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CORVINUS UNIVERSITY OF BUDAPEST
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THESIS SUMMARY

To the Ph.D. dissertation of

Balázs Édes

The impacts of Service Quality and Substitutes on Demand in the Hungarian rail passenger market

Supervisor: Attila Chikán Ph.D

Member of Hungarian Academy of Science

Budapest, 2021

Corvinus University of Budapest
Department of Logistics and Supply Chain Management

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CONTENTS

1 RESEARCH BACKGROUND AND JUSTIFICATION OF THE TOPIC

For decades, the rail passenger transport sector played a special role among other public services both globally and locally. Beyond the economic and social context, its role is also important from an environmental perspective. Therefore, there has been an increasing focus on this mode of transport as a means of easing many of these difficulties in recent decades (Lalive, Luechinger and Schmutzler, 2013).

Motorisation, suburbanisation trends, increasing congestion problems and pollution are now making it clear to more and more people that it is in the community's interest to increase the share of rail transport in the modal split (Jaffe, 2012).

As passengers no longer choose this mode out of necessity, a truly competitive offer must be in place to increase demand. In addition to large-scale improvements, often small but carefully considered steps can make the daily lives of hundreds of thousands of people easier (Vitézy, 2014).

However, up-to-date business and technical knowledge is only rarely present in the Hungarian public transport sector. Data-driven operations and decision-making and the application of business intelligence tools are still on the margins.

But transport development and encouraging the use of socially useful rail transport is a task that requires a conscious, measured and planned improvement in the quality of services.

The aim of my research is to investigate how the demand for rail passenger transport is influenced by quality, service standards and the impact of substitutes in Hungary. My aim is to show that a useful analytical tool could be created by combining already available data with appropriate methodology, which could be suitable for both scientific and business purposes. On the other hand, the aim of the research is to investigate what can be learned about the demand for rail services, how could qualitative factors and developments improve the competitiveness of railways.

The review of the literature on the subject can be concluded with a number of lessons. Although the subject is mainly related to corporate or public policy issues, and thus much of the research is typically not carried out in the context of academic life, there is a considerable literature on modelling rail demand and quality. The available data and the purpose of the study primarily determine the choice of methodological tools. For the analysis of demand, the use of a sales database by destination pair within the framework of the gravity base model is a realistic methodological solution (Brand et al., 1992, (Thakuriah et al., 2010), (Martín and Nombela, 2007), (Lythgoe, Wardman and Toner, 2004).

In the literature presented here, we can find many examples of abstract approaches and quantification of different soft quality factors, which have provided good starting points for defining different quality variables.

2 RESEARCH QUESTIONS, METHODOLOGY AND DATA

1. Is it possible to develop an appropriate explanatory model for rail sales data based on the available data sources?

2. What are the impacts of substitutes, economic background variables and quality factors on rail demand?

3. Is there a relevant relationship between quality factors?

Supplementary questions:

4. What policy implications follow from the above results? Can the results be used to draw conclusions for transport policy?

5. Do the results suggest any research directions that could be further explored?

Methodology

The research is based on the analysis of a sales database with complex background data using econometric tools. The conceptual form of the model is as follows:

