Developing a Swiss model for light commercial vehicles

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Abstract

This paper reports on efforts to develop a novel traffic model for commercially-used light good vehicles in Switzerland. The data comes from various sources, including the national vehicle register as well as the largest and most recent survey, namely 3'874 vehicle trip diaries collected in 2013 by the Swiss federal office for statistics, including both freight and service trips. The methodology consists in estimating and applying behavioral models for individual vehicles, where tours are built in an iterative fashion. The paper presents some preliminary results for the estimation of the part of the model reproducing the destination choice.

1 Introduction

Light commercial vehicles (LCVs) are defined by their targeted usage (the carriage of goods) and by their gross weight, which must not exceed 3.5 tonnes. Their usage goes however beyond the carriage of goods. In a survey conducted in 2013 in Switzerland, 53% of the surveyed LCVs indicated "service" as one of their main usages (Federal Statistical Office, 2015a). LCVs have gained the attention of public authorities in the last decades due to their central role in city logistics and home deliveries. They are also becoming increasingly common: the annual number of LCV registrations in Switzerland has surged by 82% between 1999 and 2019 (Federal Statistical Office, 2022) and the most recent Swiss transport Outlook (Federal Office for Spatial Development, 2021) projects a 58% increase of LCV vehicle kilometers between 2017 and 2050.

The transport modeling team within the Swiss Federal Department of the Environment, Transport, Energy and Communications aims at developing a national model for LCVs (hereafter LCV-model). The main objectives are (i) to provide a reasonable description of the current average daily traffic at the link-level for the road network and (ii) to permit the translation of long-term demographic and economic projections into traffic forecasts suitable for infrastructure planning.

The LCV-model should integrate with the existing models dedicated to the mobility of persons (Federal Office for Spatial Development, 2020) and heavy freight (Federal Office for Spatial Development, 2015), in particular for congestion modeling. The main challenges come from the large heterogeneity of vehicle usages, the limited available data and the fact that many LCV trips are organized into tours, which should be accounted for. The envisioned approach is inspired from Hunt and Stefan (2007), which allows for a rather fine description of the touring behavior.

This paper is articulated as follows. Section 2 provides a brief review of the literature dedicated to freight and service traffic modeling. Section 3 describes the data available, Section 4 sketches out the envisioned model and Section 5 presents some preliminary estimation results for the *Next Stop Location* module.

2 Literature review

The main two usages of LCVs are freight transport and service, which can be grouped under the umbrella term "commercial traffic". Many traffic models only consider one of these two usages and when the focus is on freight, it can be either long-distance transport (where the relevant modes are generally heavy trucks, trains and cargo ships) or short-distance transport (where LCVs are more relevant). The methodological approaches have however often been directly transferred from one application to the other. We first briefly review the most common of these approaches, and then review more in detail the literature that is most relevant for the model we envision. For a broader literature review, the reader is referred to de Jong *et al.* (2021) for freight applications and to Ellison *et al.* (2017) for methods addressing service trips.

A very simple and common approach to commercial traffic modeling relies on "expanded OD-matrices". This method consists in estimating a base year Origin-Destination matrix for the most recent year for which data is available, which can then be scaled to obtain various forecasts. Such an approach is applied for instance in the current heavy freight model of Switzerland (Federal Office for Spatial Development, 2015). There, the base year matrix was obtained by associating traffic counts with origin-destination data from vehicle-based surveys. This method provides robust forecasts that can be used for "business as usual" scenarios for infrastructure planning at a large scale (e.g. national or international), when the expected demand variations remain small. It is however not ideal to model structural changes or the effect of new policy instruments.

Another common approach consists in adjusting the traditional four-step model of travel demand. The first two steps (generation and distribution) and the last step (network assignment) are almost always handled at an aggregate scale, as when modeling the movements of people. In the context of commercial vehicles, the third step (originally mode choice) should be considered together with other logistics choices such as shipment size/frequency (for the transport of goods only), trip-chaining and departure time. These choices are more naturally handled at the level of individual establishments. Many freight models simply do not include these logistics choices - e.g. Cambridge Systematics and COMSIS Corporation (1996). The commercial software PTV-VISUM, which is already used in Switzerland for modelling the mobility of persons, provides with its "TB-Freight" module a partial solution. Mode choice is not modelled but tours are described in an aggregate fashion : the producer-consumer matrix is translated into a trip matrix which satisfies the demand and the vehicle-balancing constraints, while allowing to control the average number of stops per tour (PTV GROUP, 2019). There are however many matrices that satisfy these constraints and the one produced by TB-Freight is not necessarily very realistic.[1]

