University of Pardubice
Faculty of Transport Engineering

THE MODEL OF THE INTEGRATED TRANSPORT SYSTEM AT THE SUPRA-REGIONAL LEVEL

DISSERTATION THESIS

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Content

Introduction

The PhD thesis called "The model of the integrated transport system at the supra-regional level" deals with the analytical part of integrated transport systems in Czechia focussing on the differences between individual systems in connection with the possible cooperation of individual systems so that the border of the region does not form an administrative barrier in the planning and use of public transport. The first part of this thesis is evaluating the current state of integrated transport systems in Czechia based on the criteria set by the author (a composition and options for purchasing tickets, marking lines or zones, an integration of transport modes). Next part is introducing the current state of scientific knowledge on the given issue, and last part presents a proposal that will solve this issue. In the thesis, the author presents the methods by which he subsequently wants to achieve the goal of designing a mathematical-graphic conceptual model at a supra-regional level. Subsequently, the author processes 3 options of the unification proposal at the supra-regional level, namely:

- option A – connecting and supplementing the current integrated transport systems using selected superstructures,
- option B – unification of existing integrated transport systems by adopting the proposed conditions and measures,
- option C – proposal of one new integrated transport system for Czechia.

The tariff charts and flowcharts, which will make the processing of individual options illustrative, can be cited as essential in the processing of model proposals. As part of the proposals, the author sets as a basic point of view to achieve simplification of the system from the passenger's point of view and the unification of the purchase of tickets.

1 Current state of the studied issue

This chapter summarizes the analytical part of the thesis.

1.1 Current state of integrated transport systems in Czechia

Currently, a total of 16 integrated transport systems are operating in Czechia. The system can be found in every region, and from this point of view, almost the entire territory of the country is covered. It is this fact that there are many individual and differently functioning systems in a relatively small area that can be seen as a problem, especially for roads near regional borders. In many cases, individual integrated transport systems overlays have already been introduced into the territory of the neighbouring region to achieve simplification for commuters. The absence of integrated transport systems overlays can lead to complications when traveling, especially when the passenger is forced to use the carrier's tariff, which may be more expensive than the integrated tariff, or must purchase multiple tickets. Such facts lead to a decrease in the attractiveness of public transport.

The output of the analysis of integrated transport systems in Czechia is a comparison of individual systems within Czechia from the point of view of the criteria determined by the author. These criteria are: a designation of the system and its organizer, a territorial validity, a coverage to other regions, a type of tariff, individual tickets, a subscription fare, a chip card, a payment card check-in, a mobile application for purchasing tickets or the possibility of using an SMS ticket. Other criteria are: the integration of bus lines, the integration of rail transport, the integration of city public transport, the integration of other modes of transport (cable cars, ferries, etc.), marking of zones/lanes, marking of bus lines and marking of railway lines. The criteria were set by the author in such a way that the differences between the individual systems were pointed out using the basic properties and

parameters of the systems. From the mentioned comparison of integrated transport systems in Czechia, it can be determined that the only one of the mentioned criteria in which all systems in Czechia agree is the integration of railway transport.

1.2 Current state of knowledge

As a part of the analysis of the state of scientific knowledge, the author dealt with 36 contributions of available literature from Czechia, abroad, and within the contributions of the author of the thesis. No contribution directly addressed the topic of this thesis, i.e. the proposal of a model for the unification of integrated transport systems in Czechia or in another country. The authors of the contributions always dealt only with a partial area of integrated transport systems or public transport, especially from the point of view of support, attractivity, or evaluation. The author will use some ideas, conclusions, or methods in the design part of the work, for example the use of a tariff chart to represent the composition of tickets. The essential contributions for the development of the PhD thesis proposal are:

- the contribution of Pavel Drdla (2020), who in his contribution to the Scientific and Technical Proceedings of the Railway Administration presents the possibilities of unifying different tariff structures within Czechia and defines the zonal tariff structure as generally suitable for IDS [1],
- the contribution by Ralf Borndörfer et al. (2020), who in his contribution presents a graphic model for charging public transport and finding price-optimal routes in the chart [2],
- the second contribution by Ralf Borndörfer et al. (2018) solving a mathematical model for the description of prices in public transport, which is applied to six examples of transport unions from Germany and

shows the possibilities of tickets in the given system from the basic options to the maximum price of an individual fare [3],

- the contribution by Thomas Balser et al. (2020) presenting the introduction of the new tariff "bwtarif" from 9th December 2018, which is valid throughout Baden-Württemberg in any of the 22 transport or tariff associations or across these associations [4].

None of the available contributions mentioned the fact that any author would deal comprehensively with the topic of the unification of integrated transport systems, the creation of a new system on the territory of a state, etc. Based on this finding, the main idea of this thesis was justified.