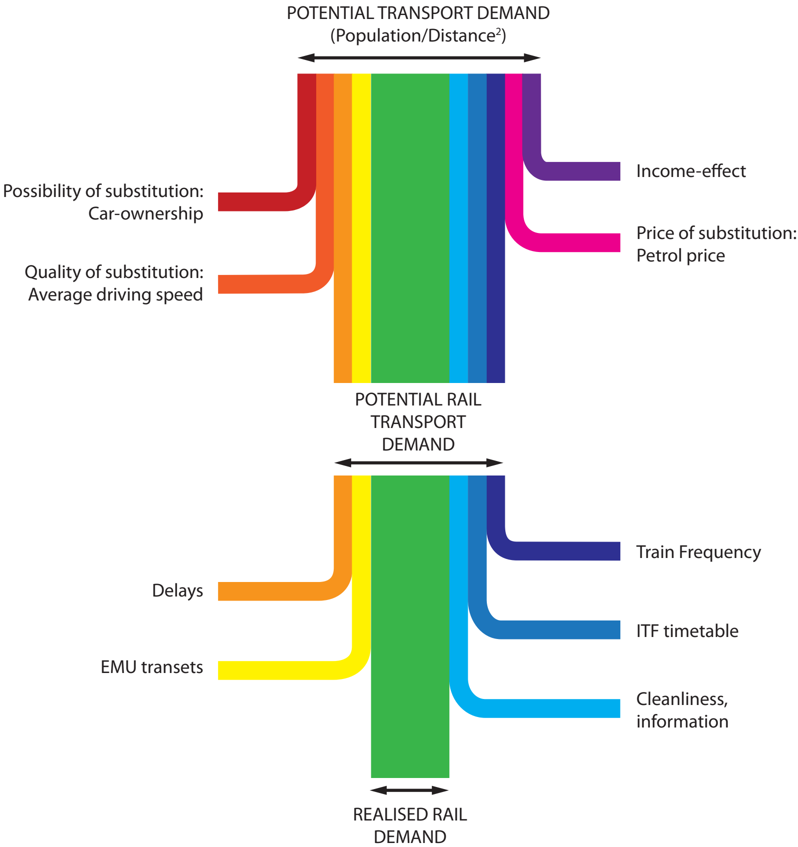
$$D_{ij} = \left(\frac{P_i P_j}{d_{ij}}\right)^{\beta_1} (I_i I_j)^{\beta_2} C_{ij}{}^{\beta_3} P^{\beta_4} T_{ij}{}^{\beta_5} f\left(Q_{1_{ij}}{}^{\gamma_1} Q_{2_{ij}}{}^{\gamma_2} \dots Q_{x_{ij}}{}^{\gamma_x} \dots Q_{s_{ij}}{}^{\gamma_s}\right)$$

where:

$\beta_{1,2}$	Coefficients
D_{ij}	Passenger rail demand between settlements *i* and *j*
P_i, P_j	Population of settlements *i* and *j*
d_{ij}	Distance between settlements *i* and *j*
I_i, I_j	Income levels in settlements *i* and *j*
C_{ij}	Density of car ownership *i* and *j*
Pt	Annual average petrol price
T_{ij}	Road speed between *i* and *j*
$Q_{x_{ij}}$	Value of quality indicator *x* for route *ij* (log or dummy)

In the estimation process, I tested several versions of each factor, using the statistical results to identify the most suitable variables. Following the structure of the available data, the model is based on the gravity model commonly used in the literature. The estimation was log-log panel regression with fixed-effects.

Figure 1: Logical framework of the model



Source: Author's compilation

Data

The initial database contains the annual ticket sales data of MÁV-Start Zrt. between 2010 and 2019 for Origin–Destination pairs. The source of the municipal background variables is the spatial statistical database the Hungarian Central Statistical Office (KSH), the T-STAR system (MTA KRTK, 2021). An additional background variable is the annual average consumer fuel price (KSH, 2021). Individual and community road alternatives are represented by road travel times in the model, the current data for 2021 is obtained through the Google Maps Platform Distance Matrix API system (GDM API). This was supplemented by the MTA KRTK GEO database, which contains public transport data for 2014, for a total of 45 555 inter-census district travel trips. As a source of rail travel times, I used data retrieved from the Google DM API database.

The data on quality and service levels have been compiled from several sources:

- The MÁV Delay Database (contains 16 million recorded delay events over a ten-year period)
- The cleanliness, accessibility and quality of information services are based on the MÁV-Start Zrt. Quality Status Assessment (MÁF) system

- Manually recorded timetable data (number of daily train pairs and the existence of an ITF timetable for each line by processing the 10-year timetable of 86 railway lines)
- To represent the quality of the rolling stock, I used data from Stadler EMU trainsets that have been continuously arriving on the MÁV network since 2006.