Another approach in commercial traffic modeling consists in adopting a microscopic (i.e. agent-based) view to describe logistics choices - see de Jong *et al.* (2021) for a review of the latest developments. The most well established approach is probably the Aggregate-Disaggregate-Aggregate (ADA) freight model system (de Jong and Ben-Akiva, 2007), which focuses on freight and has been applied to several countries (Norway, Sweden, Denmark and ongoing work in Austria). It describes the choice of shipment size/frequency, of the number of legs in the transport chain and of mode and vehicle type for each leg. Yet, with a high level of detail come large data needs. The ADA approach requires a commodity flow survey to be available, describing the full trip chain. Such surveys can be expansive to conduct and are not very common. The application of ADA in Austria required such a survey to be conducted specifically for the needs of model development - see Grebe *et al.* (2020). There is no such survey in Switzerland.

To avoid the difficulties associated with the explicit consideration of shipments, Hunt and Stefan (2007) proposed a model of tours which is purely vehicle-based. This type of approach seems to be the most suitable in the Swiss case, given the data available. This model is microscopic in that it considers individual vehicles, but it is also macroscopic in that it considers only zones, and not individual establishments. Every zone is the base for a number of tours. These tours are associated to various purposes and vehicle types. The total number of tours is estimated based on land-use and economic characteristics of the zone via a regression analysis. Stops are then generated one by one, via an iterative procedure. After every stop, a *Next Stop Purpose* module determines whether the vehicle goes back to its establishment or continues its tour. If another stop should be made, the *Next Stop Location* module determines the next destination. Yet another logit-model determines the stop duration. A schema of this modular structure is provided in Section 4.3.

We would like to highlight at this point an important difference between the approach of Hunt and Stefan (2007) and those based on the four-step model : the *Next Stop Location* module does not require any pre-estimated demand matrix (which would normally be the result of the generation and distribution steps). Instead, the destinations are chosen based a behavioral model.

[1] One criticism is that TB-Freight tends to produce a large number of internal trips in isolated zones, thereby implying that the few tours serving these zones have an extremely large number of stops.

Some subsequent models (Thoen *et al.*, 2020; Sakai *et al.*, 2020) proposed alternative formulations which explicitly describe shipments. They take as input a set of shipments (which are either real, or generated from another submodule), and generate tours compatible with these shipments. The data needs of such an approach are however far beyond what is available in Switzerland for the whole country. Indeed, these approaches require the knowledge of not only the origin and destination zones, but also of the schedule constraints and of the companies responsible for each shipment.

3 Data

3.1 LCV survey

The main data source is a vehicle-based survey conducted in 2013 in Switzerland (Federal Statistical Office, 2015a). The survey was conducted with two types of questionnaires. Questionnaires of type 1 only contained a few questions about the mileage and the main use of the vehicle during a reference day. It serves mostly calibration purposes. Questionnaires of type 2 contained the same questions as those of type 1, but also questions about the individual shipments transported during that day (postal codes of origin and destination, weight, type of good, mileage of the vehicle at the origin and destination). Empty legs also had to be registered, thereby allowing for the reconstruction of all vehicle movements. This second part however was only required for vehicles that carried at least 50 kg of goods during the reference day. Overall, according to the survey report (Federal Statistical Office, 2015b):

- Questionnaires of type 1 were sent to the owners of 42'000 LCVs. The response rate was 76%.
- Questionnaires of type 2 were sent to the owners of 28'000 LCVs. The response rate was 71%, but the part with questions about individual shipments was only completed for 3'874 LCVs.

Besides, to limit the respondent burden with questionnaires of type 2, a simplified form was proposed for tours containing at least four different locations distant from each other from at most 20 km with shipments of a single type. This simplified form does not contain the information for every single shipment, but only the overall weight and the mileage at the first and last stop, as well as at the origin.

The 3'874 questionnaires with detailed data correspond to 1.2% of the entire LCV fleet. These surveys contain detailed information about 11'473 individual shipments, and summarizing information (i.e. simplified forms) for 830 tours.

3.2 National vehicle register

The second most important data source is the Swiss national vehicle register. This register contains data about all vehicles registered in Switzerland, such as the name and address of the owner, the vehicle type and some additional vehicle characteristics.

Here we are only interested in the LCVs owned by companies and other organisations (i.e. excluding those owned by private persons). It is not clear yet whether we will have access to the data for individual establishments, or only in an aggregated format (e.g. based on the branch of the company owning the vehicle and on some type of zone). Besides, the matching of this vehicle register with the establishment register (which is required to infer the branch of vehicle owners) is not automatic and might fail in some cases.

3.3 Additional explanatory variables

A large variety of land-use and socio-economic variables is available. The most relevant ones should be the number of jobs (full-time equivalents) per branch and the number of inhabitants. Travel time and distance matrices can be estimated using the national model dedicated to the mobility of persons (Federal Office for Spatial Development, 2020).

4 Modeling considerations

4.1 Zones

The LCV survey provides data at the level of postal codes. These corresponded in 2013 to 3'186 geographical areas. We plan to use this definition of zones for the purpose of model estimation, but to then apply the model with the more than 8'000 zones of the national model for passenger transport (Federal Office for Spatial Development, 2020), to facilitate the network assignment. The use of various zone definitions for the estimation and application of the models is not expected to be problematic as long as the estimated statistical models do not rely on zone-specific constants.

Note that some postal codes indicated in the survey do not correspond to geographical areas, but to specific large organisations - for instance the federal government. These organizations might have various locations, which are sometimes far from each other but associated to a single postal box. As we could not obtain explanatory variables of sufficiently good quality for trips involving these postal codes, the corresponding survey entries were discarded.[2]

4.2 Demand segmentation

The final demand segmentation will be adjusted in the process of estimating the model. We only present here the segmentation criteria we foresee.

We envision the following aggregates of economic branches, which is based on the Swiss General Classification of Economic Activities (NOGA):

- Industrial (NOGA A - F),
- Trade (NOGA G),
- Transport (NOGA H),
- Services (NOGA I-S).

[2]More specifically, for the estimation of the model for destination choice in Section 5, we only considered tour legs where the postal codes of (1) the start of the leg (2) the end of the leg and (3) the origin of the tour all corresponded to geographical areas. This led to discarding 8.6% of the dataset.

This segmentation corresponds to the one proposed by Hunt and Stefan (2007), except that we rely on the NOGA instead of the North American Industry Classification System (NAICS) and that we do not distinguish retail from wholesale. A drawback with this segmentation is that not all observations of the LCV survey could be assigned to a branch (the matching failed for 36 % of questionnaires of type 1).

The main purpose for using the vehicle as registered in the LCV survey (see Section 3.1) is also an important criterion. The respondents had many options in the questionnaire ("Goods transport", "service", "passenger transport", "rental", "measurements", "private use" and "other"). They were also allowed to select multiple answers. To avoid over-segmentation, we envision the following 3 segments:

- *Goods Transport*: if the set of main purposes indicated by the respondent contains "Goods Transport" and does not contain "Service". This category contains 3'751 observations for the choice of *Next Stop Location*.
- *Service*: if the set of main purposes indicated by the respondent contains "Service". This category contains 2'224 observations for the choice of *Next Stop Location*.
- *Other*: this category contains all the observations which did not fall in the first two categories. It contains 149 observations for the choice of *Next Stop Location*.

Note that this is a "vehicle purpose", which remains the same for the entire day. It is not trip-specific.

Finally, a third degree of segmentation could be a distinction between short tours (for which we have detailed data about each shipment) and long tours (for which simplified forms were filled). As mentioned in Section 4.3, the case of long tours will require some simplifications and is not treated here.

We should also note that the segmentation will not be exactly the same in all modules. The vehicle purpose for instance is only defined in the second module of the structure presented hereafter, and thus cannot be used as a segmentation criterion for the first module.

