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Loading Unit in Freight Transport Modelling

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Abstract

Freight transport flows are generating high number of vehicle movements. Modelling freight flows gives consequently crucial information for both public and private decision makers. Generally freight transport models consider flows by commodity type between meso-level traffic analysis zones. Only a few models are taking into account loading units, as they make the difference between containers and general cargo. There is, however, a huge variety within the general cargo category. Pallets, liquid bulk, solid bulk and others have different characteristics in terms of volumes, inventory costs, transshipment costs, et cetera. Considering those issues is new and primordial contribution in the evolution of freight transport modelling towards more disaggregated agent-based systems. Nine different types of loading units are together with ten commodity types integrated in an agent-based freight transport model for Belgium which is currently under development.

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Keywords: Freight transport model; freight generation model; loading unit

1. Introduction

Transport of freight is the result of the spatial spread of production and consumption. It is a crucial component of our society, as it sustains our daily lives and economy. The huge amount of freight transport movements creates however different negative effects, affecting our health (emissions, noise and accidents), our economy (congestion) and our ecologic system (emissions). Those effects are having an impact on both global and very local scale. Understanding freight transport systems and their related impacts is consequently of crucial importance for both the public and the private sector, as it will help them to achieve their social, economic and/or ecologic goals. Freight

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transport models are offering toolkits to simulate real life transport systems. Like every model, they give a simplified description of (a part) of reality, and for freight transport, this simplification is amplified due to the complexity of the freight transport system. That system is in comparison to passenger transport very heterogeneous (volume, weight, value of the goods, shelf life, et cetera). Moreover, only a limited amount of freight flow data are available, cost structures are as a result of negotiations not transparent at all and often confidential, flows are generally more asymmetric than passenger flows and finally various stakeholders are involved in the decision making process. However, despite the increased complexity of freight transport systems, freight transport models are generally based on passenger transport models[1]. State-of-practice in both passenger and freight transport modelling are FOUR-step models, for which the consecutive steps are trip generation, trip distribution, modal split and route assignment. Whereas FOUR-step models prove themselves to be relatively straight forward and fast, theory in transport modelling has shifted towards a focus to individual agents and trips. The advantages are multiple. Firstly, the so-called agent-based methodology is more flexible than the FOUR-step one, as it is able to map individual actions and reactions. This leads to better interpretations of the produced results[2]. It secondly also allows to take into account behavioral aspects into the transport model, of which its importance is recognized by many authors[3 4 5]. Thirdly, agent-based transport models are, despite their related higher necessity of computational resources and higher level of complexity, making the shift from aggregated results towards disaggregated results. This consequently also leads to better interpretations, better assessment of policies and better communication[6]. The shift towards more disaggregated freight transport modelling started with the integration of logistical aspect in the late nineties with models like SMILE[5], GOODTRIP[7], and SLAM[8]. More recent models are discussed in Ben-Akiva and de Jong (ADA)[9], Liedtke (INTERLOG)[10], Roorda et al.[11], Holmgren et al. (TAPAS)[12] and Baindur and Viegas[13]. They all try to disaggregate the gathered aggregated data to some extent. The focus of the disaggregation process lies on the logistic relations, the use of distribution centers and the commodity type. All parameters which influence logistics decision making. The next section of this paper will address different freight transport models and the disaggregated parameters that they are taking into account. One parameter that is generally not considered is the used loading unit. Like demonstrated in the next section, some existing freight transport models are including containerized goods and non-containerized ones. However lots of different loading units exist, who are influencing logistic decisions and should consequently be integrated in freight transport modelling. The used loading unit has an impact on transshipment costs and possibilities, storage costs and requirements, the use of distribution centers, used transport mode and routing type (A to B, milk round, etc.).

In the development of a new agent-based freight transport model for the Belgian territory, called TRABAM, nine types of loading units were integrated. This is in our knowledge new and an important contribution in transport modelling and logistic decision making. In Section 3 of this paper the used methodology for including the loading unit will be explained. Finally, a conclusion will be given.

2. Towards the disaggregated reality

Looking at the developments in freight transport modelling, one can see a trend towards disaggregation and simultaneously agent-based systems. Different, recently developed freight transport models are trying to disaggregate their analysis in order to be able to include logistic decision making into their models. However, detailed freight transport data are scarce and fragmented amongst the multiple actors who are influencing logistics. As a result, often only aggregated data are available, leading transport model developers to search fitting methodologies to disaggregate the data as much as possible. The focus of disaggregation lies on one hand on data influencing logistic decision making and on the other hand on the purposes of the model outcome. In this paragraph different freight models are compared in terms of data disaggregation and focus. In order to make correct comparisons, only regional and national freight models are addressed, as they are faced with similar data issues. Urban freight models are consequently disregarded in this analysis.