The data sources and database structure are summarised in the table below.

Table 2. Compilation of the rail demand database

Adatforrás	Adattartalom	Primary connection	Secondary connection
MÁV sales data	Sales quantities	–	–
Google Distance Matrix API	Distance, time, road and rail	Origin-Destination	–
MTA KRTK GEO	Travel distance and time on road	Origin-Destination	
KSH T-STAR	Spatial data (demography, economy)	Settlement + Year	–
MÁV delay database	Delay data	Station + Year	Railway line + Year
MÁV MÁF system	Quality data (cleanliness, availability of information)	Station + Year	Railway line + Year
Supply data based on timetable	Daily train numbers, regular timetable	Railway line + Year	–
EMU trainset dummy	Electric Motor Units available	Railway line + Year	–

Source: Author's compilation

3 SCIENTIFIC RESULTS

Building on the literature and available data sources, I was able to compile a database that can adequately describe the demand for passenger rail transport in Hungary and produced acceptable results within the framework of the literature and intuition presented (Table 2).

Table 3. Coefficients of the complex demand model

Variable	Coefficient		S.E.
$ln\_Population_{destination;\ arrival}$	1.1800	***	(0.0874)
$ln\_Distance_{rail}$	–0.2662	***	(0.0165)
ln_Delay_var	0.2129	***	(0.00222)
ln_Income	0.1391	***	(0.00312)
ln_Car_ownership	–0.5837	***	(0.0731)
ln_Petrol_price	0.0575	***	(0.0156)
ln_Speed_{car}	–0.2028	**	(0.103)
$ln\_Trains\_p\_day_{min}$	0.0354	***	(0.00892)
ITF_{mean}	0.2045	***	(0.0216)
EMU_{mean}	0.2351	***	(0.0146)
$ln\_Departure\_delay_{st.\ dev.}$	–0.0101	***	(0.00248)
$Departure\_quailty_{weitghted\ mean}$	0.3980	***	(0.0551)
Constant	–5.6468	***	(0.972)
N	499 590		–
Pairs of destination	104 442		–
Within R^2	0.0530		–
Overall R^2	0.3486		–

*** p<0.01, ** p<0.05

Source: Author's compilation

The coefficients can be interpreted as elasticities according to the interpretation of the estimator. In the demand model, the effect of the municipal per capita average income tax base is relatively small (13.9 %), but this value is already controlled for car ownership, so this indirect income effect is not included. It is also important to note that, without the other variables of car substitution, the income effect is negative at – 12.2 %, which clearly confirms the hypothesis that rail transport is an inferior service in Hungary today.

The model shows an indirect positive effect of the increase in fuel prices on rail demand, but its low value also indicates a more inelastic response, i.e. it is more difficult to quit driving, while the other elasticities of substitution show significantly higher values.

The strong effect of the lagged demand variable also suggests that switching transport modes is inelastic: more people are more likely to travel on rail between two cities, if the proportion of rail passengers was higher in the earlier period.

When looking at travel times, only the speed of the journey by car showed a significant effect, which can be interpreted as a stronger substitution role for the car in the range of higher average speeds. This effect could be interpreted as the role of motorways and expressways.

Other approximations of the time dimension did not show a strong effect in the model – this outcome strengthens the hypothesis that a large proportion of today's passengers are less sensitive to travel time, which may be due to individual preference (subjectively prefer to use it) or constraint (no real substitution possibility). A more accurate analysis of this factor would be supported by more exact sources on travel data over the whole ten-year period.

Consistent with the above hypothesis about time, the weight for delays was also relatively low, with coefficients never exceeding 1.0 %. Although the quality of the database is good, it is imaginable that a more accurate, better linked database would give a different result. The different calculation methods I tested showed that the standard deviation of delays is more important than their absolute average value. The estimate of the proportion of delays over 10 minutes produced coefficients that approximate the standard deviation impact, in this case the effect of departure delay was much more important than the average value.

For the timetable supply, the effect of the minimum of departure and arrival frequencies (number of train pairs per day) is stronger than the average. Thus, in this dimension, the minimum value determines the value of the service for a passenger.

A frequent timetable has a noticeable additional benefit, and here it is less important whether it covers the whole travel chain (the average value at the departure and arrival stations has a stronger effect than the minimum of them). The impact of EMU trainsets is dominated by the average value, and the impact is the second strongest of the qualitative variables after cleanliness.
The estimation of the soft quality factors – cleanliness and information – is based on a database with a high frequency, fixed methodology, but with a relatively low variance scoring system. Nevertheless, the impacts estimated are significant and substantial.
The hypothesis concerning the effect of the minimum quality is not confirmed by the results. Among the quality effects, it is relevant that the effect of the outgoing station is much higher than that of the incoming station.

Based on the results, the following answers were given to the research questions I had previously asked:

1. Is it possible to develop an appropriate explanatory model for rail sales data based on the available data sources?
The complex model created by fitting the processed databases together has adequate explanatory power. By including additional data sources, improving the data quality or the level

of detail in a particular area, this analytical framework could be used to investigate certain questions in more depth, but even at this level it is suitable for drawing conclusions.

2. What are the impacts of substitutes, economic background variables and quality factors on rail demand?

Qualitative factors have a significant impact on demand when the data sources are sufficiently fine scaled and of good quality, and their impact is confirmed in the model. For a given quality factor, it makes sense to use specific sub-indicators or calculated values (average of different values in some cases, minimum in others, etc.).

3. Is there a relevant relationship between quality factors?

For the quality dimensions of rail supply, no stronger than average role of the minimum service level was observed, so this general hypothesis was not confirmed. However, it is clear, that the impact varies depending on what type of quality indicators is considered within a category.

The results also suggest that the examination of the two supplementary questions is relevant:

4. What policy implications follow from the above results? Can the results be used to draw conclusions for transport policy?

In terms of transport theories, the results are consistent with intuitive expectations and the literature. However, several issues emerge that may have direct implications. First of all, there are some factors where the demand for rail services is inelastic: it follows that a very conscious and complex transport development is needed to achieve a modal shift from private motorised transport to rail, which is clearly in the public interest from an ecological and quality of life point of view. It must be recognised that demand depends on a delicate balance of many factors, so a single development intervention alone might not be effective.

A key question is to what extent rail transport could be considered an inferior service in general. The results lead to a twofold conclusion: on the one hand, rail is no longer locked into the inferior, undesirable service category it was in after the regime change. The quality-sensitive demand and some of its elements show that timetable improvements, modern rolling stock, cleaner trains, evolving information have a real impact on travellers, there is a quality-oriented part of the demand.

On the other hand, the evidence of inelasticity points to the fact that rail is still much less preferred by those for whom other modes are available. For example, with highly developed rail services and transport culture and, of course, a more ecologically focused population, car ownership should explain much less of the evolution of demand for rail services.

5. Do the results suggest any research directions that could be further explored?

Perhaps the most important conclusion of the research is that the database compiled is well suited to investigate the demand for rail services and the quality of service. With such a large amount of data, it is possible to analyse even finer details and thus to answer not only general questions but also more detailed ones.

In particular, the incompleteness of the data sources and the necessary simplifications during linking the databases shows that additional data and eliminating simplifications, could result in a much more accurate and detailed database and results.

In addition, a research study that measures consumer preferences focusing on soft factors could be an excellent basis. A specific, larger-scale survey, complementing the regular relatively narrowly focused customer surveys, could answer many of the questions and these data combined with demand would significantly increase our knowledge of the demand for rail services, and to establish more effective and efficient public policy interventions.

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