2 The aim of the dissertation

The aim of the dissertation is to propose a conceptual mathematical-graphical model of the unification of integrated transport systems at the supra-regional level. This model will be gradually developed in three options, which will be solved simultaneously. The first option (the option A) takes into account the currently functioning systems in Czechia, and within this option of the model, the author proposes the connection of existing systems using so-called superstructures. The next option (the option B) considers the existing division of Czechia between individual systems, but the author will deal here with a greater unification of systems (and thus also the solved criteria) using the proposed conditions and measures. The last option (the option C) will not respect the current systems and the author will propose a completely new system applicable to Czechia. In summary, the following sub-steps of the preparation of the future dissertation can be listed, which will lead to the achievement of the set goal:

- the development of the model in three specified options, (A, B, C),
- the evaluation of the benefits of each option of the model,

- each option will be processed as a mathematical-graphical model,
- a selection of the most suitable option according to the criteria from the passenger's point of view and a verification in the selected territory of Czechia.

3 Methods of processing and the solution

This chapter deals with the methods used in the design part of the thesis and the introduction of individual options of the solved model.

3.1 Solution methods

In the analytical part of the thesis, the author uses the following methods: qualitative research, literary research, an analysis, a synthesis and a SWOT analysis. In the design part of the thesis, the following methods are used: a force field analysis, a pairwise comparison method, a weighted sum method, system analysis tools, the Gantt chart, the tariff chart and a flowchart. The last two mentioned methods are essential for the processing of individual design options.

The **tariff chart** shows the structure of tickets of a certain system and the transition between individual tickets. Nodes marked in red are the basic (default) options for tickets, including so-called short-distance tickets. The other nodes represent other possible tickets in the system up to the maximum price for an individual ticket. The edges of the graph represent transitions between tickets based on the limitation of the number of stopped stops or tariff zones.

The **flowchart** is a graphical representation of a process or a step-by-step solution to a problem using geometric figures connected by curves for the purpose of designing or documenting a process.

3.2 A connection model using superstructures (option A)

The author proposes a unified mobile application as a usable superstructure for connecting existing integrated transport systems, which will allow the passenger to purchase tickets through this sales application (or also a sales system, if the possibility of purchasing via websites or points of sale is also considered). This ticket will be valid for several systems, or the passenger purchases a chain of connected integrated tickets through the application, without having to orientate himself in detail in the structure of the various systems. The operating principle of the model can be defined as follows: in the basic option, passengers purchase a ticket for one tariff zone, or multiple tariff zones within one system; if the passenger crosses the border of the region (integrated transport system border), they purchase the so-called extended version of the ticket, which combines the tariff of the first system and the neighbouring system, or multiple downstream systems; within the framework of the model, there is also the theoretical possibility of purchasing the maximum ticket, i.e. all-day network tickets for all systems when the maximum number of used integrated transport systems is reached.

3.3 A model of unification by uniform conditions (option B)

The author considers a generally applicable tariff structure for the unification of existing integrated transport systems to be a zonal tariff structure, which is simple, easy to create and obvious even for the passenger (it is enough to know the number of zones passed, or the name of the starting and destination stops, if there is a sales system). Despite the fact that different systems in Czechia and abroad use different tariff structures and have their own arguments for using a given structure, the zonal tariff structure can generally be understood as the simplest and most universal. The operating principle of the model can be defined as follows: in the basic version, a passenger buys a ticket for one tariff zone in the first system, if the passenger travels through

several tariff zones, he buys a ticket for the corresponding number of zones. If the ticket in the first integrated transport system will no longer be changed, it can be considered final. Subsequently, if the passenger crosses the border of the region, or the border of the system, he will similarly purchase a ticket for the required number of tariff zones in this neighbouring system as well. Similarly, tickets can also be purchased in other related systems. Within the model, there is also the theoretical possibility of purchasing a maximum ticket, i.e. an all-day network ticket for all integrated transport systems upon reaching the maximum number of tariff zones travelled or systems used.

3.4 A model of the new system for Czechia (option C)

For the proposal of a unified integrated transport system for Czechia, the author would use a honeycomb tariff structure, which has all the advantages of a zone structure, but is clearer compared to it (precisely thanks to the display of individual "zones" using a honeycomb). At the same time, the author wants to use a structure that has not yet been used in Czechia, as well as to apply some foreign experience (especially from the SVV system, where a honeycomb structure is used). The principle of operation of the model can be described as follows. In the basic option, the passenger purchases a ticket for one tariff honeycomb. If he travels further through several tariff honeycombs, the passenger purchases a ticket for the relevant number of tariff honeycombs, up to the maximum option (i.e., that the price remains the same after passing a certain number of honeycombs). The basic ticket can also be a ticket for the "CITY", "CITY XL", "CITY XXL" or "PRAGUE" tariff honeycomb. In the ticket, it is also possible to combine journeys via all types of tariff honeycombs. If the passenger is moving within one region (or in specified overlaps) and the price of the ticket would exceed the price of the regional ticket for the used tariff honeycomb, he will use this ticket. If the price of a ticket for used tariff honeycombs or regional tickets exceeds the price of the maximum network ticket, the passenger will use this ticket.

