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PRAGMATIC APPROACH IN REGIONAL RAIL TRANSPORT PLANNING

Summary. In the field of transport planning in the Czech Republic, there is increasing need not only for infrastructure planning, but also for public transport planning and creating operational concepts. Public transport, as well as investments and operationally intensive industries, requires a guaranteed long-term strategy in the field of transport services. The first prerequisite for successful transport planning is the most accurate description of passenger flows, including the parameters affecting the choice of transport mode. These inputs constitute an important basis for the following steps: setting up the line network, timetable design, managing the circulation of vehicles and courses of staff, controlling, and any eventual requests for infrastructure improvements. There are currently, in the Czech Republic, few transport models that provide relevant outputs for transport planning tasks in public services. For this reason, we use a variety of heuristics, one of which is described via a practical example, i.e., the transformation of a timetable concept on a selected rail network, including the effects resulting from a change in the number of passengers.

Keywords: public transport planning; public transport service; passenger transport; railway timetable; gravity model; timetable planning.

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1. OBJECTIVES OF TRANSPORT PLANNING

Currently, transport planning in the Czech Republic stands on its factual beginnings. Institutionally, transport planning was established by the Law on Public Passenger Transport Services (194/2010 Coll.), with individual purchasers of public transport thus required to build transport plans to reflect its scope. Public transport, in terms of the concept of transport service quality, is more than just a social service for those who have no other option, but whose aim is to achieve overall transport accessibility in the region. In short, public transport represents an attractive alternative to individual transport.

It is clear that public transport cannot cover all the passenger flows, nor satisfy all transport needs of individuals. Public transport, with respect to the need for compensation (income from fares does not cover the cost of providing), must include elements of the mass. If there are common transportation needs of individuals in a certain place and time, the transport flow is formed, which can then be addressed by public transport organized on a collective basis. With respect to the rational planning of public transport and the final volume of funds for compensation payments, these resources cannot be spent inefficiently on the transportation of single individuals, as this would deny resources to ensure a satisfactory level of transport relations with much higher demand.

Theoretical public transport planning consists of seven classic steps:

1. Estimation of passenger flows (part of transport modelling)
2. Setting up the line network plans
3. Implementation of line networks within the infrastructure (modal choice revision)
4. Timetable design
5. Circulation plans of vehicles and staff courses
6. Evaluation of operation performance and controlling
7. Defining the requirements for infrastructure improvements

In this article, we only pay attention to the first point. Any information regarding transport relations and passengers is important for line network planning and timetable improvements. Outputs from the gravity model, introducing the core and collecting lines with high (not yet used) potential, will be gradually applied to the ongoing optimization of single areas in the region.

Using the example of the Ústí nad Labem Region (one of the 14 regions in the Czech Republic responsible for regional public transport), we will describe how the simple principles of the well-known gravity model were used in public transport planning and what practical result was achieved.

2. CONDITIONS FOR SURVEYING TRANSPORT RELATIONS IN THE CZECH REPUBLIC

Identifying transport relations is a difficult task in the Czech Republic.

In most cases, when it is necessary to define transport relations using transport modelling, you cannot use the classic four-stage transport model or the EVA model based on the principles of transport demand and supply.

Classic intelligent transport modelling methods are typically without the necessary databases, with the available data in many instances lacking the temporal relationship in terms of the “same time”. Many data that are important to understand transport demand (level of population, number of jobs, educational facilities etc.) and usually collected for each zone are simply not available in the required quality and detail.

Although purchasers of public transport (public authorities) are responsible for transportation planning in their territory, creating high-quality transport models should not pose a major priority. However, they are usually not even willing to finance the necessary surveys to obtain data on population mobility and travel behaviour. In cases where models, based on classical four-stage transport models, are applied in the Czech Republic, very rough data or generally available external data (e.g., from Germany) are often used.

In view of the above, it is necessary to establish priorities in public transport very easily. For this reason, his paper presents gravity models using basic data that are generally available in the Czech Republic.

The information on passenger flows is currently available mainly in the form of CSO data (Census 2001, 2011), including data on the number of permanent residents in the municipalities and their local areas, as well as information about regular commuting. Further information is available from carriers, such as about the load factor, number of boarding and alighting passengers at each stop, in the form of origin-destination matrices. More information on origins and destinations relate mainly to the number of employment opportunities (data from major employers) and regularly commuting schoolchildren, with these data used in abundance in the case of the larger optimization of timetables in the region.

Available CSO data are not broken down by the mode of transport attributable to a specific origin-destination pair, because this is information about total passenger flows across all modes of transport. On the contrary, data from carriers are exclusively related to a certain type of service and thus only have explanatory power for passengers who already use public transport.