The first model which will be described is SMILE[5]. SMILE is a FOUR-step model for the Netherlands that integrates the use of logistic centers into the modelling process. SLAM[8] is built on the bases of SMILE and SCENES for the European scale and takes into account location analysis of logistic centers and their use. Both models are not making any distinction between used loading units. SAMGODS[14] is another FOUR-step model, developed for Sweden, also taking into consideration logistic centers. The SAMGODS model addresses three type of loading units:

containers, bulk and general cargo. Another Swedish model is TAPAS[12]. TAPAS is an agent-based model that again takes into consideration logistic centers. The use of logistic centers is a result of a decision making process and can therefore be linked with agents. It is however not making any distinction in used loading unit. The ADA model[9] is a model focusing on the disaggregation process, as it disaggregates aggregated production-consumption flows in a logistics module. The flows are disaggregated on firm level, where through logistic decisions shipments are produced. Those shipments are aggregated again to an origin-destination matrix. The ADA methodology is applied as input for another agent-based freight model[15] for the Flemish Region. Also in ADA no distinction is made between used loading units. The SVRM VLA[16] is on its turn again a FOUR-step model for the Flemish Region. It makes the distinction between containerized and general cargo at a relative detailed zonal level of 518 traffic analysis zones (TAZ). DIDAM[17] is an agent-based model for freight transport by road in the Walloon Region of Belgium. It does not consider different loading units. Baindur and Viegas[18] developed an agent-based freight model for the Mediterranean Region. Roorda et al.[19] consider in their agent-based model for great Toronto area also no different loading units. Finally, INTERLOG[10] is an agent-based model for Germany where logistic reactions are integrated in different modules. INTERLOG takes into account four types of loading platforms, being closed, open, kipper and container. Those influence transshipment costs, but are not affecting storage cost and other costs like loading units do. Table 1 gives an overview on the different freight transport models which were addressed in this literature review.

Table 1. Overview on different freight transport models.

Freight transport model	Region	TAZ	Type	Specification	Loading units
SMILE	Netherlands	42	FOUR-step	Logistic centers	No differentiation
SLAM	Europe	200	FOUR-step	Logistic centers	No differentiation
SAMGODS	Sweden	288	FOUR-step	Logistic centers	3 types
TAPAS	Sweden	/	Agent-based	Logistic centers	No differentiation
ADA (Maes[15])	Flanders	308	Agent-based	Shipments firm level	No differentiation
SVRM VLA	Flanders	518	FOUR-step	Logistic centers	2 types
DIDAM	Wallonia	262	Agent-based	Incl. passenger transport	No differentiation
Baindur and Viegas	Mediterranean	/	Agent-based	Supply-demand dynamics	No differentiation
Roorda et al.	Toronto area	/	Agent-based	Business decisions	No differentiation
INTERLOG	Germany	/	Agent-based	Logistic reactions	~ 4 types of platforms
TRABAM	Belgium	4 934	Agent-based	Loading unit	9 types

From Table 1 one learns that some FOUR-step models make the differentiation between loading units as far as containers and general cargo. Examples are addressed in this paper, being SAMGODS and SVRM VLA. Agent-based models benefit more from the disaggregation, but to our knowledge there is currently no differentiation in terms of loading unit in agent-based freight transport models. All agent-based simulations are at the moment based on one type of loading unit, like for example pallets in Schröder and Liedtke[20].

Contacts with private actors in logistics and common sense are suggesting that the used loading unit is playing an important role in the transport system. It is incontestably influencing cost factors like storage costs and transshipment costs, it plays a role in mode choice and route type. Therefore our research is considering nine different loading units in order to research its impact in logistics. In the next paragraph, the used methodology will be explained.