4 Achieved results

This chapter deals with the determination of the resulting design option and its verification.

4.1 The determination of the resulting option

The author decided to determine one of the options that is the most suitable, the least demanding and has a great benefit for passengers with the help of the criteria:

- the effect of system unification,
- willingness to implement,
- simplification for passengers,
- boot time,
- financial difficulty,
- technical complexity.

The WSA method was used to determine the total benefits of the options, while the highest value was calculated for the **option A**, i.e. the option that solves the connection of existing systems using superstructures, specifically with the help of one mobile application mediating the sale of a ticket collectively as a chain of partial tickets of existing integrated transport systems. Considering the current state of integrated transport systems in Czechia, the author determined this option as the most suitable.

4.2 A verification

For each option, the author verified whether the model gives the expected results, using a specific example.

The principle of purchasing a ticket within the recommended option is as follows:

- after opening the application for purchasing tickets, the passenger enters the required data, i.e. route (from where to where), number of people, discount, date, time, or a specific connection,
- the application calculates the resulting price of the ticket with the help of knowledge of the tariffs of the affected IDS (in the case of the specific connection Kolín-Pardubice IREDO system and PID+IDSK system),
- after payment, a ticket is generated for the passenger, which he presents at the transport control and which includes the price of the IREDO and PID+IDSK tariff, without the passenger having to know, for example, the affiliation of cities to tariff zones or bands or the fact that there are more than one on the route systems.

According to the author, for the purposes of this thesis, the model is designed correctly and gives the expected results.

The author also suggests that the described options of the model could be considered as individual sub-steps to the introduction of a unified integrated transport system in Czechia, while option C would be considered as the target state.

5 Benefits of the dissertation

The author considers the greatest contribution to be the **use of so-called tariff charts for the issue of model designs in the field of integrated transport systems,** which have not yet been used anywhere in the available Czech sources. These charts are a clear display of individual options of tickets and transitions between these tickets. In this way, the tariff issues of any

system can be presented comprehensively and universally. The presentation of the tariff issue of the proposed model options is suitably complemented by flowcharts illustrating the process of operating individual systems.

Other benefits are the **designs of the model options themselves**. They have not been published anywhere in a similar form yet. Although there are currently some applications for the sale of tickets in integrated transport systems (e.g. PID Lítačka or POSEIDON), there is none that covers the sale of the tickets of multiple systems or that would be able to generate one uniform ticket using the tariffs of several systems. Moreover, no available source mentions that a similar app is coming anytime soon. The second option solving the unification of the systems by adopting a single tariff structure (in this case zonal) confirms the ideas of some expert articles. Apart from these contributions, however, there is no information about the possible unification of tariff structures. The third and, according to the author, the most progressive version of the model deals with the design of one new system. **The greatest benefit of this option is the use of a honeycomb tariff structure in the territory of Czechia,** where it has not yet been used, based on the inspiration of the Salzburg SVV system. Here, the author also proposed his own map background showing the division of the territory of Czechia into individual tariff honeycombs. All the mentioned options demonstrate their benefits based on the given example of operation.

According to the author, the work brings a large number of previously unpublished matters in the field of integrated transport system unification at the supra-regional level. The author also considers it beneficial that the work can be used in practice, at the same time this work can also serve as a basis for further research, for example:

- detailed solution of the model in option A, including the creation of the proposed application,
- detailed solution of the model in option B, including verification of another tariff structure (or structures),
- detailed solution of the model in option C, including the examination of another tariff structure suitable for application to Czechia and the design of the organizational chart and other functionalities of this system,
- stimulus for the proposal of a different solution to this issue.

Conclusion

In the design part of the thesis, the author elaborated the mentioned three options of the integrated transport system unification model, while he mainly used tariff charts and flowcharts for clarity. Other methods that were used in the thesis to achieve the set goal were, for example, Fuller's method, Gantt chart or force field analysis. The author subsequently determined option A, i.e. connection of existing systems using one mobile application, as the most suitable, especially considering the current state of integrated transport systems and passenger habits. At the same time, the author points out the possibility of looking at the three elaborated proposals as individual steps to achieve one functioning system in Czechia. The author also points out the point of view he is aiming for in this work, which is a simplification from the passenger's point of view. Any further research in this area could focus on a different point of view (e.g. financial, organizational, etc.) or address each of the options separately and in more detail. According to the author, this thesis appropriately deals with the topic of integrated transport systems in Czechia (and abroad), both from the point of view of analysis and from the point of view of the proposal itself, which has not yet been developed in this form.

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Abstract/Summary

Based on the analysis of integrated transport systems in Czechia and abroad and the state of scientific knowledge, the author proposed 3 options of a mathematical-graphic model solving the unification of integrated transport systems at the supra-regional level. The author mainly used tariff charts and flowcharts to process the option proposals. Option A was determined as the most suitable option – connection using a mobile application, which will enable the purchase of a tickets across existing systems.