For a description of all passenger flows in the region across all transport modes, we must use theoretical transport models. Thus, established passenger flows can be followed based on the availability of origin and destination information according to each mode of transport. In turn, theoretically calculated passenger flows assign a theoretical modal split, which emphasizes the importance of the role played by public transport in a whole transport system where there is generally a high demand for transport and identified passenger flows, while, at the same time, potential usage of public transport is maximized.

Today, no region has yet processed a quality transport model, because the benefits of high-quality and comprehensive transport modelling in the Czech area are still not fully appreciated. What is missing, however, are quality travel surveys, as well as surveys on transport behaviour and sensitivity of users towards parameters of the public transport offer. Finally, it is difficult, or even impossible, to group incommensurable time-related data needed for transport model settings.

For the purpose of transport planning, incremental theoretical gravity models of passenger flows in the region are therefore often used. The output of these models is the proportional comparison of the significance of passenger flows, typically associated with the theoretical calculation of the modal split.

From the gravity model, when taking into consideration the modal split, we can see how public transport is successful in individual relations. It clearly follows that the disproportion in the region and the relations represents the greatest potential for growth in public transport. The juxtaposition of relations can also be inferred where there is potential for core railway lines, connecting railway lines and core bus services.

3. USING THE GRAVITY MODEL AND APPLICATION OF OUTPUTS

In 2011, the author of this article created an extensive gravity model for the Ústí nad Labem Region, based on the well-known "Lill's travel law" [2]:

$$v_{ij} = k \frac{Q_i \cdot Z_j}{w_{ij}} \quad (1)$$

where:
- v_{ij} passenger flow between *i*-th and *j*-th places
- k gravity constant
- Q_i source/origin potential of *i*-th place
- Z_j destination potential of *j*-th place
- w_{ij} deterrence function

The model assumes that the transport relation between settlements (Qi and Zj) increases with their size and decreases with transport resistance (usually time or geographic distance). In the case of a proportional comparison, we can omit the constant k; however, in this solution, the use of a territorial, regional and district administrative hierarchy was reflected by constants from 0.7 to 0.9. Travel resistance w_{ij} in this case was determined as the square of travel time. Source and destination (Q_i, Z_j) in this case were determined as the square root of the number of inhabitants of the cities (with the square root, we can take into consideration a higher level of attraction or production of individual cities). The trip matrix was assumed to be symmetrical. The calculation results were thus only numerical values, which, after conversion, reflected the "relative size" of traffic flow.

The aim of developing the gravity model was to determine the proportional comparison significance of individual transport relations in the region, according to relative significance.

In addition, we sought to find out which relations generally have the highest theoretical travel potential and what the public transport offer is today, which is provided in relations with a "similar" significance. Furthermore, a relative comparison was made of the availability of public/private transport, and we ultimately defined the relationship growth potential for public transport and endangered relations (where a fundamental change in the operational concept of public transport needed to be carried out).

Within the configuration of the model, all the towns in the Ústí nad Labem Region with more than 5,000 inhabitants (27 towns) were taken into consideration, including the usual destinations in regular commuting to neighbouring regions and the capital city of Prague (13 additional targets).

The basis for the model processing were the CSO data (Census 2001), while the comparison of travel times was based on timetables (2010/11) that were available at that time, as well as a publicly available route planner (for centre-centre relations). We also considered the travel time by public transport with connections showing regularity or "usual" travel time. For reaching a public transport station, a surcharge of 20 min was generally applied. Average waiting time for a service/connection has been neglected.

During the assembly of the model, we categorized relations showing daily commutes from sessions without daily commutes. Interval connection was initially ignored, as it applies the premise that, in daily commutes, it is hardly acceptable that the interval between connections in public transport will significantly exceed the regular travel time.

For determining the modal split, we used outputs from the “Configuration of IFIT Nodes in the Czech Rail Network” research and development project, carried out in 2007-2010 by the Czech Technical University, after being commissioned by the Czech Ministry of Transport.

