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A methodology for assessing the impacts of enhanced rail services in South East Europe

Iraklis Stamos[*a], Evangelos Mitsakis [a], Josep Maria Salanova Grau [a], Georgia Aifadopoulou [a]

[a]*Centre for Research and Technology Hellas – Hellenic Institute of Transport*

Abstract

Rail transport in South East Europe (SEE) has received limited attention, although its role remains important for future transport sustainability. Albeit general efforts towards making rail competitive to other transport modes, the latter has become less attractive in recent years. For this reason, the recently initiated "Rail4SEE – Rail Hub Cities for South East Europe" project, financed by the EU, examines the introduction of enhanced rail services on a transnational level, and their impacts on future modal choice. In this paper, a methodology is presented for quantifying the impacts of such services in terms of modal shift and for evaluating their overall contribution towards rail transport enhancement in a transnational level. Insights are given on the modal split model development, the data requirements at a transnational level and the parameters of a rail trip chain that are influenced by such services (e.g. access, transfer or travel time). The outcomes of the applied methodology will be expressed as the overall number of trips conducted with each mode and reveal the contribution of such services to rail transport enhancement.

Keywords: Rail enhancement; modal split model; South East Europe; Rail4SEE project

Résumé

Le transport ferroviaire en Europe du Sud-Est (ESE) a reçu une attention limitée, bien que son rôle reste important pour la viabilité future des transports. Malgré les efforts généraux réalisés pour rendre le rail compétitif par rapport aux autres modes de transport, celui-ci est devenu moins attrayant au cours des dernières années. Pour cette raison, le projet récemment lancé "Rail4SEE – nœud ferroviaire de villes pour l'Europe du Sud-Est", projet financé par l'UE, étudie la mise en place de services ferroviaires améliorés à un niveau transnational ainsi que leurs impacts sur le futur choix des moyens de transport. Dans cet article, une méthodologie est présentée pour quantifier l'impact de ces services en termes de report modal et pour évaluer leur contribution globale à l'amélioration du transport ferroviaire à un niveau transnational. De plus, l'article donne des aperçus sur le développement du modèle de choix modal, sur les besoins de données au niveau transnational, et sur les paramètres de la chaîne du transport ferroviaire qui sont influencés par ces services (par exemple, l'accès, le transfert ou le temps de déplacement). Les résultats de la méthodologie appliquée, exprimés en nombre total de voyages effectués avec chaque mode, révèlent la contribution de ces services à l'amélioration du transport ferroviaire

Mots-clé: Rail amélioration; modèle de répartition modale, l'Europe du Sud-Est; projet Rail4SEE

[*] Corresponding author information here. Tel.: +302310498268; fax: +302310498269.
E-mail address: stamos@certh.gr

1. Introduction

South East Europe (SEE) increasingly faces the need for enhanced transnational rail connections among its hubs, especially on TEN-T networks as well as along the main intercity lines. Rail transport in SEE represents a low percentage of the total trips due to various reasons, for instance the lack of connections and interoperability among countries. Rail and in general public transport within these regions need for upgrade, strengthening and better organisation. That calls for a multimodal integration of local/city transport networks, regional transport systems and transnational transport axes. The main objective of this paper is to analyse the impact of new and enhanced rail services based on information and communication technologies (ICT). Three basic services are tested: trip-related information provision, harmonization of timetables and integrated ticketing. The impact of these services is evaluated in terms of modal shift from road- and air- to rail transport, which is calculated by using a modal split function calibrated with real world data.

The paper is structured as follows: The Rail4SEE project is presented in the second section, the proposed methodology for evaluating the contribution of selected rail services toward the enhancement of rail transport at SEE level and the data input needs for the methodological approach are categorized and presented in the second section. The development of the modal split model is presented in the third section. Finally, section four presents the conclusions of the presented methodology and the necessity for analysing the impact of ICT on the travellers' choice behaviour. A similar methodology has been developed for the impact quantification of climate change on transportation networks (Mitsakis et al. 2014).

