Computers & Operations Research 73 (2016) 92–103

Contents lists available at ScienceDirect

Computers & Operations Research

journal homepage: www.elsevier.com/locate/caor

The combination of continuous network design and route guidance

Linghui Han [a,b], Huijun Sun [a,c,*], David Z.W. Wang [b], Chengjuan Zhu [a,b], Jianjun Wu [a]

[a] State Key Laboratory of Rail Traffic Control and Safety, Beijing Jiaotong University, Beijing 100044, China
[b] School of Civil & Environmental Engineering, Nanyang Technological University, 50 Nanyang Avenue, 639798 Singapore, Singapore
[c] Key Laboratory for Urban Transportation Complex Systems Theory and Technology, Ministry of Education, Beijing Jiaotong University, Beijing 100044, China

ARTICLE INFO

Article history:
Received 1 July 2014
Received in revised form
3 December 2015
Accepted 25 March 2016
Available online 1 April 2016

Keywords:
Continuous network design
Route guidance
System optimal
Traffic demand management

ABSTRACT

In this study, a traffic management measure is presented by combining the route guidance of Advanced Traveler Information System (ATIS) and the continuous network design (CNDP) to alleviate increasing traffic congestion. The route guidance recommends the travelers to choose the shortest path based on marginal travel cost and user constraints. The problem is formulated into a bi-level programming problem. The most distinct property of this problem formulation is that the feasible path set of its lower-level problem is determined by the decision variable of upper-level problem, while in conventional transportation network design problems the feasible path set for lower-level traffic assignment problem is fixed to be all the viable paths between each specific origin-destination pair. The simulated annealing algorithm is improved to solve this bi-level problem. A path-based traffic algorithm is developed to calculate the lower-level traffic assignment problem under the route guidance. Compared to the results of conventional CNDP, the measure presented in this study can better improve the transportation network performance.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

In presence of rapid economic development, urbanization and population growth, almost all large cities worldwide in the world are facing the serious problem of traffic congestion. Traffic congestion has induced not only huge economic loss, but also environmental deterioration. Based on the report of Texas Transportation Institute, the congestion bill in the United States alone was $67.5 billion in the year 2000, comprised of 3.6 billion hours of delay and 5.7 billion gallons of gas [25]. International Energy Agency said that 23% of global energy related carbon emission in 2004 are related to transportation [13]. It is reasonable to believe that the world will soon have to confront high levels of air pollution and congestion problems caused principally by the unrestricted use of private cars, and have to deploy practical instruments to achieve transportation sustainability efficiently, effectively and in a politically feasible manner [35].

There are generally two ways to alleviate traffic congestion: increasing traffic supply (capacity) and reducing traffic demand [35]. The former way is usually called network design problem (NDP) in transportation network, which determines the enhancement of existing link capacity or the addition of network candidate links. Generally, NDP can be classified into three classes: CNDP (determining the optimal capacity enhancement for a subset of the existing links and its deterministic variables are continuous), discrete network design problem (DNDP) [30,22] (dealing with the optimal location of new links addition from a set of candidate links and its deterministic variables often are expressed by 0–1 integer), and mixed network design problem (MNDP) (mixture of the CNDP and DNDP) [18].

However, disparate evidence indicates that the enhancement of road capacity induces a greater volume of traffic [9,10]. Besides, the limitation of land resources in cities cannot support the unlimited increase of link capacity to solve traffic congestion. Basically, more sustainability issues should be considered in NDP [28]. The other measure to reduce traffic congestion is demand-oriented strategies or demand management. Historically, congestion pricing as a demand management instrument has been paid much attention both theoretically and practically. However congestion pricing is perceived as a flat tax since it requires the travelers to pay more for using public urban infrastructure. Meanwhile, there are equity debates of the congestion pricing. So congestion pricing causes the general political resistance and is only applied on urban road in a few cities worldwide [35]. Other than congestion pricing, some quantity control methods to reduce traffic demand are also applied in practice. For example, rationing policies on vehicle usage are used in Mexico City [5], Beijing and Guangzhou, China [11]. Under short-term ration of vehicle usage, observable congestion reduction and air quality improvement have been reported. But it may lose its effectiveness over time as car ownership

* Corresponding author.
E-mail address: hjsun1@bjtu.edu.cn (H. Sun).

http://dx.doi.org/10.1016/j.cor.2016.03.012
0305-0548/© 2016 Elsevier Ltd. All rights reserved.

increases (e.g., there is evidence that driving restrictions in Mexico City led to an increase in the total number of vehicles [5]).

Some researchers also study the combination of NDP and traffic demand management. For example, Wang et al. [32] considered the combination of CNDP and a tradable credit scheme and proved its effectiveness to improve traffic congestion by numerical examples. In this paper, we will study the combination of CNDP and route guidance.