3. Loading units in agent-based transport model

In the dec²4sust project, financed by the Vrije Universiteit Brussel, researchers of the VUB MOBI research group are developing a freight transport model for Belgium which enables adequate and detailed calculations of transport-related economic, ecologic and social effects. The first step of this development is the generation of demand for freight transport. Despite the existence of different freight generation models as input for freight transport models, one needs to conclude that their methodologies are often only briefly explained and their accuracy is rarely detailed[20]. While the generation of freight transport is no straightforward process and there is a lack of an ultimate best methodology for it. Methodologies are chosen and fitted in relation to the particular case. For the Belgian case, data were collected amongst different institutions. Based on economic data on establishment level (number of employees, gross floor surface, address and activity), population density and freight flows by commodity type (NST/R) and loading unit (solid bulk, liquid bulk, containers, other containers, slings, pallets, mobile units, other mobile units and others) between Belgian municipalities, an origin destination matrix is generated between 4 934 Belgian traffic analysis zones at both commodity type and loading unit. The methodologies used to do so are described in a journal paper[21].

In a first step, different regression techniques were applied on municipality level to produce generated and attracted volumes on traffic analysis zone level. Volumes (in tonnes) by commodity type and loading unit combinations, grouped combinations of commodity type and loading unit and only commodity type are tested as dependent variables, whereas population density, gross floor space by activity sector (13 different ones) and number of employees by sector are used as independent variables. Commodity type and loading unit combinations showed too small number of non-zero values, and are therefore neglected. For grouped combinations of different commodity types and loading units and commodity type only, the generalized linear regression model with log link (GLML) showed best results. This when taking into consideration the assumptions of the used regression technique, the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC) and Likelihood Ratio Chi-square values. Moreover, also the distribution, R-squared and residual diagnostics was looked at. Grouped dependent variables showed similar results as the commodity type ones; however grouped variables are faced with reduced readability. Therefore the regression analyses with volumes (in tonnes) by commodity type are chosen[21]. Measures of fit and validation results of these regression analyses are in line with values of current state-of-the-art freight generation models[21]. Rather low accuracy is however a problem where freight generation models are faced with in general.

The regression formulas which are obtained on municipality level are then applied on the 4 934 traffic analysis zones. As such generated and attracted volumes (in tonnes) by commodity type are produced for every single traffic analysis zone. In order to include the valuable information on the used loading unit, used loading units were added afterwards based on a probabilistic determination. That determination is based on the probability for a loading unit given the type of commodity and given the municipality which contains the concerned traffic analysis zone. Using detailed real world data enable to take into consideration local differences in used loading units, which could never be explained by more sophisticated methods like decision trees or discrete choice models[21]. Volumes were calibrated and the generated and attracted volumes by commodity type and loading unit were linked to another afterwards, in order to obtain an origin-destination-matrix between the Belgian traffic analysis zones. Different techniques exist to produce a trip distribution out of the freight generation model. Gravity models are one of them, and they are most often used. Opportunity models are another main technique. Both are based on rather common sense relationships. For gravity models, it is the declining relation with increasing distance/time/cost and positive association with the population and economic activity. While opportunity models are based on the relation on accessibility of opportunities that are satisfying the goal(s) of the trip. None of both are taking into consideration real world origin-destination combinations, as it is for calibrating or validating its results[21].

However, for this research origin-destination combinations between Belgian municipalities were gathered by commodity type and loading unit. This real world dataset allows us to build a case-specific probability function which applies on the used traffic analysis zones. As such, more realistic and case-specific origin-destination relations can be generated in comparison to techniques presented in literature. Therefore the case-specific probability function is preferred. The municipality level is broken up to traffic analysis zones by combining the probability of freight flows between municipalities with the probability that freight volumes, by commodity type and loading unit have a specific traffic analysis zone with the municipality of arrival as their end destination. That last element of the equation is derived from the attracted volumes produced by the earlier described freight generation model. In its mathematical form, the probability function can be written as[21]:

$$P_i^{kl}(j) = P_m^{kl}(n) \cdot P_n^{kl}(j) \text{, with } i \in m, j \in n \qquad (1)$$

Where: $P_i^{kl}(j)$ is the probability that a volume of commodity type k and loading unit l and with traffic analysis zone i as origin has traffic analysis zone j as destination.

$P_m^{kl}(n)$ is the probability that a volume of commodity type k and loading unit l and with municipality m – which contains traffic analysis zone i – as origin has municipality n as destination.

$P_n^{kl}(j)$ is the probability that a volume of commodity type k and loading unit and with municipality n – which contains traffic analysis zone j – as destination has traffic analysis zone j as destination. It is independent of municipality m.