2. The RAIL4SEE project

"Rail4SEE – Rail Hub Cities for South East Europe (SEE)", is a project of the "SEE program" which, in the framework of the Regional Policy's Territorial Cooperation Objective, aims to improve integration and competitiveness in the area. The Rail4SEE's objective is to provide passengers in SEE with an attractive, efficiently organized and developed (in terms of high interconnectivity) rail transport system. The project examines the introduction of enhanced rail services at a transnational level, and assesses their impacts on future modal choice. These services include the provision of Information Communication Technologies (ICT) for informing passengers, the harmonization of timetables in an effort to reduce transfer times and the introduction of integrated ticketing in order to facilitate passengers' needs. The Rail4SEE project examines passengers' transportation in South East Europe and focuses especially on 11 cities (Bologna, Venice, Trieste, Ljubljana, Vienna, Bratislava, Budapest, Thessaloniki, Sofia, Zagreb and Bucharest. The project reference area is presented in Figure 1.

Fig. 1. Rail4SEE reference area

2.1. Methodological approach

In general, a rail trip chain is considered to be conducted as depicted in Figure 2. A traveller is assumed to begin his/her trip from an origin within the catchment area of a hub towards the origin hub[†]. He/she then travels from the origin hub, possibly via various other hubs, to the destination hub, before completing his/her trip to his/her final destination within the catchment area of this last hub. As the examined rail services will influence this trip chain, it is essential to define the parts it consists of, in terms of traveller perceived costs. The time (and cost) needed between a hub and the origin/destination within its catchment area is defined as access time. The time (and cost) spent within a hub (at a starting) is defined as waiting time. The time (and cost) needed for reaching a destination or intermediate hub is defined as travel time, while the time (and cost) needed within an intermediate or the destination hub is defined as transfer time.

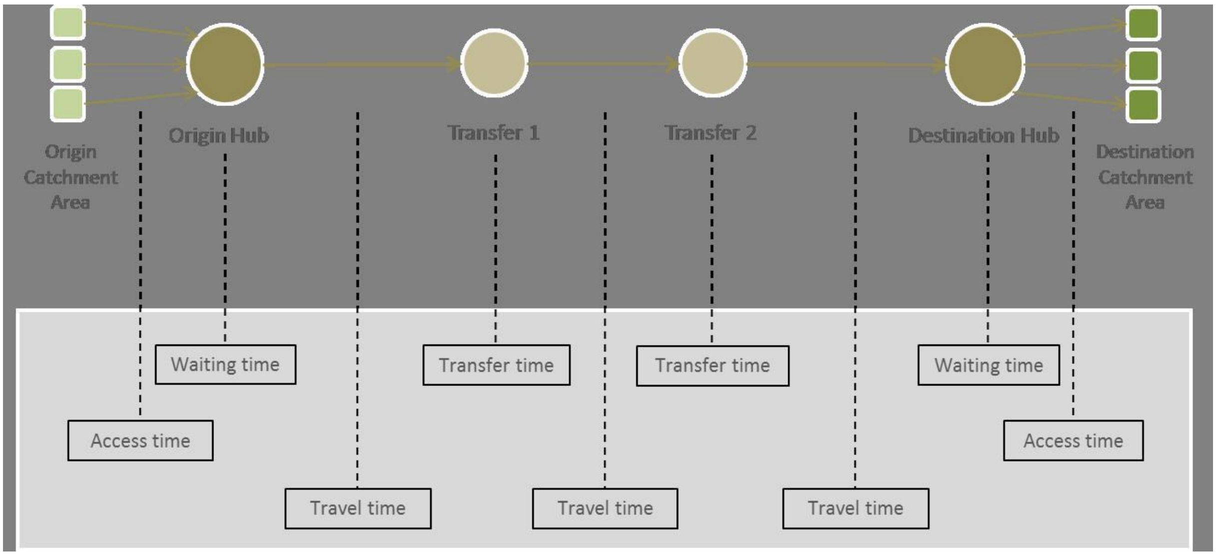

Fig. 2. Description of a rail trip chain

In order to assess the impact of the examined rail services on future passenger flows, a modal split approach is adopted. The outcomes refer to the comparison of a base case scenario, which describes the situation as it currently stands, against scenarios where various services, as then ones studied under the Rail4SEE project, have been introduced. Expressed in percentage change of passenger trips between modes, the results reveal the influence of such services on rail transport in the SEE area.

2.2. Data requirements

The data required for feeding this modal split approach concern the connection characteristics from and to each hub (transnational level) for all competitive transport modes (rail-road-air). The modal classification refers to the separate characteristics of each connection per mode, while the types of data can be further categorized into:

- Travel demand data
- Transport supply data
- Other data

2.2.1. Travel demand data

Travel demand data include the total number of trips conducted with each mode for each connection for a pre-chosen reference year. Table 1 summarizes the required demand-related data.

[†] A hub's catchment area is defined as the geographical area from which a hub attracts trips. The exact definition of a catchment area is a customized procedure, since neighbouring land uses and geographical extents to which a hub remains attractive (for its activities or connections) cannot be predefined for all cases.

Table 1. Travel demand data description

Travel demand data for all hubs		Units
Transnational level	Origin/Destination Matrices (Hub - Hub)	passengers/ year/mode

2.2.2. Transport supply data

In general, transport supply data required for the proposed modal split approach include: cost of connection (in €), duration (in hours), distance covered (in km), frequency (number of daily connections), transfers required (number and duration of intermediate transfers) for each mode and for each connection among the 11 hubs of the RAIL4SEE project. In addition, the existence of functionalities (such as integrated ticketing, harmonized timetables, ICT functionalities, web-interfaces for intermodal route planning) and general qualitative parameters (safety, security, etc.), supporting the passengers in the usage of the public transport system and removing, at least partially as well as the barriers that hinder the accomplishment of intermodal trips have to be included in the model. Table 2 summarizes the required transport supply and quality data.

Table 2. Transport supply data description (and quality data)

Transport supply data for all modes (rail, road and air)		Units
Transnational level	transport network geometry (all links)	-
	transport services data (for all connections)	-
	ticket cost	€
	travel time	time between terminals
	number of operated lines	-
	number of service trips	per day/per hour
	vehicle capacity	passengers/vehicle
	frequency	time unit (hours)
	headway	-
	daily or weekly hours of service	hours
	toll or vignette (if exists)	€
	passengers	number of
	vehicle-kilometres	km
	person-kilometres	km
	number of transfer stations	number of
	Transport services extras (for all connections)	-
	Wireless Internet	yes or no
	Integrated ticketing	yes or no
	Internet ticketing	yes or no
	Time plan harmonization	yes or no
	Trip planner	yes or no
	ICT	yes or no
	Non ICT (visual/print-outs)	yes or no
	Comfort	yes or no
	Safety	yes or no
	Punctuality	% of operations late
	Reliability of services	% of schedule irregularity
	Door to door intermodal services	yes or no
	Security	yes or no

2.2.3. Other data

Besides the travel demand and transport supply data, a series of general descriptive data are also required. Table 3 summarizes necessary data, which include, besides the geographical and demographical characteristics of the areas, average GDP or income data and Value of Time indicators. In order to have a similar reference of the generalized costs of each mode under examination, it is essential to “translate” travel time of trips into monetary cost. For this reason, a value of time (VoT) parameter is used.

Table 3. General data description

General data for all hubs		Units
Transnational level	Population of hub	-
	GDP	€
	Area extent	Km^2
	Value of Time indicator	€/hour
	Vehicle Occupancy	%

3. Development of the Rail4SEE modal split model

3.1. Literature review

Mode choice is in general assumed to be influenced by a number of main factors. In the case presented herein, these factors can be classified in the following groups (Ortuzar & Willumsen, 2001)

Table 4. Factors influencing travel mode choice

Group of factors	Factors
(a) Characteristics of the travelers	car availability, car ownership, income, age, sex, other
(b) Characteristics of the journey	trip purpose, trip distance, time of day, single or group traveller, luggage, other
(c) Characteristics of the transport system	travel time, waiting time, transfer time, monetary cost (fare, fuel, direct cost), comfort, reliability, safety, other

3.1.1. Aggregate modal split models

Trip end modal split models

Trip-end modal split models were mainly used in the past, when the characteristics of travellers were the basic premise, according to which mode choice was made. Such models however did not include information on the characteristics of the journey and the transport systems, and are thus scarcely used, as they are not sensitive to changes regarding characteristics (b) and (c) (e.g. reducing parking cost, or increasing public transport frequency does not result in any changes in the modal split model) (Ortuzar & Willumsen, 2001).

Trip interchange modal split models

Trip interchange modal split models, on the other hand, include information on the characteristics of the journey, but fail to include the case when travellers have limited available options (e.g. travellers that do not own or drive a personal car). In addition, these models ignore factors related to the characteristics of the transport system, such as public transport fares.

Synthetic modal split models

Synthetic models use the principle of maximum entropy, in order to generate trip distribution and mode choice at the same time. They have been used in the past for small and medium sized urban areas but they are now being replaced by disaggregate models (Domencich & McFadden, 1975).

Direct demand modal split models

Direct demand modal split models, in an alternative approach, try to develop one single model including the three first stages of transport planning i.e. trip generation, distribution and mode choice (Ortuzar & Willumsen, 2001)

3.1.2. Disaggregate modal split models

Discrete choice models

In this modelling method individuals have to select an option from a set of alternatives. To predict if an alternative will be chosen, the value of its utility must me contrasted with those of alternative options and transformed into a probability value between 0 and 1.

The multinomial logit model is the simplest discrete choice model. Its formulation is given by Domencich & McFadden (1975):

$$P_{ij}^{m} = \frac{\exp\left(-\beta C_{ij}^{m}\right)}{\sum_k \exp\left(\beta C_{ij}^{k}\right)} \qquad (1)$$

where P_{ij}^{m} is the proportion of trips conducted by mode m from zone i to zone j, C_{ij}^{m} is the generalized cost of mode m from zone i to zone j, and β is a scale parameter. The scale parameter β is used in order adjust a model and its initial results to data obtained from real life, so that the model describes a situation in the most realistic possible way. The binary logit model is a simpler form of MNL, where only two modes of transport are examined.

Hierarchical (nested) logit model

This method's structure is about grouping all subsets of correlated options in hierarchies or nests and was introduced in order to overcome simplified assumptions of MNL (alternatives are not correlated to each other). Each nest represents a composite alternative, which competes with the other alternatives available to the individual. At every nest a binary or multinomial logit is used and the expected maximum utility (EMU) of each nest is calculated as

$$EMU = log \sum_{m} expU_m \qquad (2)$$

where U_m is the utility of the nest selection(s) m, while the composite of the whole nest is given by

$$V_t = \varphi EMU + az \qquad (3)$$

where φ and α are estimated parameters and z are the common variables of the nest's t selections (McFadden, 1978).

In cases where an alternative can belong to more than one nest, a cross-nested logit model is used, with the following expression (Ben Akiva, 2011)

$$P(m) = \sum_{t=1}^{T} \frac{exp\left[\mu_t\left(U_m + \frac{1}{\mu} ln\alpha_{mt}\right)\right]}{\sum_{n\in C} exp[\mu_t\left(U_m + \frac{1}{\mu} ln\alpha_{nt}\right)]} \frac{exp(\mu\widetilde{V_t})}{\sum_{l=1}^{T} exp(\mu\widetilde{V_l})} \quad (4)$$

where α_{mt} is a parameter reflecting the degree to which alternative m is a member of nest t, $l \in T$, μ is a calibration parameter, and U_m is given by

$$U_m = \frac{1}{\mu_t}\sum_{n\in C} exp[\mu_t\left(V_m + \frac{1}{\mu} ln\alpha_{nt}\right)] \quad (5)$$

and α_{mt} must satisfy the following conditions:

$$\sum_{t=1}^{T} \alpha_{mt} = 1, \forall_m \quad (6)$$

and

$$\alpha_{mt} \geq 0 \quad (7)$$

Mixed logit model

According to this model, the utility function of option j for an individual q in a choice situation t is

$$U_{jqt} = \theta_q X_{jqt} + \varepsilon_{jqt} \quad (8)$$

where X_{jqt} is a vector of observable variables, θ_q is a vector of unknown coefficients that vary randomly according to the individual tastes and ε_{jqt} is a random error term (Cardell & Reddy, 1977).

Assuming that preferences vary among individuals of the population according to a density function given by

$$f(\frac{\theta}{\tau^*}) \quad (9)$$

The mixed logit choice probability is given by the integral of the multinomial logit choice probability weighed by the density function of θ:

$$P_{qjt}(\tau^*) = \int \frac{e^{\theta_{qjt}X_{qjt}}}{\sum_{A_j\in A(q)} e^{\theta_{qjt}X_{qjt}}} f(\theta/\tau^*)d\theta \quad (10)$$

where τ^* represent the parameters of the distribution.

3.1.3. Other choice models

Multinomial probit model

Probit and logit models differ slightly in regard to their results, as they are generally indistinguishable and they tend to produce similar predictions in most cases. However, probit models, which can be derived from a multivariate Normal distribution, capture cases where travellers perceive costs based on a certain characteristic (e.g. their income)

3.2. The R4S modal split model

In order to capture the complexity of travellers owning or having the ability to travel by car, versus travellers that could only travel by mass transit means (air, rail), a nested (hierarchical) model is applied, which groups modal alternatives into private and mass transit. In this way, the subsets of mass transit are correlated, due to bearing common characteristics (as no commuter needs to own a vehicle or have a driving license in order to travel). Figure 3 considers the case examined in this methodology, where a trinomial modal choice situation exists, involving road (R), rail (Ra) and air (A) transport.

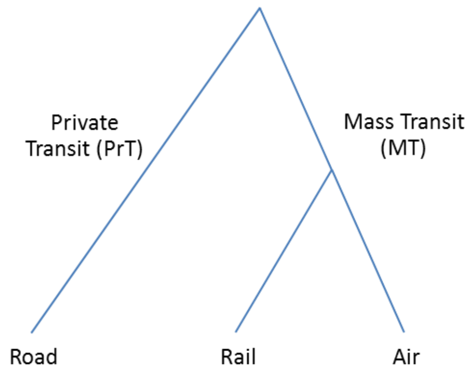

Fig. 3. Trinomial modal choice in Rail4SEE

In this case, the mass transit (MT) nest is modelled by a simple binary logit model of the form

$$P_{im} = \frac{expU_m}{\sum_{q=1}^{n} expU_m} \qquad (11)$$

The probabilities for each mode are:

$$P(A/MT) = \frac{expU_A}{expU_A + expU_{Ra}} \qquad (12)$$

and

$$P(Ra/MT) = 1 - P(A/MT) \qquad (13)$$

the binary logit model for road transport is:

$$P(R) = \frac{exp(\mu_R * U_R)}{exp(\mu_R * U_R) + exp(\mu_{MT} * U_{MT})} \qquad (14)$$

and

$$P(MT) = 1 - P(R) \qquad (15)$$

The modal utilities U_A, U_{Ra} and U_R include the sum of monetary and non-monetary costs of using each mode and are built in such a way, so as to include qualitative variables' change attributed to the introduced services examined within the project. The form of the utilities' function is:

$$U_m = \alpha_m + \sum_{i=1}^{I} (\beta_{im} * x_{im}) \quad \forall m \in M \qquad (16)$$

where,
U_m - utility of mode *m*
α_m - fix term of mode *m*
x_{im} - variable i of mode *m*
β_{im}- coefficient of variable *i* and mode *m*
I - number of characteristics in the model
M - set of modes

It is here noted that fix terms of each mode (α_m) include various quality parameters such as comfort and safety, as well as the Rail4SEE examined services, namely ICT, Harmonization of timetables, and integrated ticketing.

The impacts of the proposes services at parameter and variable level are presented below:

- Integrated ticketing: Reduction of the transfer time since there is no need for acquiring a new ticket, but most important, reduction of the fix term which represents the stress of travellers among other quality factors.
- ICT: Reduction of the "safe margin times" due to the uncertainty on timetables of rail services schedule.
- Harmonization: Reduction of the transfer time variable and the perception parameter that users have of this "lost time".

3.3. Calibration of the model

The calibration of the modal split model is done by solving the following minimization problem.

$$min \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{m=1}^{M} \left(D_{ijm} - D_{ij} \cdot \frac{exp(\mu_m \cdot U_m)}{\sum_{k=1}^{M} exp(\mu_k \cdot U_k)} \right) \qquad (17)$$

where,
D_{ijm} – the number of observed trips from zone i to zone j using mode m
D_{ij} – the number of observed trips from zone i to zone j
U_k - utility of mode *k*
μ_k – calibration parameter for modal split of mode *k*
M - number of modes
n - number of zones

The existence of the proposed services in some of the rail connections will permit the calibration of the parameters and variables directly and indirectly (e. g. transfer time) related to these services.

4. Conclusions

The methodology presented herein concerns the development of a modal split model, which after its calibration and validation will assess the contribution of the introduction of selected rail services to the enhancement of rail transport in the SEE region. At the same time, the same approach can be applied to other regions of Europe in an effort to estimate the impacts of similar services in travelers' modal choice. The output of the model will concern the shift of passengers' flows among available transport modes, given the described enhanced rail services, in terms of absolute values and percentage changes. The results will represent the difference in the number of trips conducted with each mode as is, and after the introduction of pre-defined enhanced rail services.

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