With the development of Intelligent Transport System and advanced techniques of information in the past decades, the advanced traveler information system (ATIS) can easily provide travel information or give travel recommendations. It is widely believed that route guidance information to the travelers is able to efficiently reduce traffic congestion and enhance the performance of traffic networks [34]. Nowadays a large portion of the private cars have been equipped with ATIS devices. While the prices of those deices keep going down, many more travelers are likely to use them and rely on route guidance to achieve trips in the near future. Therefore, it is imperative for the transportation authority to understand how to incorporate the route guidance into the transportation network design so that the network performance is optimized. Traditional network design problems in the literature have not considered the route guidance, assuming that travelers follow user equilibrium (UE) principle to minimize their individual travel costs. In this study, we assume that when transport planners decide to improve the road network, they have to consider that route guidance information would be provided to the travelers and therefore the resultant network traffic flow pattern is different from the UE traffic assignment. Besides, noting that the simple and naive system-optimal based route guidance is subject to unfairness issue, we assume that route guidance strategy with certain user constraints is applied to reduce the unfairness. Indeed, the network traffic flow pattern achieved with this route guidance strategy is constrained system optimal (CSO). The problem studied in this paper, i.e., the combined continuous network design and route guidance, is then formulated into a bi-level programming. A modified simulated annealing algorithms are proposed to solve the problem. To summarize, the main contribution of this research work is to fill in the research gap in transportation network design problems by considering the route guidances of the traveler information system.

The paper is organized as follows: Section 2 presents a bi-level programming problem to model the combination of CNDP and route guidance. The algorithm to solve the bi-level programming problem is given in Section 3. Section 4 gives the numerical test and the conclusions of the study is presented in Section 5.

2. Problem formulation

In NDP, the traffic authorities make a decision on the link capacity enhancement or the addition of new link to optimize a specific network index (e.g. total travel time or generalized cost). Meanwhile, the route choice of travelers is considered in NDP. Therefore, NDP is naturally described by bi-level program. Abdulaal and LeBlanc [1] is the first one who describe CNDP by bi-level programming, in which the lower-level is the user equilibrium (UE) assignment problem. In this study, the general CNDP is called UE-CNDP. There is also NDP in which the lower-level problem is a stochastic user equilibrium [17]. In the following, we will present the notations used in our paper.

2.1. Notations

In this study, $G=(N,A)$ denotes a direct connected traffic network of a node set N, a link set A. W is the set of origin-destination (OD) pairs, R_w is denoted as the set of paths between OD pair w, and all paths in this network are denoted by R, $R=\bigcup_{w\in W}R_w$. x_a and c_a respectively denote the traffic flow and the capacity on link a. $t_a(x_a)$ is the travel cost of link a and increases with x_a. x is the link flow vector. f_r^w, c_r^w are the flow and travel cost of path r, $r\in R_w$, $\forall w\in W$,

$$c_r^w=\sum_{a\in A}t_a\delta_{ar}^w,\quad r\in R_w,\ w\in W \tag{1}$$

where $\delta_{ar}^w=1$, if link a is used by path r, and $\delta_{ar}^w=0$ otherwise. q_w denotes the traffic demand between OD pair w. y_a is the capacity enhancements in CNDP and y is the vector of y_a. $G_a(y_a)$ is the cost function of incremental capacity on link a, $\forall a\in A$. The lower and upper bounds of allowed capacity enhancement for link $a\in A$ are respectively denoted by l_a and u_a. τ_r is the normal length of path $r\in R_w$, its definition is given in Section 2.3. T_w is the minimum normal length for all paths between OD pair w and φ is a parameter. $\mathcal{P}_w$ is the feasible path set under route guidance between OD pair w. Based on the notations, the UE-CNDP model is given in Section 2.2.

2.2. UE-CNDP model

The upper-level of UE-CNDP model:

$$\min z(\mathrm{x},\mathrm{y})=\sum_{a\in A}t_a(x_a,y_a)x_a(\mathrm{y})+\alpha\sum_{a\in A}\mathrm{G}(y_a) \tag{2}$$

$$\text{s.t.}\quad l_a\le y_a\le u_a,\quad \forall a\in A \tag{3}$$

where the parameter α is a scaling coefficient which converts cost of increase link capacity into the travel cost. x_a is the solution of the lower UE assignment problem:

$$\min\ \sum_a\int_0^{x_a}t_a(\omega)\,d\omega \tag{4}$$

$$\text{s.t.}\quad \sum_r f_r^w=q_w,\quad \forall r\in R_w,\ \forall w\in W \tag{5}$$

$$f_r^w\ge 0,\quad \forall r\in R_w,\ \forall w\in W \tag{6}$$

$$x_a=\sum_w\sum_r f_r^w\delta_{ar}^w,\quad \forall a\in A \tag{7}$$

2.3. Travel pattern under route guidance

Roughgarden and Tardos [24] have showed that the user optimal route guidance generally cannot improve the performance of traffic network. However, from the traffic authority's perspective, it is certainly desirable to explicitly minimize the total travel time. To alleviate traffic congestion, it is imperative to develop route guidance based on system optimal principle. However, in system optimal, despite that the total system travel time is minimized, some travelers are routed on unacceptably long paths so that shorter paths can be used for many other travelers [14]. So, directly implemented, the route guidance based on system optimal may be not accepted by travelers. Jahn et al. [14] developed a route guidance method which recommends the shortest path based on the marginal travel cost to travelers at current traffic flow. And the recommended paths all satisfy user constraints. With this route guidance, traffic system will attain constrained system optimal (CSO). The user constraints are described by the normal length of path and the parameter φ. Specifically, for the path $r\in R_w$, its normal length is τ_r. Let T_w:=$\min_{r\in R_w\tau_r}$, if $\tau_k\le\varphi T_w$, path k belongs to

دریافت فوری ← متن کامل مقاله

ISIArticles
مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات