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Hybrid large neighborhood search for the bus rapid transit route design problem

پژوهشی عملیاتی بر:

یک روش ترکیبی جستجوی همسایگی بزرگ، برای طراحی مسیر در سامانه اتوبوسی تند رو (بی آر تی)

دپارتمان مهندسی صنعتی، دانشگاه لاس آندل، کولومبیا

چکیده

در دهه‌ی اخیر، با توجه به افزایش تقاضایی که در خصوص سرویس حمل‌ونقل عمومی و جابجایی درون‌شهری[1] صورت گرفته است، نیاز به وجود یک سازمان حمل‌ونقل عمومی کارآمد موردتوجه زیای قرار گرفته است. در این مقاله قصد داریم با ارائه‌ی تعداد ثابتی از مسیرهای حمل‌ونقل، یک مدل فرمول‌بندی شده[2] (تدوینی) را برای مسئله‌ی طراحی سامانه اتوبوس تندرو (بی آرتی) ارائه دهیم. به منظور روبرو شدن با این مسئله، می‌توان از استراتژی تجزیه استفاده کرد، چراکه در این استراتژی، طراحی مسیر و تعیین فرکانس و جریان عبور و مرور مسافرین به‌صورت مجزا مدنظر قرار می‌گیرد. یک روش متا هیروستیک (فرا ابتکاری) مبتنی بر ترکیبی از جستجوی همسایگی بزرگ (**LNS**) و برنامه‌نویسی خطی **(LP)** را ارائه خواهیم داد. الگوریتمی که ارائه خواهیم داد، ماهیتی تکراری دارد. تصمیم‌هایی که به‌محض طراحی مسیرها صورت می‌گیرد را با استفاده از **LNS** مدیریت خواهیم کرد. جریان‌ها و فرکانس عبور و مرور مسافرین نیز به‌وسیله‌ی حل یک **LP** مشخص خواهد گردید. راه‌حلی که به دست می‌آوریم ممکن است به‌عنوان رهنمودی برای کاهش تعدا طراحی‌های جدید مسیر در تکرارهای بعدی داخل **LNS** بکار گرفته شود. چندین عملگر مربوط به مسئله نیز پیشنهادشده و مورد تست قرارگرفته‌اند. الگوریتم پیشنهادی، به‌طور کاملاً مطلوبی اقدام به مقایسه‌ی راه‌حل‌ها نموده و می‌تواند در کوتاه‌ترین زمان محاسباتی، دست به انتخاب راه‌حل‌هایی بزند که بالاترین کیفیت را به همراه دارند.

واژگان کلیدی: جستجوی همسایگی بزرگ، متاهیروستیک ترکیبی، طراحی مسیر انتقال سریع اتوبوس، حمل‌ونقل عمومی، روش تجزیه

[1] Intra-urban moility
[2] Model formulation

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Discrete Optimization

Hybrid large neighborhood search for the bus rapid transit route design problem

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ABSTRACT

Due to an increasing demand for public transportation and intra-urban mobility, an efficient organization of public transportation has gained significant importance in the last decades. In this paper we present a model formulation for the bus rapid transit route design problem, given a fixed number of routes to be offered. The problem can be tackled using a decomposition strategy, where route design and the determination of frequencies and passenger flows will be dealt with separately. We propose a hybrid metaheuristic based on a combination of Large Neighborhood Search (LNS) and Linear Programming (LP). The algorithm as such is iterative. Decision upon the design of routes will be handled using LNS. The resulting passenger flows and frequencies will be determined by solving a LP. The solution obtained may then be used to guide the exploration of new route designs in the following iterations within LNS. Several problem specific operators are suggested and have been tested. The proposed algorithm compares extremely favorable and is able to obtain high quality solutions within short computational times.

1. Introduction

Due to an increasing demand for public transportation and intra-urban mobility, an efficient organization of public transportation has gained significant importance in the last decades. Cities have continued to grow and hence require more transport capacity and improved access to those. In this paper we will focus on a specific type of public transportation system: the design of routes and their frequencies for bus rapid transit (BRT) systems.

BRT systems enjoy great popularity. Currently more than 168 cities world-wide employ BRT systems, covering a network of 4424 km and providing service to approximately 31 million passengers on a daily basis. BRT systems are especially popular in Latin America, where BRT systems are currently in use in 56 cities. One of the largest among those is operated in Bogotá (Colombia), covering a network of 106 km and offering 1.98 million passenger trips per day (see WWW, 2013).

BRT systems deliver fast and cost-effective public transportation through busses. The route design problem for BRT systems involves the design of routes given the current infrastructure, as well as the determination of their frequencies they will be operated. The network under consideration consists of a single corridor and stations, which are located within the corridor in a predefined way. Busses may be operated on designated lanes, allowing them right-of-way with respect to regular traffic. For the problem under consideration the network of the BRT system is given. A typical network consists of corridors (composed of several individual lanes), as well as the sequence and the location of stations along them. The travel time of busses is assumed to be given. Additional time will be taken into account for ac- and deceleration of busses after or before stopping at a station. Similarly we assume waiting times at stations to be fixed and given.

The demand for the public transport system can be represented in terms of an origin–destination matrix, which provides us with an estimate of the number of passengers requiring transportation between any pair of stations within the time horizon under consideration. This matrix is assumed to be known beforehand and is assumed not depend on the set of routes offered. Depending on the variation of demand throughout the day, the demand during peak hours should be taken into account preferably. The actual demand will depend on the offered set of routes and their frequencies, as passengers may react upon the offer. For the purpose of this paper we assume the demand to be constant and independent of the set of routes offered. The reaction can be seen as a dynamic process (see Guihaire & Hao, 2008), which is beyond the scope of this paper.

We consider a homogeneous and limited fleet of busses. Passengers may enter, leave or transfer among routes, at any station a route stops. As passengers tend to become confused if the number

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