Optimal capacity location problem of parking and accelerated moving walkways to design a car-free city center

Extended abstract for hEART 2017

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1 Introduction

A car-free city center is a valuable solution for decreasing traffic congestion and C02 emission, and improving active mobility and quality of live. For achieving these goals, one of the biggest challenges is the relocation of parking places scattered in the inner district, which cause cruising for available parking as well as car inflows. However, this may decrease the level of accessibility moving the parking away from the final destinations. The key idea of this study is to use "accelerated moving walkway (AMW)"s[4], a novel transport system, in combination with parking relocation. Unlike other public transport systems, AMWs do not have operational constraints such as routes, drivers and timetables. AMWs also have a low energy consumption of approximately 0.11 megajoule per passenger per km, only a third of electric buses, and high capacity of 7'000 passengers per hour being only 1.2 wide, four times more capacity using half of the space of a street for private vehicles. We expect that the optimal location of this combined facilities contributes to design of a car-free city center.

In this study, we develop a network design problem of the above-mentioned transport system. Regarding parking policy, the literature on parking location problem is considerably thinner, while a lot of papers have investigated the optimal pricing scheme [2, 3] and the smart guidance[7, 6]. Scarinci et al. (2017)[5] investigated an optimal network configuration for AMWs, but the origin-destination demand of pedestrians is given, and the combination with other transportation modes has not been considered. Also, the installation of AMWs requires the reduction of road capacity for vehicular traffic, which causes the interaction between the flows of vehicular traffic and pedestrians.

The main contributions of this study are 1) to introduce a multi-layer network with parking and AMWs to deal with the interactions between vehicular and pedestrian networks, 2) to solve a parking location problem with AMWs and 3) to consider the elastic demand of pedestrians on AMWs.

2 Methodology

This study is based on a network design optimization approach in which a facility location is optimized at the upper-level and the travel demand of both vehicular and pedestrian trips are evaluated at the lower-level.

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To deal with the problem in which the flows of vehicular traffic and pedestrians interact, this study first introduces a multi-layer network (Figure 1). The network consists of two network layers for vehicular traffic and pedestrian and four types of arcs (car, parking, walking and AMW arcs). Vehicular and pedestrian networks are described as different networks but share the same physical space. Therefore, an increase in pedestrian capacity leads to a decrease of vehicle capacity in the corresponding arc. The two layers are also linked with each other by only parking arc. The study considers only car travelers and assume that the origin nodes are always included in the vehicular layer network, and the destination nodes are in the pedestrian layer network.

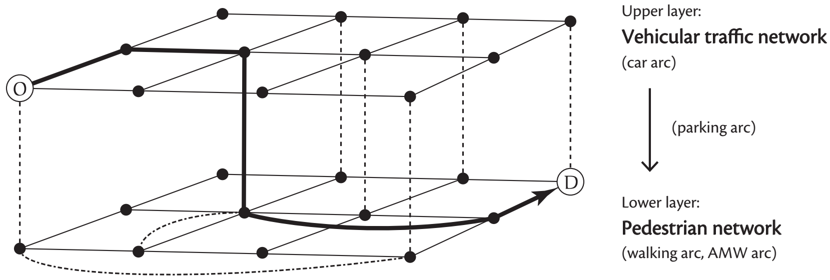


Figure 1: A multi-layer network with parking and AMWs

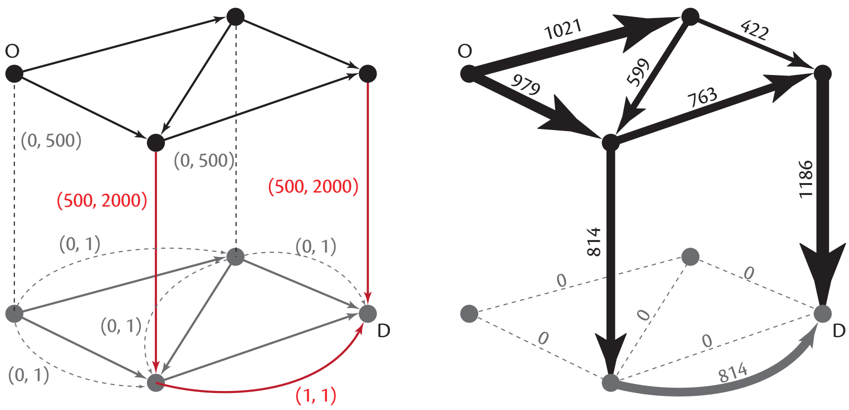
Based on the description of the multi-layer network, an optimal facility location problem of parking and AMWs is formulated. The decision variables are capacities at each parking and AMW arcs. The decisions are constrained by the maximum capacity on each physical space. This means that the increase of AMW arc capacity causes the decrease of car arc capacity on the same street. This constraint is described as $\sum_m n_a^m = \kappa_a, n_a^m \geq 0$, where $n_a^m \in \mathbb{N}_0$ is the arc capacity of mode $m \in$ {car, parking, walking, AMW} and κ_a is the maximum capacity of space a. The objective function considers the total travel time, expected utility and CO_2 emission.

To understand the demand reaction to the network configuration, we also develop a traffic assignment model in the multi-layer network. In the framework, a path choice behavior including route choices on both of two layers and parking choice is modeled in the equilibrium context to explicitly describe the effect of the capacity supply on the traffic flow pattern.

3 Results & Conclusion

We present the numerical results of a simple example based on the Braess network[1] with one origin-destination pair (Figure 2). We solve a multi-objective problem that has a trade-off between the total travel time and the capital cost using a heuristic algorithm developed by Scarinci et al. (2017)[5]. In Figure 2(a), the read lines are the located facilities, and the arrows in Figure 2(b) are the traffic flows on the solved network configuration. The result shows that the installation of AMWs can change the parking demand and its optimal location, but a large number of travelers still go directly to the destination by cars in the network. We further investigate the network configuration patterns with different objective functions using a larger network, which will be presented at the conference.

This research first introduces an optimal capacity location problem for parking and AMW network. The work on this innovative transport system is expected to contribute to not only the design of a car-free city center but also the methodology development especially on traffic assignment and network optimization fields.



(a) Solution: (n, κ)

(b) Flows

Figure 2: A numerical example result

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