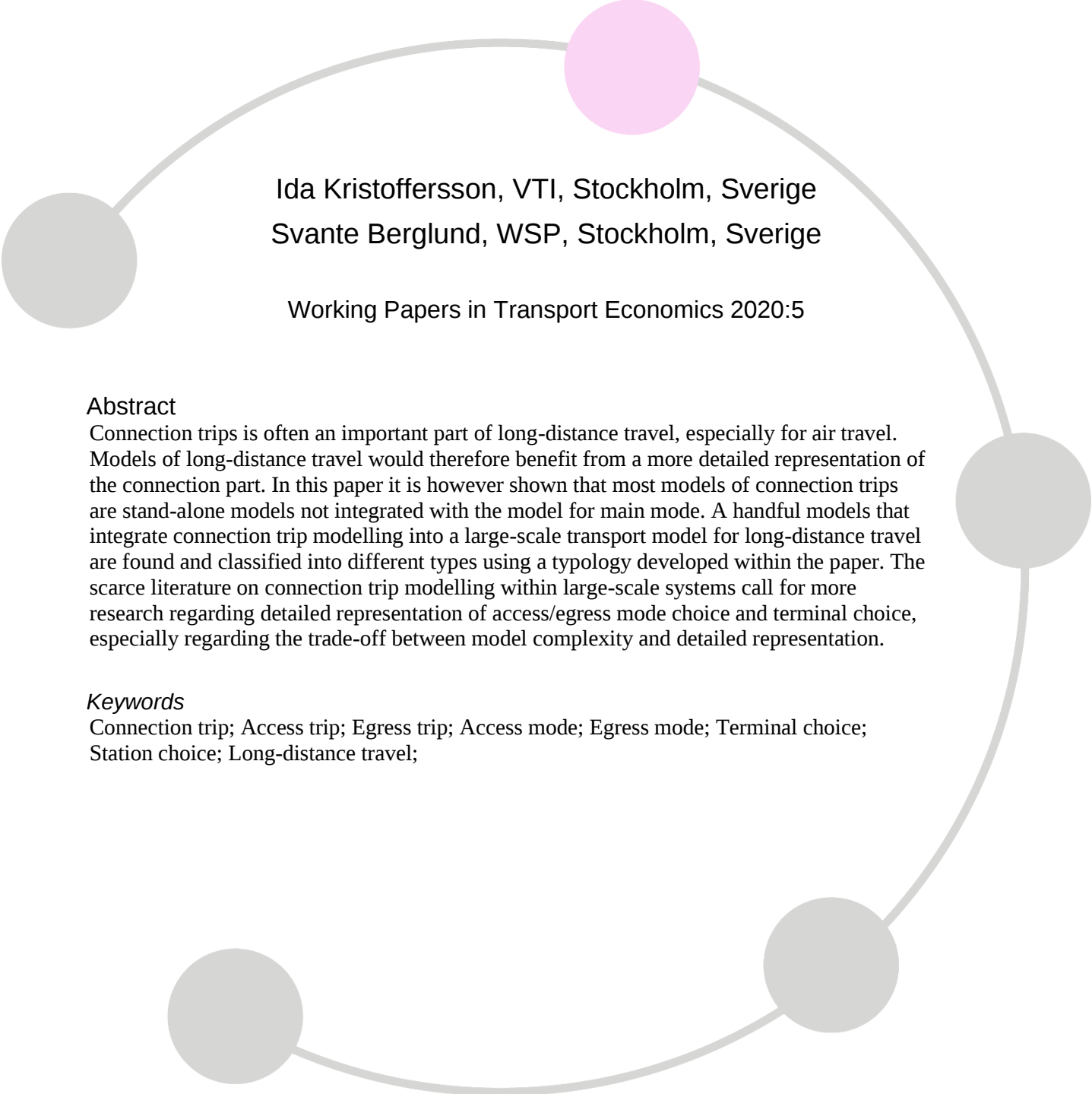


Modelling connection trips to long-distance travel – State-of-the-art and directions for future research