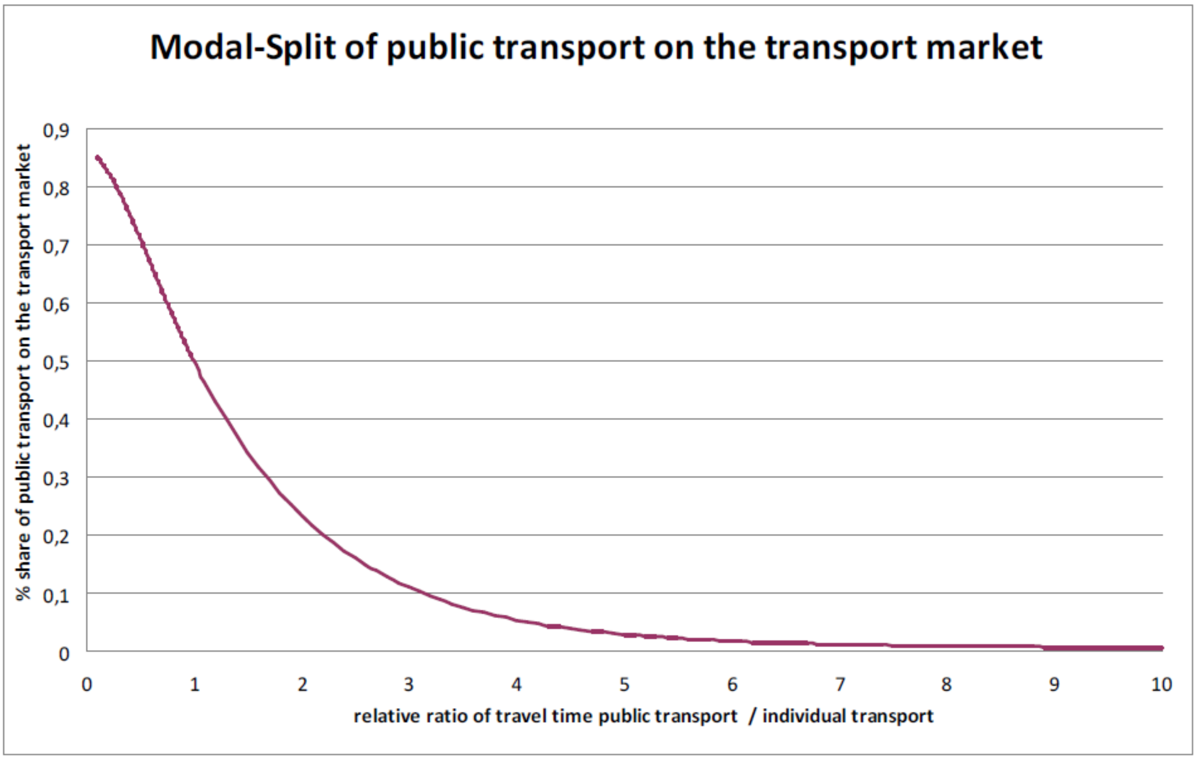

Fig. 1. Modal split in public transport on the transport market

For processing the outputs of a gravity model, we first compared the travel times by public transport and by individual transport.

		Ústí n.L.	Most	Děčín	Teplice	Chomutov	Litvínov	Litoměřice	Jirkov	Žatec	Louny	Kadaň	Varnsdorf	Bílina	Klášterec
	IAD		44	34	21	63	45	30	57	73	54	81	83	29	80
Ústí nad Labem	VD		64	35	36	85	70	36	82	109	110	105	129	55	101
	IAD			70	29	29	19	49	24	31	28	47	119	18	47
Most	VD			104	46	40	34	104	33	59	49	60	211	31	57
	IAD				46	89	68	47	83	98	80	106	52	55	106
Děčín	VD				68	117	102	81	114	141	137	137	101	88	134
	IAD					48	26	40	43	58	39	66	97	14	65
Teplice	VD					67	48	70	60	91	90	87	183	40	83
	IAD						29	67	11	28	34	24	136	35	24
Chomutov	VD						67	141	25	50	80	38	233	52	35
	IAD							60	24	49	38	47	119	24	47
Litvínov	VD							127	60	90	67	113	219	55	91
	IAD								62	65	46	85	81	42	84
Litoměřice	VD								134	164	122	187	187	90	165
	IAD									34	40	30	132	31	30
Jirkov	VD									60	73	50	226	45	46
	IAD										28	27	145	46	36
Žatec	VD										60	83	258	75	78
	IAD											49	124	27	51
Louny	VD											126	266	70	104
	IAD												156	54	14
Kadaň	VD												253	71	40
	IAD													105	156
Varnsdorf	VD													200	250
	IAD														54
Bílina	VD														67

Fig. 2. Extract of the time-availability matrix

Based on the travel-time comparison, a theoretically achievable modal split was calculated for public transport in individual relations.