Yet, by applying above probability function, one is confronted with unrealistic fragmentation of the small volumes (in tonnes). To avoid this error, one therefore used the probability function on shipments is used. Those shipments are calculated based on optimal average shipment sizes by commodity type and loading unit. Generally, its calculations is done by an optimization function including both inventory and transport cost[22]. However, in our research, it is impossible to include transport cost as shipment sizes must be calculated before the generation of origin-destination combinations in order to avoid above mentioned fragmentation. The shipment size is consequently based on the work of de Jong and Ben-Akiva[22], which used the following standard Economic Order Quantity formula:

$$q_{kl} = \sqrt{\frac{(o * Q * 2)}{(w + d * v)}} \qquad (2)$$

Where q represents the average shipment size of commodity k and loading unit l; o is the constant unit cost per order; Q is the annual demand in tonnes per year; w is the storage cost per unit per year; d is the discount rate per year and v is the value of goods per tonne. The necessary values were based on the work of Maes. The assumption of letting out the transport costs will be tested once the freight transport model (TRABAM) will be running well, like de Jong and Ben-Akiva[22] did in their research.

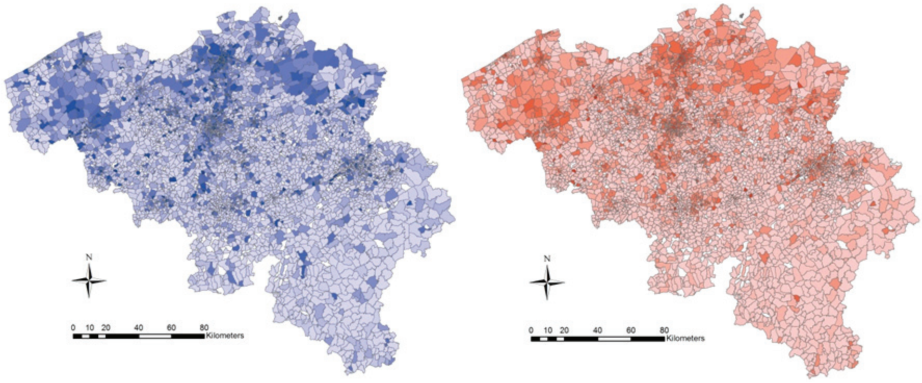

Figure 1: Generated (left) and attracted (right) volumes (in tonnes) for all commodity types and loading units on TAZ level[21].

Figure 1 illustrates the geographical distribution for generated (left) and attracted (right) volume (in tonnes) for all commodity types and loading units on traffic analysis zone level. Large volumes are seen in and around urban areas and airports and seaports. Note also the difference between the larger rural areas and small urban areas. This enables that the output of the freight generation model can be used for city distribution analyses. With 4 934 zones, the presented work increases also the level of detail of freight flows within Belgium, and is as such a valuable input for an agent-based freight transport model. The most important contribution of this work is however the integration of nine different loading units. This enables more profound research on the impact of loading units on transport choices, like the modal choice. One thinks of new analyses with the static LAMBIT[23] and LAMBTOP models[24]. LAMBIT focusses on the market areas of intermodal container terminals, while LAMBTOP targets the feasibility of a modal shift of palletized goods. Its main application will however be an input for the TRABAM model which is currently under development.

4. Conclusion

Knowledge about freight transport flows is important for public and private decision makers. Generally freight transport models consider only flows by different commodity type between meso-level traffic analysis zones. Only a few models are taking into account different loading units, while those are influencing transshipment costs, storage costs, transport costs, etc. All are influencing the transport system and need therefore to be taken into consideration as good as possible. However, only few freight transport models are including loading units in their analyses. And if so, only the distinction between containerized freight and general cargo is made. While in reality, there are other important loading units, like pallets, liquid bulk and solid bulk. A reason for this aggregation on loading unit level is the limited amount of available data on freight transport flows.

For this research freight data for Belgium were gathered, which include nine different types of loading units. In contrast to international literature on freight modelling, it was opted, for previously mentioned reasons, to include those nine categories in further modelling phases. To do so different regression techniques were tested. Best results were found when applying the generalized linear regression model with log link (GLML) on volumes by commodity type only as dependent variable. In order to move to more disaggregated agent-based transport models and to be able to illustrate the importance of loading units in the modelling and in reality, one integrated the available information on used loading units was integrated after the regression analysis via a probability function which considers both a geographical and a commodity type parameter. Results proved stable and robust. New insides thanks to this contribution will be created by its use in the agent-based freight transport model for Belgium, called TRABAM.

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