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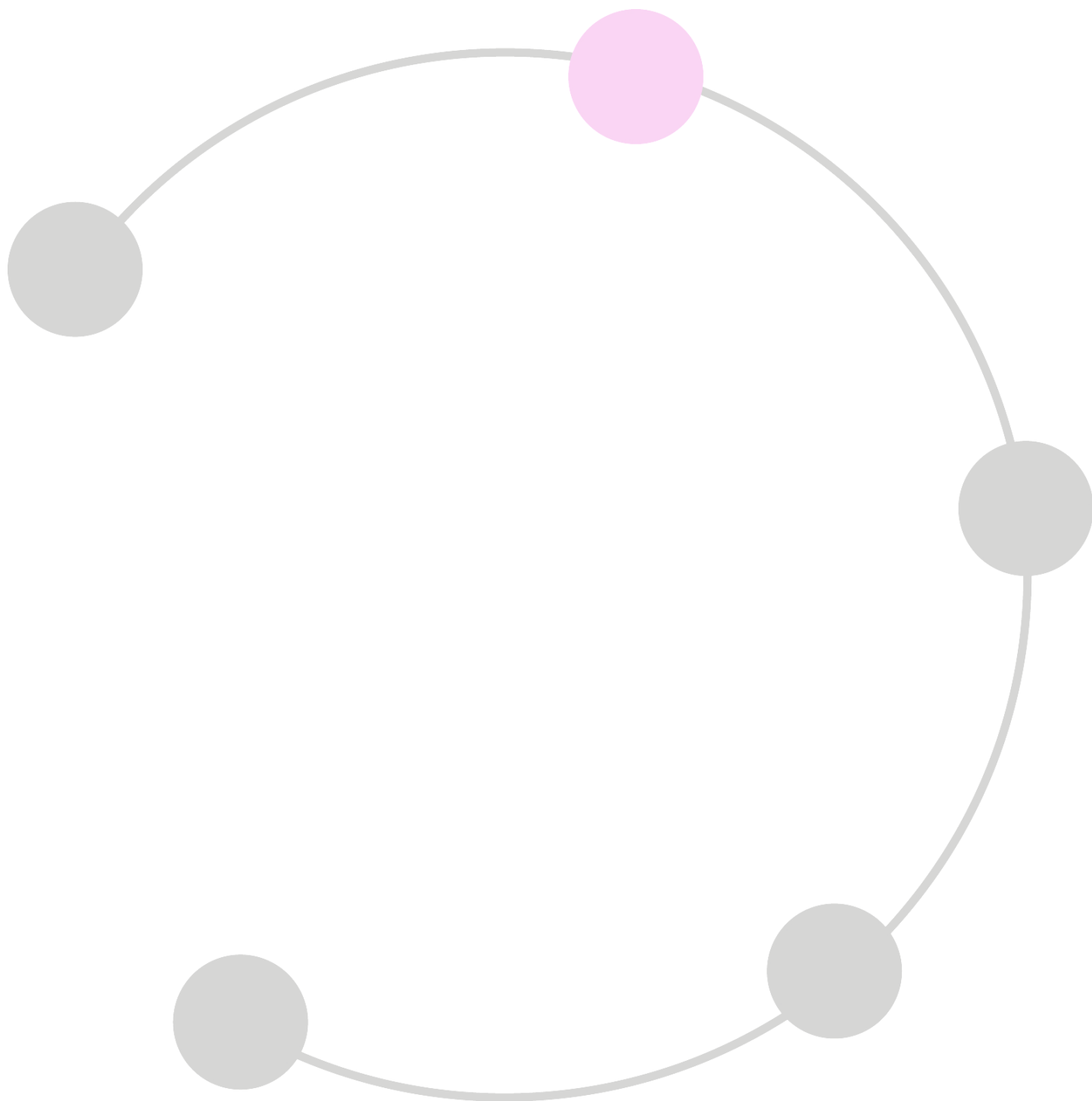
Working Papers in Transport Economics 2020:5

Abstract

Connection trips is often an important part of long-distance travel, especially for air travel. Models of long-distance travel would therefore benefit from a more detailed representation of the connection part. In this paper it is however shown that most models of connection trips are stand-alone models not integrated with the model for main mode. A handful models that integrate connection trip modelling into a large-scale transport model for long-distance travel are found and classified into different types using a typology developed within the paper. The scarce literature on connection trip modelling within large-scale systems call for more research regarding detailed representation of access/egress mode choice and terminal choice, especially regarding the trade-off between model complexity and detailed representation.

Keywords

Connection trip; Access trip; Egress trip; Access mode; Egress mode; Terminal choice; Station choice; Long-distance travel;



1. Introduction

Many large-scale models of long-distance travel lack sophisticated modelling of connection trips. This can be problematic, especially if the models are intended to evaluate investments such as high-speed rail, where travel on the train is fast but terminals often located quite far away from city centres. It is also important to be able to evaluate investments such as a new rail line to the airport. New rail lines to airports have traditionally been evaluated by estimating a stand-alone model for access mode choice to the specific airport in question (for a review of access mode choice models to airports see e.g. ACRP (2008)). Modelling of connection trips to long-distance travel is however not only relevant for air trips alone, it may very well also be relevant for the choice of main mode for long-distance travel.

An investigation of the Swedish national travel survey from years 2011-2016 shows that the cost for connection trips is a much larger part of the total trip cost for air (30-50%) compared to rail (in most cases below 10%) (Berglund & Kristoffersson, 2020)¹. The same pattern is found for connection travel time. Thus, the main mode in-vehicle travel time and travel cost gives a much more complete description of the total trip for rail compared to air. A long-distance model without a model for connection trips thus runs a risk of being more or less biased towards air travel.

In this paper, the existing literature on connection trip modelling in the context of long-

¹ We see no reason for this to be a particularly Swedish phenomenon – airports are located quite far from city centres compared to main train stations in most countries.

distance travel is reviewed. It is shown that few models take a broader picture when modelling connection trips. The contribution of this paper is threefold: First, a typology is developed which classifies models that include connection trips into different types depending on the included choice dimensions; second, existing literature on connection trip modelling is classified and discussed within the context of the developed typology; and third, directions for future research are outlined given the identified research gaps.

2. Method

2.1 Literature search

A literature search has been performed in the databases Scopus, Web of Science and Google Scholar. The search terms that has been used are “access trip long-distance” and “access mode”. The literature search resulted in 33 relevant papers found. Backward snowballing added 3 more papers to the list. Furthermore, the authors had access to 13 relevant reports (grey literature) in the field of modelling access trips to long-distance travel already before conducting the literature search. All in all, this leads to 49 research items that the analysis in this paper is based upon.

2.2 Topology

Modelling of connection trips to long-distance travel can be done in several ways, differing in which choice dimensions are included and thus in complexity. The simplest connection trip model covers only access mode choice to a specific terminal, whereas the most complex model includes both connection trip mode choice and terminal choice in a complete model system for long-distance travel. Because of this variety in model structures, a topology is developed in this paper which classifies models that include connection trips into nine different types depending on which choice dimensions are

included. Table 1 describes the different model types in the typology and Table 2 shows which choice dimensions are included in which model type.

Table 1: Description of the model types in the developed topology for connection trip modelling.

Type	Description
1	Stand-alone models of access mode choice
2	Stand-alone models of terminal choice
3	Stand-alone models of joint access mode and terminal choice
4	Models of access and egress mode choice as part of a model of main mode choice
5	Models of terminal choice as part of a model of main mode choice
6	Models of access and egress mode and terminal choice as part of a model of main mode choice
7	Models of access and egress mode choice as part of a model of joint main mode and destination choice
8	Models of terminal choice as part of a model of joint main mode and destination choice
9	Models of terminal and access and egress mode choice as part of a model for joint main mode and destination choice

Table 2: Included choice dimensions of the model types in the developed topology for connection trip modelling.

Type	Access mode	First terminal	Main mode	Destination	Last terminal	Egress mode
1	X					
2		X				
3	X	X				
4	X		X			X
5		X	X		X	

6	X	X	X		X	X
7	X		X	X		X
8		X	X	X	X	
9	X	X	X	X	X	X

All types are theoretically possible, but they do not have to exist as implemented models. During the research it has become clear that what constitutes a model of terminal choice is not self-evident. Any assignment of public transport trips to a network need to include some kind of terminal choice. The approach taken in this paper is that simple rules and assumptions are not enough to qualify for a type which includes terminal choice (Type 2, 3, 5, 6, 8, and 9).

3. Results

In this section, results from the literature search are shown. The results are discussed in the context of the typology developed in the previous section. Models found in the literature are classified into the different types in the typology and the more advanced models are discussed in more detail. Only models that explicitly consider connection trips are included in the classification. In several large-scale transport model systems connection trips are handled within public transport route choice. Models where connection trips are represented by a very low speed on access/egress links, in order for the closest terminal to be chosen in most cases, and which do not include access/egress mode choice, are not included in the classification, as described in the previous chapter. There is however a grey zone here since public transport assignment can be made more sophisticated using for example advanced route choice algorithms such as Path-Size Logit. These types of models could potentially be eligible for classification into the typology.

3.1 Stand-alone models of connection trips (Type 1, 2 and 3)

Most models found in the literature search belong to the category of stand-alone models for connection trips. This category includes three model types in the typology above – models of access mode choice only (Type 1 – see Figure 1), models of terminal choice only (Type 2 – see Figure 2) and models of joint terminal and access mode choice (Type 3 – see Figure 3).

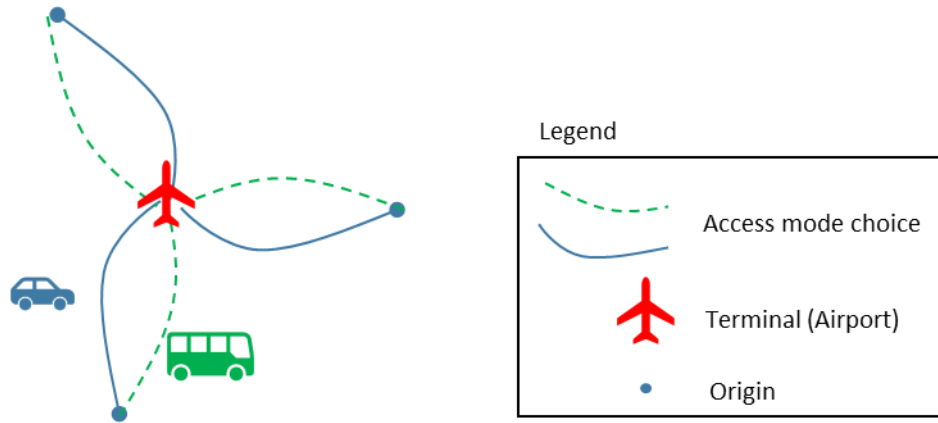


Figure 1: Schematic figure of stand-alone access mode choice models (Type 1).

The typical Type 1 model is a model of access mode choice to a specific airport. This type of model has been developed for airports in the US (ACRP, 2008; Akar, 2013; Ameen & Kamga, 2013; Gosling, 2006), Europe (Bergantino et al., 2019; Birolini et al., 2019; Budd et al., 2014; Gokasar & Gunay, 2017; WSP, 2015), and Asia (Alhussein, 2011; Chang, 2013; Jou et al., 2011; Roh, 2013; M. L. Tam et al., 2005; M.-L. Tam et al., 2011; Yazdanpanah & Hosseini, 2016, 2017). Also some Type 1-models when rail is the main mode exist (Wen et al., 2012), even though it is not at all as common.

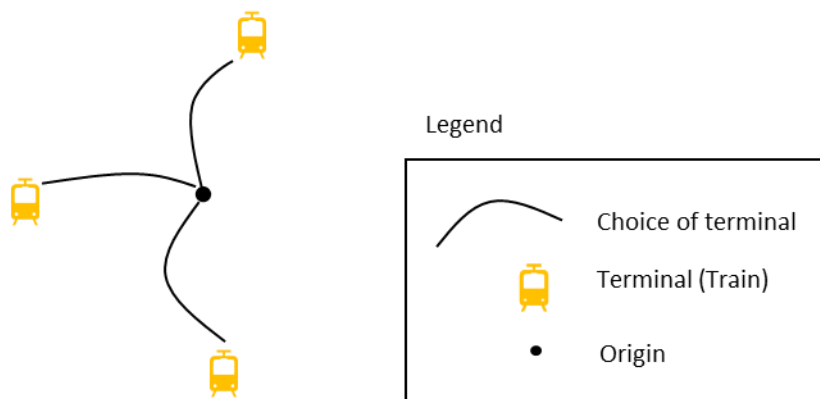


Figure 2: Schematic figure of stand-alone terminal choice models (Type 2).