4.3 Model structure

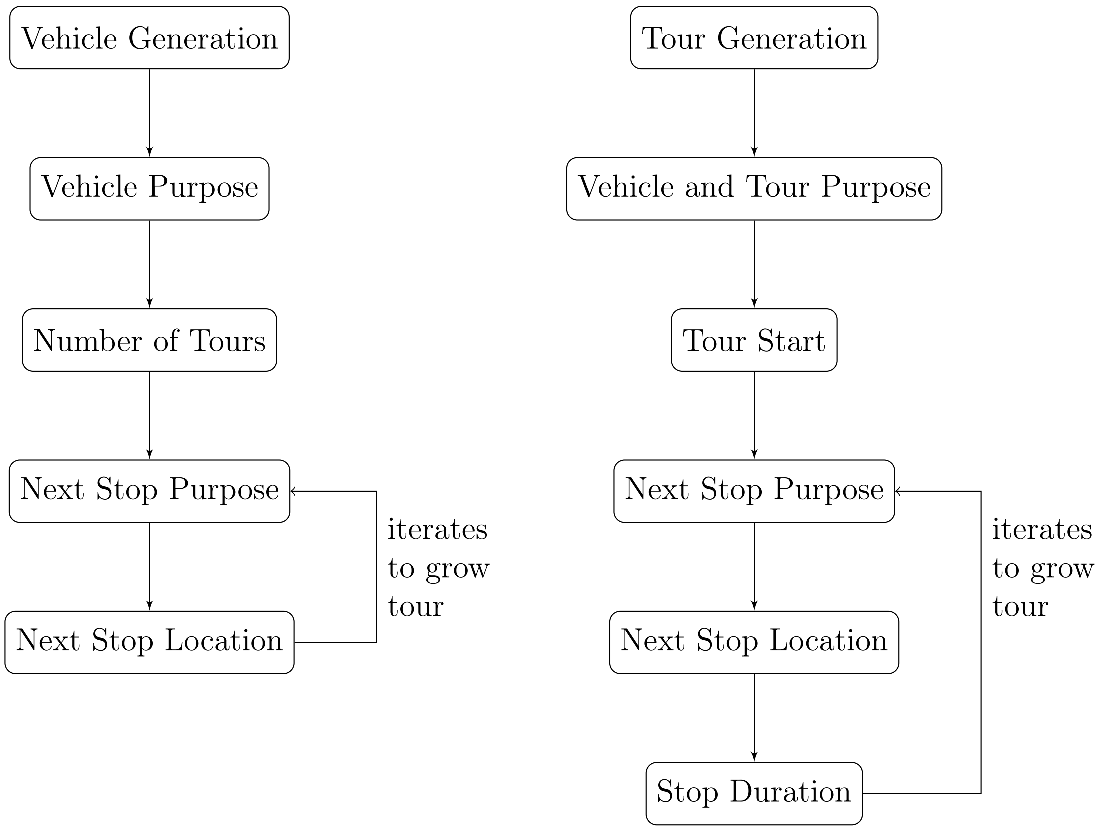
The envisioned model structure is illustrated in Fig. 1, together with the one originally proposed by Hunt and Stefan (2007). Our proposed structure consists of five modules, which we present hereafter:

- *Vehicle Generation*: This module provides an estimate of the number of LCVs per zone and per economic branch. We envision a linear regression, estimating the number of registered LCVs based on explanatory variables such as the number of employees in various branches, as well as eventual land-use characteristics of the zone.[3] *Data for model estimation*: national vehicle register.[4]
- *Vehicle Purpose:* This module assigns a purpose (*Goods transport*, *Service* or *Other* - see Section 4.2) to each vehicle. We envision a multinomial logit model for each branch. These models would be based on e.g. the density of employees or on land-use characteristics. *Data for model estimation*: LCV survey, questionnaires of types 1 and 2.
- *Number of Tours:* This module assigns a number of tours to each vehicle of each zone. We envision using average rates that are specific for each combination of branch and purpose. *Data for model estimation*: LCV survey, only the questionnaires of 2 with data about individual shipments.
- *Next Stop Purpose:* This module determines whether the vehicle makes an additional intermediate stop or goes back to its establishment. We envision estimating a multinomial logit model for each vehicle purpose. The explanatory variables might include the number of intermediary stops made so far, the distance to the establishment, and perhaps also the accessibility to employment. *Data for model estimation*: LCV survey, only the questionnaires of 2 with data about individual shipments.
- *Next Stop Location:* When an additional intermediate stop should be made, this module models the destination choice. We envision estimating a multinomial logit model for each vehicle purpose, with sampling to reduce the number of alternatives (=zones corresponding to postal codes). The explanatory variables will include the distance from the current zone to the possible destinations as well as measures of the attractivity of the zone (e.g. land-use characteristics, population size and

[3]It is not clear yet whether we will be able to estimate such a model at the establishment level, or only at a zone level. An estimation at the establishment level would allow to describe a non-linear relationship between the number of employees and the number of LCVs. This requires however a matching between the vehicle register and the establishment register - see Section 3.2. In any case, the results at the end of this module should be aggregated at the zone level.

[4]The data used for explanatory variables for this module and the next ones stem mainly from the national population and enterprise registers (or from statistical products derived from these registers).

Figure 1: Two model structures: structure envisioned in this paper (left), structure proposed by Hunt and Stefan (2007) (right).



employment). *Data for model estimation*: LCV survey, only the questionnaires of 2 with data about individual shipments.

The key differences compared to the structure of Hunt and Stefan (2007) are the following:

- We do not model the departure time and stop duration (no module *Tour Start* and *Stop Duration*) ;
- The module *Vehicle and Tour Purpose* of Hunt and Stefan (2007) is replaced by a module *Vehicle Purpose*, because we only focus on LCVs and in our data, the purpose is a characteristic of the vehicle, not of the tour ;
- The module *Tour Generation* of Hunt and Stefan (2007) is replaced by a module *Vehicle Generation* and a module *Number of Tours*, to better correspond to the data available. Indeed, we have no data about the number of tours originating in each zone, but the national vehicle register tells us how many LCVs are registered in each zone and the LCV survey allows us to estimate the number of tours made by each

vehicle.

Note that the number of observations available for the modules *Next Stop Purpose* and *Next Stop Location* may not allow for the estimation of separate models for each combination of purpose and branch. We envision therefore to estimate only one model per purpose for these two modules. Similarly we will only be able to estimate the *Next Stop Purpose* and *Next Stop Location* models for the tours for which we have detailed data about all individual shipments. Those that were registered using the simplified forms do not contain the locations of each individual stops. Some simplified solution will have to be designed to address such cases, but this is left for future work.

4.4 Microscopic vs macroscopic view

The work of Hunt and Stefan (2007) and those that followed adopt a microscopic approach both for model estimation and for its application. As individual vehicles are simulated (via Monte Carlo processes), the results are necessarily stochastic. To reduce variability, the results are averaged over several simulations.

To avoid stochasticity and to reduce the computational time, we envision a deterministic application. In other words, we would not sample individual vehicles, but we would consider instead all the possible outcomes and work with proportions. This would impose some limits on the types of explanatory variables that can be used to avoid a curse of dimensionality.

Specifically, we would require that:

- the probability $r^n_{b,i}$ that vehicles whose base establishment is in zone b and which are in zone i after n intermediate stops finish their tour might depend on b, i and n, but not on the zones visited between b and i.
- the probability $t^n_{b,i,j}$ that vehicles whose base establishment is in zone b and which are in zone i after n intermediate stops make a new intermediate stop in zone j might depend on b, i, n and j, but not on the zones visited between b and i.

We would furthermore impose a bound on the total number of intermediate stops in a tour. Under these assumptions, the state can be described by vectors of predefinite sizes. Let $x^n_{b,i}$ denote the number of vehicles originating from zone b which are in zone i after n

intermediate stops and who have not yet finished their tour. The overall flow of vehicles that move from i to j is given by

$$q_{i,j} = \sum_n \left(r^n_{j,i} x^n_{j,i} + \sum_b (1 - r^n_{b,i}) x^n_{b,i} t^n_{b,i,j} \right).$$

The first term in the sum over n represents the vehicles whose base is in j, who were in i after n intermediate stops and now finish their tour. The second term represents the vehicles who continue their tour. The following equation permits the iterative building of matrices corresponding to various numbers of intermediate stops:

$$x^{n+1}_{b,i} = \sum_j (1 - r^n_{b,j}) x^n_{b,j} t^n_{b,j,i}.$$

5 Estimation of destination choice models: preliminary results

This section presents preliminary results of the estimation of *Next Stop Location* models for each demand segment. The estimation was carried out in R, using the Apollo package (Hess and Palma, 2019, 2022), with defaults parameters. To keep the computational time within reasonable bounds, we relied on a stratified sampling of alternatives: instead of considering a choice set made of 3'186 geographical areas defined by postal codes, we only kept 80 zones (including the one chosen in the empirical data) : 20 among the 200 zones which are the closest from the one where the vehicle currently is, 40 among the next 1'000 zones, and 20 among the 1'986 furthest zones.

Given the relatively small amount of data, we only estimate in this paper very simple models of the form:

$$\begin{aligned} U_{\text{zone } j} =& \theta_{\text{land use}} + \theta_{\text{travel time}} \times \text{travel time for trip from current zone to zone } j \\ & + \theta_{\text{size term}} \times \ln(\text{population in zone } j + \theta_{\text{emp/pop size term}} \times \text{employment in zone } j) \end{aligned}$$

The parameters to be estimated are denoted by θ. The travel time is expressed in minutes.

The notation for $\theta_{\text{land use}}$ is somewhat abusive. It stands for a land-use specific constant.

Inspiring us from Hunt and Stefan (2007), we define 4 mutually exclusive land-uses:

- Low density: at most 100 inhabitants/km^2 and 100 jobs/km^2,
- Residential: more than 100 inhabitants/km^2 and a density of population at least twice as large as the density of jobs,
- Intermediary: at most 3'000 jobs/km^2 and neither a residential area nor a low density area,
- Employment Node: more than 3'000 jobs/km^2 and neither a residential area nor a low density area.

The utility formulation proposed by Hunt and Stefan (2007) contained additional explanatory variables such as the disutility to return to the base zone, the average income in the destination zone or the accessibility to employment in the destination zone. Such variables might be considered later in this project.

The results for three segments corresponding to the three purposes defined in Section 4.2 are presented in Table 1.

Table 1: Estimation results for *Next Stop Location*

	Segments		
	Goods Transport	*Service*	*Other*
Estimated coefficients			
$\theta_{\text{land use}}$ Low Den	0.58 (4.10)	0.50 (2.29)	0.91 (1.19)
$\theta_{\text{land use}}$ Residential	0.25 (2.27)	0.07 (0.42)	0.49 (0.83)
$\theta_{\text{land use}}$ Interm	0.30 (3.22)	0.09 (0.74)	0.40 (0.87)
$\theta_{\text{land use}}$ Emp Node	0 (-)	0 (-)	0 (-)
$\theta_{\text{travel time}}$	-0.13 (67.33)	-0.14 (57.25)	-0.14 (14.73)
$\theta_{\text{emp/pop}}$	6.86 (1.85)	1.21 (1.63)	20.30 (0.21)
$\theta_{\text{size term}}$	0.56 (22.96)	0.63 (21.35)	0.49 (3.96)
Goodness of fit statistics			
Number of obs.	3751	2224	149
Ln-Likelihood init.	-21'621	-12'819	-859
Ln-Likelihood final	-9141	-9'746	-653
AIC	18'293	10'269	703
BIC	18'330	10'303	721

Note: values in parentheses denote |robust t-ratio|, computed by taking into account the panel structure of the data (several observations can correspond to the same vehicle).

The land-use specific constants are defined relatively to the one for employment node (set to 0). For the segment *Goods Transport*, the three estimated constants are positive and statistically significant, indicating a lower attractivity for denser areas (all other variables, including the absolute number of employees or inhabitants, being equal). This is rather intuitive. Similarly for the *Service* segment, low-density areas are more attractive than employment nodes. The other two constants are not statistically significant. For the segment *Other*, none of the land-use specific constant is statistically significant.

The travel time variable is highly significant for the three segments and its coefficient is negative, as expected. The size terms are significant for the three segments and positive. The ratios $|\theta_{\text{travel time}}|/\theta_{\text{size term}}$ are similar for the three segments. It takes its largest value (0.29) for the segment *Other* (compared to 0.22 for *Service* and 0.23 for *Goods Transport*), indicating that distance matters a bit more for this segment.

Finally, the variable $\theta_{\text{emp/pop}}$ is always positive. The large value it takes for the segment *Other* is not significant at all. The values for *Goods Transport* and *Service* are somewhat more significant, but must be considered carefully. The fact that the estimate of $\theta_{\text{emp/pop}}$ is much larger than 1 for *Goods Transport* is intuitive, as this segment is much more important in the B2B (Business to Business) market than in the B2C (Business to Customer) market.

6 Some concluding remarks

This is work in progress. The main purpose of this paper is to generate a basis for discussion, and eventual collaborations.

This paper does not aim at bringing methodological contributions and therefore remains very close to the original approach of Hunt and Stefan (2007). We see however some interesting potential in a deterministic application of these micro-models, as sketched in Section 4.4. This might allow for larger-scale applications, at a reasonable cost.

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