		Ústí n.L.	Most	Děčín	Teplice	Chomutov	Litvínov	Litoměřice	Jirkov	Žatec	Louny	Kadaň	Vamsdorf	Bílina	Klášterec
Ústí nad Labem	VD/IAD		1,45	1,03	1,71	1,35	1,56	1,20	1,44	1,49	2,04	1,30	1,55	1,90	1,26
	MS VD		35,70	48,80	29,20	38,50	33,00	43,00	35,60	34,50	22,50	40,00	33,10	25,30	41,20
Most	VD/IAD			1,49	1,59	1,38	1,79	2,12	1,38	1,90	1,75	1,28	1,77	1,72	1,21
	MS VD			34,50	29,00	37,60	27,50	21,50	37,60	25,30	28,40	40,60	28,00	29,00	42,70
Děčín	VD/IAD				1,48	1,31	1,50	1,72	1,37	1,44	1,71	1,29	1,94	1,60	1,26
	MS VD				35,00	39,50	34,30	29,00	38,00	36,00	29,00	40,00	24,50	31,80	41,40
Teplice	VD/IAD					1,40	1,85	1,75	1,40	1,57	2,31	1,32	1,89	2,86	1,28
	MS VD					37,00	26,30	28,40	37,00	32,60	18,50	39,30	25,50	12,20	40,50
Chomutov	VD/IAD						2,31	2,10	2,27	1,79	2,35	1,58	1,71	1,49	1,46
	MS VD						18,50	21,70	19,20	27,50	18,00	32,30	29,20	34,50	35,60
Litvínov	VD/IAD							2,12	2,50	1,84	1,76	2,40	1,84	2,29	1,94
	MS VD							21,40	16,00	26,40	28,30	17,30	26,40	18,80	24,40
Litoměřice	VD/IAD								2,16	2,52	2,65	2,20	2,31	2,14	1,96
	MS VD								20,80	15,00	14,30	20,10	18,60	21,90	24,30
Jirkov	VD/IAD									1,76	1,83	1,67	1,71	1,45	1,53
	MS VD									28,30	26,60	30,20	29,20	35,70	33,50
Žatec	VD/IAD										2,14	3,07	1,78	1,63	2,17
	MS VD										20,90	10,50	27,50	31,00	20,60
Louny	VD/IAD											2,57	2,15	2,59	2,04
	MS VD											15,20	20,90	14,90	22,60
Kadaň	VD/IAD												1,62	1,31	2,86
	MS VD												31,40	39,70	12,20
Varnsdorf	VD/IAD													1,90	1,60
	MS VD													25,30	31,80
Bílina	VD/IAD														1,24
	MS VD														41,80

Fig. 3. Extract from the matrix of the theoretically achievable modal split

The last step was to calculate the proportional transport relations, which were weighted by the theoretically achievable modal split. This defined relations with the greatest potential for public transport development, while, at the same time, it was clear where the public service offer was already close to theoretical saturation.

		Ústí n.L.	Most	Děčín	Teplice	Chomutov	Litvínov	Litoměřice	Jirkov	Žatec	Louny	Kadaň	Vamsdorf	Bílina	Klášterec
Ústí nad Labem	Vij		41,45	60,77	158,45	17,48	25,14	52,58	13,75	8,06	14,54	6,29	5,65	46,17	6,01
	váž. MS		14,80	29,65	46,27	6,73	8,30	22,61	4,89	2,78	3,27	2,52	1,87	11,68	2,47
Most	Vij			9,64	55,88	55,49	118,54	13,26	52,14	30,06	36,37	12,57	1,85	80,59	11,70
	váž. MS			3,33	16,20	20,86	32,60	2,85	19,61	7,60	10,33	5,10	0,52	23,37	5,00
Děčín	Vij				19,44	5,16	6,48	12,61	3,82	2,63	3,90	2,16	10,59	7,56	2,01
	váž. MS				6,80	2,04	2,22	3,66	1,45	0,95	1,13	0,87	2,59	2,40	0,83
Teplice	Vij					17,64	44,09	17,32	14,14	7,48	16,32	5,55	2,42	144,99	5,33
	váž. MS					6,53	11,60	4,92	5,23	2,44	3,02	2,18	0,62	17,69	2,16
Chomutov	Vij						35,20	6,13	268,29	31,86	21,33	52,10	1,22	18,43	48,51
	váž. MS						6,51	1,33	51,51	8,76	3,84	16,83	0,36	6,36	17,27
Litvínov	Vij							5,61	33,08	7,63	12,53	7,97	1,17	28,75	7,42
	váž. MS							1,20	5,29	2,01	3,54	1,38	0,31	5,41	1,81
Litoměřice	Vij								4,61	4,03	7,95	2,27	2,35	8,73	2,16
	váž. MS								0,96	0,60	1,14	0,46	0,44	1,91	0,53
Jirkov	Vij									13,90	9,92	21,46	0,84	15,12	19,98
	váž. MS									3,94	2,64	6,48	0,24	5,40	6,69
Žatec	Vij										24,33	20,38	0,67	6,60	10,68
	váž. MS										5,09	2,14	0,18	2,05	2,20
Louny	Vij											6,11	0,90	18,92	5,25
	váž. MS											0,93	0,19	2,82	1,19
Kadaň	Vij												0,55	4,61	76,34
	váž. MS												0,17	1,83	9,31
Varnsdorf	Vij													1,15	0,52
	váž. MS													0,29	0,16
Bílina	Vij														4,29
	váž. MS														1,79