For rail it seems more common in the literature to focus on terminal choice only (Type 2-models) than access mode choice only. Young and Blainey (2018) conduct a literature review with focus on terminal (station) choice (mainly Type 2- and Type 3-models).

There does not seem to be similar bulk of literature on Type 2-models when the main mode is air, rather air studies seem to go directly from Type 1-models to Type 3-models in which access mode and airport choice is modelled jointly (Gelhausen & Wilken, 2006; Gupta et al., 2008; Hess & Polak, 2006). An example of a Type 3-model with rail as main mode is Debrezion et al. (2009).

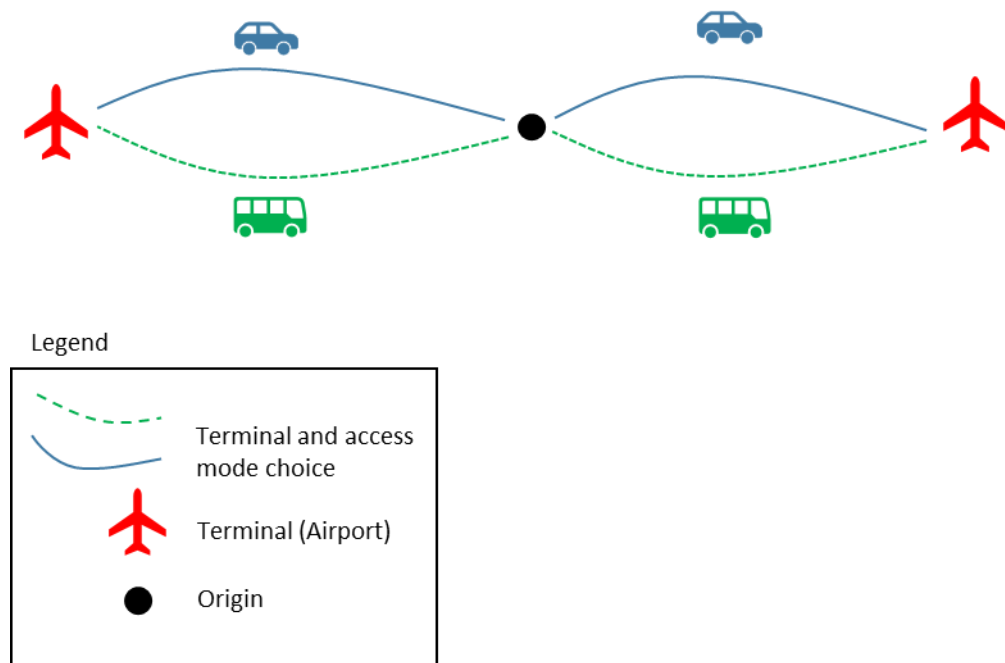


Figure 3: Schematic figure of stand-alone joint terminal and access mode choice models (Type 3).

It is worth noting that none of the studies of Type 1-3 found in literature model access mode and/or terminal choice for long-distance bus, which is commonly included as a main mode in long-distance travel models. Kristoffersson and Berglund (2020) show that 4.3 % of long-distance trips within Sweden are conducted with bus as main mode, thus this is a minor mode even though not entirely negligible. It is probable that long-distance bus is more similar to rail than air regarding the share of travel time and travel cost related to the connection trip, since bus terminals often have central locations, just as train stations.

3.2 Large-scale models of mode choice for long-distance travel with focus on connection trips (Type 4, 5 and 6)

The models included in Type 4, 5 and 6 in the typology (see Figure 4-Figure 6) has in common that they include main mode choice but not destination choice. In this case destination choice is fixed. It is thus assumed that long-distance travel destination choice does not depend on level-of-service variables such as travel time and travel cost, which is a rather strong assumption in many cases, especially if the model is used to forecast travel patterns 20 years or more into the future. The advantage is a simpler model structure which is easier to estimate and implement since destination choice typically generates a very large number of alternatives.

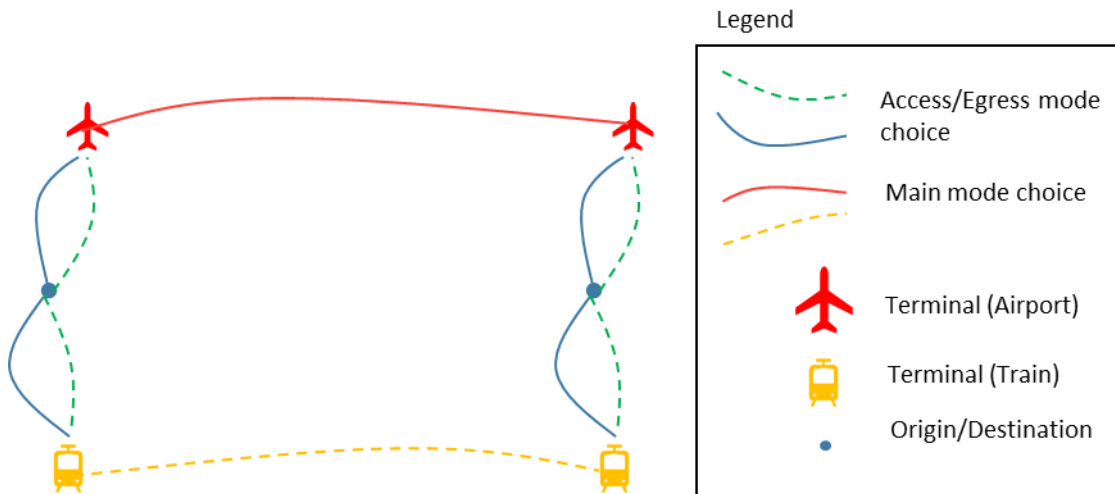


Figure 4: Schematic figure of models of access and egress mode choice as part of a model for main mode choice.

Type 4-models (Figure 4) include main mode choice in combination with access/egress mode choice but not terminal choice. The CHSR California high speed rail ridership and revenue model (Cambridge Systematics, 2016) is the only Type-4 model found in the literature. This is an advanced model with main modes car, air, and rail (divided into high-speed rail and conventional rail), where access and egress mode choice has been estimated simultaneously with main mode choice. This allows control over cost and

travel time parameters in different parts of the model such that the parameter orders of magnitude are reasonable. The cost parameter is for example set equal for different types of trips (access/egress/main) since valuation of money normally does not change during a trip. Travel time sensitivity may on the other hand differ between different types of trips and these are therefore allowed to vary within limits, e.g. that the sensitivity to access/egress travel time needs to be equal or larger than sensitivity to main mode travel time. Access and egress modes are modelled to air, high-speed rail, and conventional rail. The access/egress modes included are, for all main modes, car as a driver (parking), car as a passenger (escort), taxi and public transport.

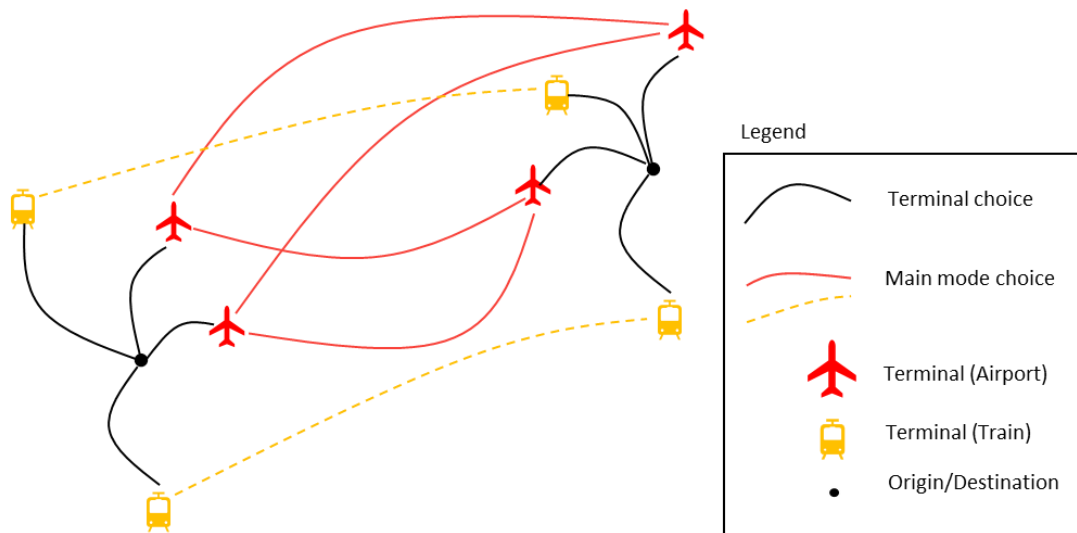


Figure 5: Schematic figure of models of terminal choice as part of a model for main mode choice.

Type 5-models (Figure 5) include main mode choice in combination with terminal choice but not access/egress mode choice. The only Type 5-model found in the literature is a model called R³Logit for long-distance trips in North Carolina, USA (Moeckel et al., 2015). This model includes car and public transport (divided into bus, rail, and air) as main modes. It is assumed that car is used as access and egress mode to all public transport modes. For the public transport main modes, choice of terminal is

determined by selecting the three terminals closest to the origin of the trip and the three terminals closest to the destination. Utility is then calculated for each of the nine combinations of start and end terminals and the station combination with highest utility is chosen.

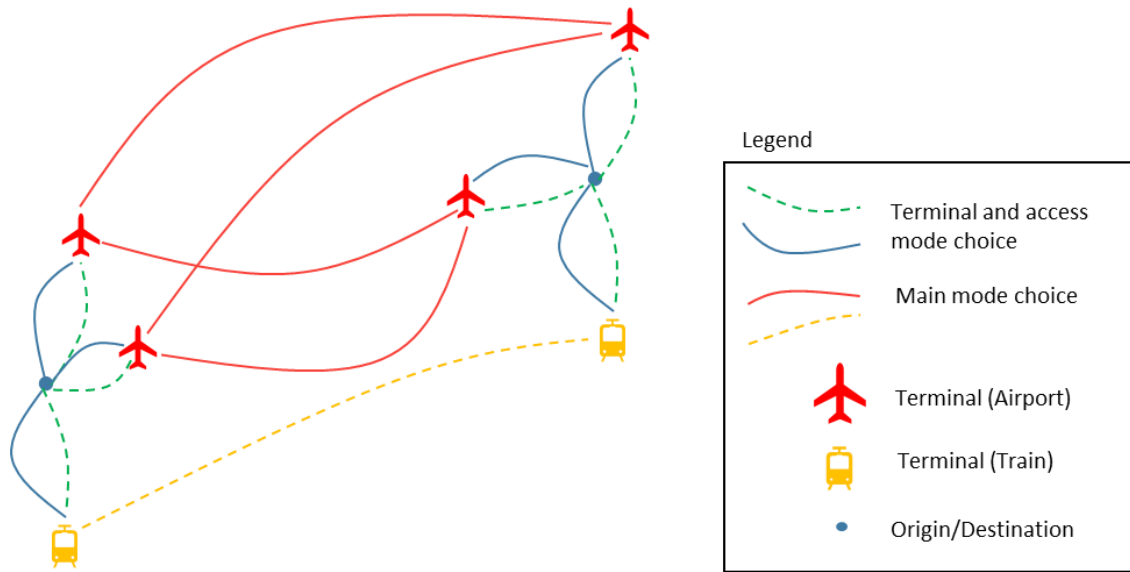


Figure 6: Schematic figure of models of joint access/egress and terminal choice as part of a model for main mode choice.

Type 6-models (Figure 6) include main mode choice in combination with access/egress mode choice and terminal choice. The only model of this type found in the literature is a model for evaluation of high-speed rail in the UK called PLANET (HS2 Limited, 2017). The PLANET model includes car, rail, and air as main modes. For rail as main mode it also includes a module for connection trips. The module for connection trips is a nested logit model with rail access mode choice (car or public transport) on the higher level and choice of station pair (first and last station) on the lower level. Egress mode choice is not modelled explicitly. Allowed stations are chosen from a catchment area, with 20 stations as maximum number of possible stations. The catchment areas are larger for car compared to public transport.

3.3 Large-scale models of joint mode and destination choice for long-distance travel with focus on connection trips (Type 7, 8 and 9)

The models included in Type 7, 8 and 9 in the typology (see Figure 7-Figure 9) has in common that they include main mode choice as well as destination choice in combination with connection trip modelling. These are thus detailed and often very complex models where it is not obvious how the model should be structured.

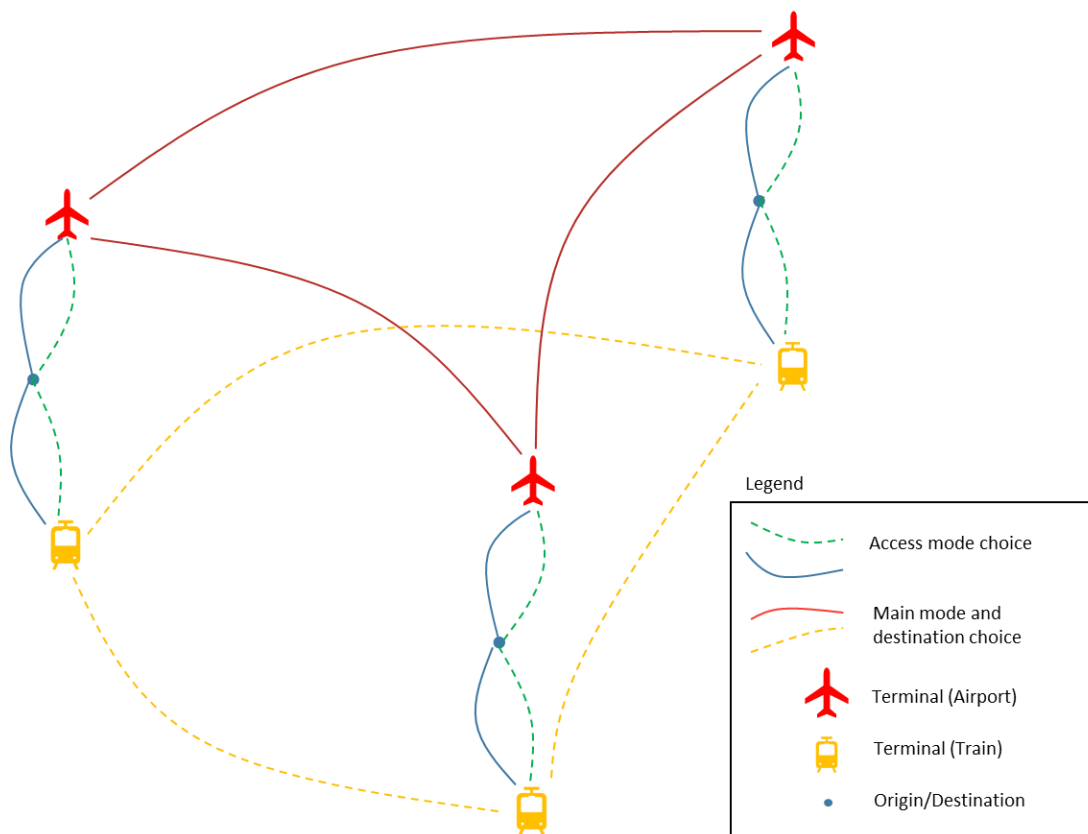


Figure 7: Schematic figure of models of access/egress mode choice as part of a model for both main mode and destination choice.

Type 7-models (Figure 7) include main mode and destination choice in combination with access/egress mode choice but not terminal choice. No long-distance transport model of this type was found in the literature search.

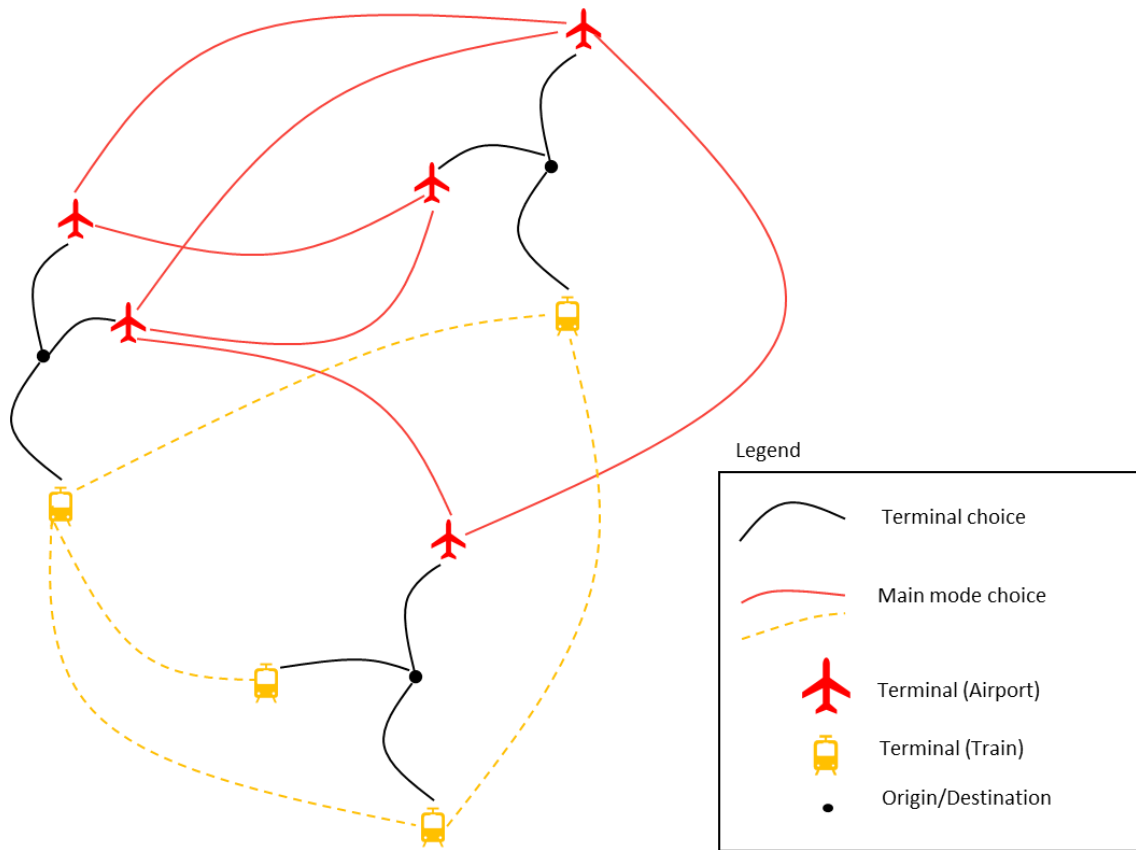


Figure 8: Schematic figure of models of terminal choice as part of a model for both main mode and destination choice.

Type 8-models (Figure 8) include main mode and destination choice in combination with terminal choice but not access/egress mode choice. Only one possible candidate for a Type 8-model was found in the literature search. This is the French national transport model called MODEV (Cori, 2019). This model includes choice of destination and choice between the main modes road, rail, and air. Accessible documentation is limited but point out that several station-to-station level-of-service matrices are compared for each trip, based on which the best route is chosen.

