right hand side of (9) can be computed by our model. Let  $r_{2a}, r_{2b}$  respectively denote the percentage savings of street time when closing delivery offices or adapting the place of delivery. Estimates for these values in Switzerland are reported in Table 3. Further, let  $\bar{k}$  denote the average nation-wide decline in mail volume, that is

$$\bar{k} \sum_{i=1}^n E_i = \sum_{i=1}^n k_i E_i.$$

Then, the sufficient condition (9) becomes

$$\bar{k} \leq (r_{2b} - r_{2a}) \frac{\sum_{i=1}^n C_i(E_i)}{p \sum_{i=1}^n E_i} \frac{1}{0.4}, \quad (10)$$

which is a condition on the break-even volume decline in response to adapting the place of delivery. The first fraction in (10) is simply the share of delivery costs of total revenues. According to NERA (2004) and Trinkner (2009) this share is approximately equal 0.17. Table 5 reports the maximal decline in national mail volume  $\bar{k}_{max}$  such that (10) is fulfilled with equality. That is, if the decline in mail volume lies below  $\bar{k}_{max}$ , adapting delivery places is more profitable than closing delivery offices. It has to be emphasized that with the assumptions made above,  $\bar{k}_{max}$  is a lower bound. Even for larger declines in mail volumes (2b) adapting

delivery places might still be more profitable than (2a) closing delivery offices. However, a more exact estimate of  $\bar{k}_{max}$  would require detailed knowledge of regionally specific variable and fixed costs.

While a  $\bar{k}_{max}$  of 1.68% appears to be small, it has to be contrasted to the reduction of coverage of only 2% and, furthermore the affected households are still served at road crossings. The values of  $\bar{k}_{max}$  in Table 5 exceed significantly Felisberto's (2006) upper bound estimates in Table 4 for home delivery coverage reductions below 10%. For small reductions below 10% it appears thus that (2b) adapting delivery places is likely to be more profitable than closing delivery offices.

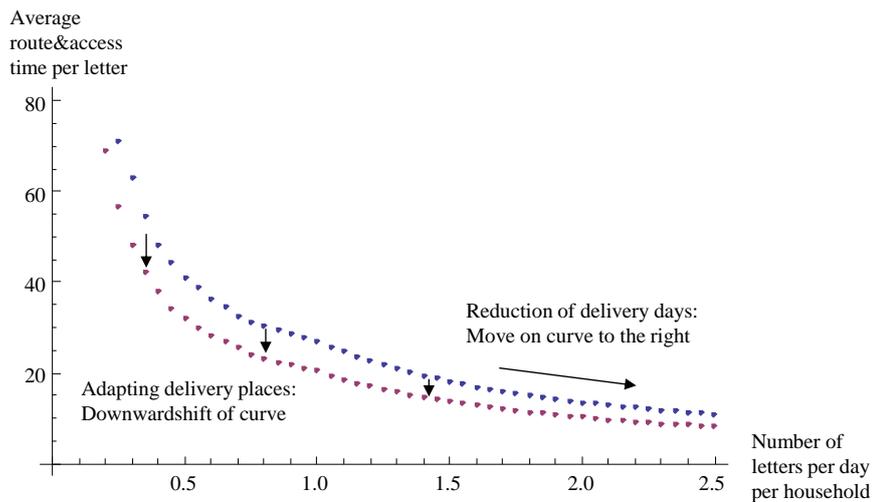
**Table 5: Limits  $\bar{k}_{max}$  for maximal decline in national mail volumes**

% Home delivery	$\bar{k}_{max}$
97.5 – 100%	1.68%
95 – 97.5%	3.15%
90 – 95%	4.65%
70.00 %	2.61%

### 4.3 Frequency vs. Coverage

The ways frequency and coverage adaptations affect profits differ. Reducing delivery days reduces average street time per item by increasing the number of letters per delivery day. Adapting places of delivery reduces average street times per item by reducing the absolute street times. This is illustrated in Figure 2.

**Figure 2: Effect of mail volumes on street time per letter.**



While the effect of reducing delivery days on profits is stronger for low volumes and in rural areas, adapting delivery places is always effective. Therefore, both optimizations might be profitably combined, in particular in rural regions. The optimal combination of coverage and frequency adaptations is a topic for future research.

A direct comparison of the net costs arising from frequency and coverage obligations is not possible in this study because rather than calculating the exact amount of net costs, sufficient conditions for the existence of net costs are derived. Additionally, the results for the frequency obligation are derived from model simulations of artificial cities while the results for the coverage obligation are based on model simulations for Switzerland.

However, the results of reducing the number of delivery days and adapting coverage indicate that the relative effectiveness depends on the country specific situation. Under rather favorable demand conditions (high letter per capita rate) the USO net cost associated with obligations on the frequency of delivery is likely to be lower than from coverage. In case of low letters per capita however, this finding might be inverted. Therefore, it can be concluded that any calculation of the net cost of obligations on home delivery requires a detailed, if possible bottom-up country-specific assessment.

## 5. Conclusions

This paper analyzes whether frequency of delivery and nationwide coverage obligations constitute USO net costs. With no USO on home delivery in place, the USP may be able to increase profits by optimizing its delivery services. Three such optimizations are scrutinized in detail:

(1) adjusting the number of weekly delivery days, (2a) discontinuing delivery services to certain areas and (2b) adjusting the place of delivery for households that are particularly costly to serve. The first measure relates to the frequency of delivery obligation, whereas the latter two concern the requirement of nationwide coverage of home delivery. Under robust demand assumptions both frequency and coverage obligations constitute USO net costs. The USO in delivery hence represents binding constraints on operators.

The analysis shows that (1) reducing delivery days is most effective in regions with low population density and when volumes are low. Under reasonable demand assumptions, a reduction will increase profits in areas that are not densely populated. Frequency of delivery obligations are therefore likely to constitute net costs. Holding the degree of coverage fixed, street time costs avoided by (2a) discontinuing delivery services in selected areas are generally lower than the costs saved by (2b) adapting the delivery places for the most remote households throughout the country. The opposite is the case in terms of foregone revenues: Not serving entire regions will c.p. lead to larger losses in revenue. Taking into account overhead costs that can be avoided in (2a) only, our analysis confirms that (2b) will be more effective with reasonable calibration assumptions. Under most demand assumptions, the net effect on profits from (2a) is positive, implying that coverage obligations constitute net costs.

While the effect of reducing delivery days on profits is stronger for low volumes and in rural areas, adapting delivery places is always effective. Therefore, both optimizations might be profitably combined, in particular in rural regions. The optimal combination of coverage and frequency adaptations is a topic for future research.

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