Fig. 4. Extract from the matrix of the theoretically achievable modal split, weighted by the travel time ratio

Based on the outputs of the gravity model (among other outputs), relations with a similar "travel importance" were compared and their offer of transport connections was evaluated. For functional testing of the hypothesis concerning the "theoretical similarities" of transport relations, the regional Litoměřice - Ústí nad Labem rail relation was selected in cooperation with the Ústí nad Labem Region. Using the gravity model, we calculated a very similar theoretical significance between this transport relation and another regional relation, i.e., Roudnice nad Labem - Lovosice - Ústí nad Labem. In both cases, those are the relations with intensive daily commutes, where the main destination is the city of Ústí nad Labem. In areas with a daily commute, the transport connections offer during the morning peak hours (which is shorter and more intensive than in the afternoon rush hour) is decisive.

Meanwhile, for the relation Roudnice nad Labem - Lovosice - Ústí nad Labem in the morning peak hours (about 5:30 to 8:00), a 30-min interval for connections was already offered at the time of the modelling (2011), while, in the relation Litoměřice - Ústí nad Labem, only four connections involving irregular intervals were offered at the same time.

For both compared relations, we can see that, in the transport peak hours in the early morning, only a regional rail connection is offered (in the morning rush hour, neither long-distance trains, nor connections by bus operate in these relations). Passengers in these relations can travel only by regional rail or individually.

A change was made in the timetable and operation concept in 2012 in the relation Litoměřice - Ústí nad Labem, introducing a 30-min interval connection to the morning peak hours (creating an identical offer to that of the relation Roudnice nad Labem - Lovosice - Ústí nad Labem, with identical theoretical significance).

In 2013, the change in the number of passengers in the relation Litoměřice - Ústí nad Labem was evaluated, based on an autumn census campaign of rail passengers and comparisons in the period 2010-2014.

Table 1

Development of the number of passengers between Litoměřice - Ústí nad Labem

Year	Number of passengers [%]
2010	100.00
2011	96.20
2012	101.78
2013	108.42
2014	106.89

Between 2010 and 2011, the original operational concept functioned, while, in 2012 and 2013, the timetable was reorganized according to the new extended concept. In view of the fact that the results of the census were not public, the number of passengers was relativized, with a default considered for 2010 (100% of passengers). Due to the introduction of a new connection offer, an increase in the number of passengers by 8% occurred after two years in the relation Litoměřice - Ústí nad Labem. The number of passengers from the 2014 autumn census campaign shows that some of the passengers who responded to the new offer were long-term “new users” of public transport in this relation.

For completeness, it is necessary to add that, throughout, the condition “ceteris paribus” was followed, i.e., that there were no major changes that could affect the demand for transport, except changes to the operational concept in the railway timetable.

There is generally verifiable that, in the Czech Republic, the total response time for passengers (settling their number) occurs at first after about three years following the concept change to the timetable. At this point, however, as only data for three years of the new operation (2012, 2013 and 2014) can be evaluated, it is thus premature to draw conclusions about the elasticity of passenger demand related to interval/frequency connections in regional traffic.

4. CONCLUSION

Although gravity models, when used in operational concept planning of public transport, represent only very limited support tools, in the case of regional rail services in the Ústí nad Labem Region, it has been demonstrated that such tools can be used to detect the potential for developing public transport and contribute to improving the offer in the relation where improvement would have tangible benefits.

For the purchasers of public transport, they need to be aware of which areas have potential for growth in public transport. The proportional comparison of the significance of single transport relations can even contribute to the elimination of historically originated incommensurability. In addition, the outputs of the gravity model are utilized for the optimization of public transport projects, in the construction of backbone lines, even by modal optimization, and in the planning of necessary capacities.

The practical application of a gravity model in the Ústí nad Labem Region clearly showed positive results in the regional rail relation Litoměřice - Ústí nad Labem. This in turn has contributed to the fact that the Ústí nad Labem Region will further continue to modify and develop operational concepts in regional transport in such relations, where the treated gravity model shows significant potential for increasing the modal split in public transport.

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