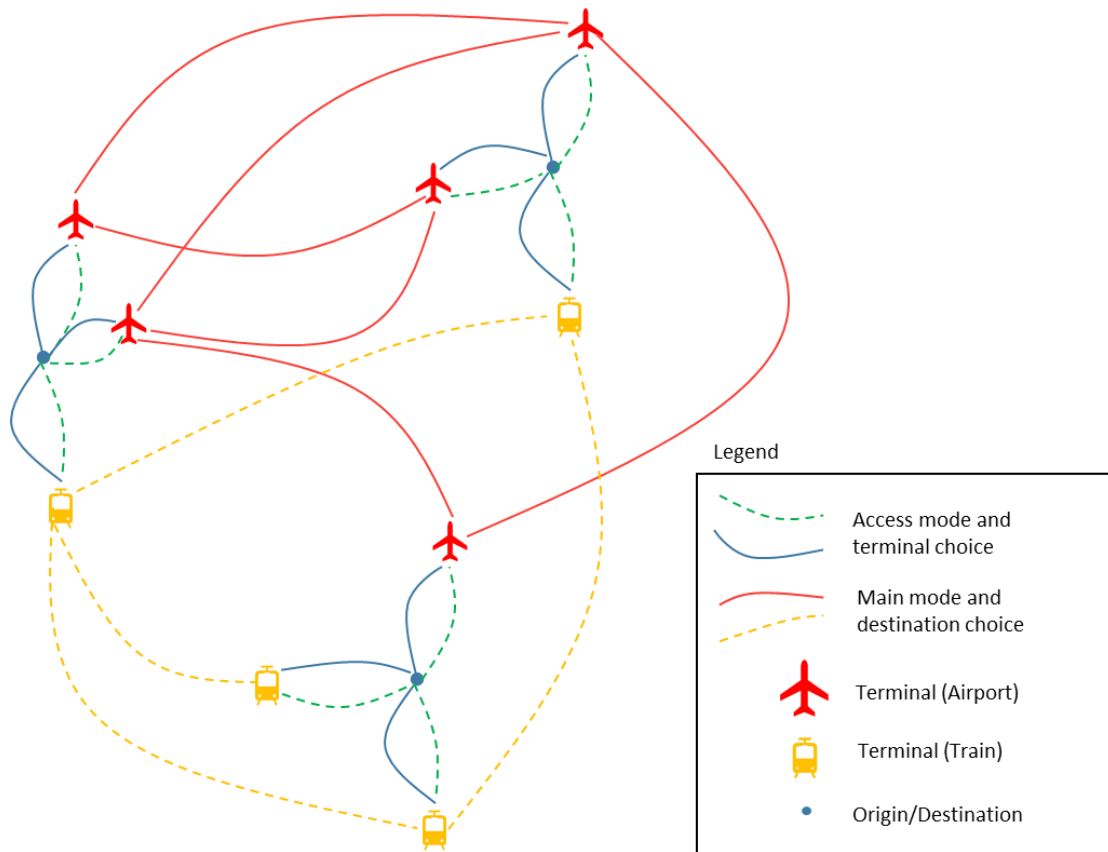


Figure 9: Schematic figure of models of access/egress mode choice and terminal choice as part of a model for both main mode and destination choice.

Type 9-models (Figure 9) include main mode and destination choice in combination with access/egress mode choice as well as terminal choice. In the literature search the only long-distance model of Type 9 found is the Netherlands national transport model called LMS (Fox et al., 2003), which has been extended over the years to include more sophisticated modelling of access trips to rail (Pel et al., 2014). The LMS model is not a model dedicated for long-distance trips only, rather it models all trips in the Netherlands and therefore includes the main modes car as driver, car as passenger, rail, bus/tram/metro, walk and bicycle. For rail as main mode, the model structure includes as many as seven choice levels in the decision tree: 1) tour generation, 2) main mode, 3) time of day (morning peak, evening peak or off peak), 4) destination zone, 5) access and egress mode, 6) embarking and disembarking stations, and 7) train. These seven choice levels are modelled using three separate logit models with logsums connecting the

models and iteration performed to ensure convergence. The choices are combined as follows: tour generation, main mode / time of day / destination zone, access and egress mode / embarking and disembarking stations / train. The utility for train choice includes variables in-vehicle time, ticket cost, boarding and transfer waiting time, and number of transfers. There does not seem to be any variables specific to access/egress mode or embarking/disembarking station other than that these choices may affect the variables mentioned above.

Two models of primarily regional trips have been found that model connection trips in a sophisticated way – the PRISM model for West Midlands in the UK (Fox, 2005) and the STM model for Sydney (Fox et al., 2011). The PRISM model was an early attempt to model park-and-ride at rail and metro stations, and the model therefore includes the access modes car – parking, car – drop off, and other (walk, bicycle, and bus).

Connection trips are modelled as a nested logit model with access mode choice above station choice. Last terminal and egress mode choice is not modelled explicitly.

The STM model for Sydney includes the main modes car as driver, car as passenger, public transport (train and bus), bicycle, walk and taxi. Three access modes to train are included: car as driver, car as passenger and other (walk and bus). Terminal choice is included for the access modes car as driver and car as passenger and a previous version of the model is used to determine the five most attractive terminals for each trip. There are as much as six choice dimensions in the model: choice of main mode, public transport mode, access mode to train, train station, destination and charged or non-charged road. One of the major challenges in the development of the STM model was therefore to develop the nesting structure of all choice dimensions.

4. Research gaps and directions for future research

In this paper it is shown that most models of access/egress mode choice and terminal choice are stand-alone models not integrated with any model for main mode and destination choice. Stand-alone models are useful for analyses of e.g. access modes to specific airports or railway stations. The disadvantage is however that the detailed description of the connection trip is not put to good use in the main model for long-distance travel. On the contrary, stand-alone models need external origin-destination matrices from a long-distance model as input. A handful examples of models which integrate connection trip modelling within a long-distance model framework are reviewed in this paper, see Table 3.

Table 3: Overview of large-scale transport models including sophisticated modelling of connection trips.

Name	Region	Type 4	Type 5	Type 6	Type 7	Type 8	Type 9
CHSR	California, USA	X					
R ³ Logit	North Carolina, USA		X				
PLANET	HS2 area, UK			X ²			
MODEV	France					X	
LMS	The Netherlands						X
PRISM	West Midlands, UK						X ³
STM	Sydney, Australia						X ⁴

² Egress mode choice is not included.

³ Egress mode choice and terminal choice from the last terminal is not included.

⁴ Egress mode choice and terminal choice from the last terminal is not included.

The seven existing models show that integrating access/egress mode choice and/or terminal choice into large-scale systems of long-distance travel is feasible. Given that the connection trips are often a large part of the generalised travel cost, especially for air travel, the motivation for a more sophisticated connection trip modelling is strong.

Adding access/egress mode and terminal choice dimensions to an already large model structure will inevitably make the model more complex. Therefore, it is reasonable that simplifications must be made. The developers of the models reviewed in this paper have chosen different ways to simplify the models – e.g. by setting the destination choice as fixed or by limiting the number of terminals possible to choose between in the terminal choice. In the end, which simplifications are chosen, is dependent on the application areas the model is developed for. In general, however, more research on the trade-off between model complexity and detailed representation of connection trips is called for.

Acknowledgement

This work was funded by the Swedish Transport Administration under Grant number TRV 2019/6553.

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