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Class Library for Simulations of Passenger Transfer Nodes as Elements of the Public Transport System

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Abstract

Transfer nodes are essential elements of public transport systems which provide door-to-door transport services for passengers. Parameters of the technological processes in public transport systems are stochastic variables, thus, computer simulations are usually used for solving optimization problems of public transport. There is a number of simulation tools supporting decision-making in public transportation, but they don't provide the flexibility for solving the transfer nodes optimization problems. Authors present a library of classes implemented in Python, which could be used for computer simulations of public transfer nodes. The proposed software allows researchers to change technological parameters during simulation procedures and makes possible automatization of simulation experiments in the field of passengers' transportation.

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Keywords: public transportation, transfer nodes, computer simulations, Python code, specialized classes' library, optimization methods

1. Introduction

In the contemporary engineering science, the use of simulation tools is necessary while planning and analyzing systems at the macrolevel, especially while solving the problems of public transport systems. Processes in public transportation are characterized by the influence of a large number of different random parameters on the system

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elements. In a consequence, all the resulting characteristics of these elements and a public transport system as a whole are stochastic variables. Estimations of the resulting parameters as stochastic variables cannot be performed in practice without using of computer simulations.

Transfers are unavoidable for the creation of an efficient transit route network as it is impossible to ensure the door-to-door access in all directions without transfer nodes. The passenger transfer nodes development is an essential problem to be solved in order to maximize service coverage, support multimodal transportation and ensure sustainable connectivity. The presence of transfer nodes in a public transport system makes it possible to assign routes for a network with optimal headways, vehicle sizes etc., and, as a result, to meet passenger demand and minimize operation costs. However, uncoordinated transfers decrease the service quality and the attractiveness of public transportation to passengers due to additional waiting time.

In a process of decision-making on sustainable development of the public transport systems, transportation engineers often use approaches based on analytical models, but the adequacy of such models is much lower in compare to simulation models. The simulation models of public transport systems allow researchers and engineers to consider stochastic parameters of technological processes. In addition, the inner relations between the system elements and input parameters could be described with high precision, and this makes the simulation models of public transport systems much more adequate than analytical ones.

2. Review of existing optimization problems in passenger transfer nodes

The main objectives of transfer optimization usually are minimization of the passengers waiting time and maximization of the number of arrivals due to synchronization (simultaneous arrivals of public transport vehicles) at the transport system interchanges. The existing literature considers the trade-off between the passenger waiting time and operating costs [1, 2] as well. There also exist multi-objective optimization approaches, such as a model formulated for the multi-objective re-synchronizing of bus timetable problem by Yinghui Wua et al. [3].

As scheduling problems are recognized to be an NP-hard problem, it is difficult to solve them with exact algorithms, so different technics, such as Tabu search method, simulated annealing, genetic algorithms, iterated local search, branch-and-bound, local search algorithms are applied to obtain some rational solution.

The model aimed at minimization of the total waiting time of all passengers at transfer nodes was formulated on the basis of the Fuzzy Ant System by Teodorović & Lućić [4].The authors of this model emphasize that the transfer waiting time depends on schedule synchronization. But it should be noted, that stochastic parameters of the demand for public transportation (such as interval of passengers appearance at public transport stops) influences the waiting time as well.

Ceder et al. developed a mixed integer programming (MIP) model for the problem of generating a timetable [5]. It is objected to maximize the number of simultaneous bus arrivals at the connection nodes. The bus travel time is assumed to be deterministic.

Schroder & Solchenbach tackled the optimization of transfer quality and modeled the problem of timetable synchronization as a quadratic semi-assignment problem [6]. They distinguish five transfer types, which vary from “Convenience” to “No transfer” and propose a penalty-function for each of them.

In order to develop realistic and adequate models it is necessary to take into account randomness of different public transport attributes. The existing literatures also propose a timetable synchronization models considering uncertainties. Stochastic disturbances appear due to the variation of traffic intensity over time, traffic jams, weather condition, driver´s behaviour etc. Moreover, any demand change results in the dwell time deviation. The mentioned uncertainties lead to increasing the variability of the travel time and diminishing service reliability.

A stochastic programming model for metro train rescheduling problem was proposed by Yin et al. [7]. The developed model includes uncertain time-variant passenger demands. The rescheduling problem was successfully solved due to the use of an approximate dynamic programming based algorithm.

Some published timetable synchronization models consider uncertainties in the travel times. Focusing on transfer optimization, Bookbinder & D’esilets proposed to combine a simulation procedure and an optimization model (relaxation of the Quadratic Assignment Problem) [8]. The developed model considers travel time as a stochastic variable.