Transit network design augmented with shared vehicles acting as feeders on short distances

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1 Introduction

Usage of small capacity shared vehicles (SV) is rapidly increasing in recent years, in part because they offer cheaper transport than taxis and privately owned vehicles. Price-wise, public transport (herein named transit) is cheaper but has less personalized routes. Since the major cost difference between SV and transit comes from human labor, an introduction of autonomous vehicles can level down the cost difference between SV and transit.

Before proceeding we define some terms that are frequently used. Transit network design problem (TNDP) refers to a process of determining the routes and frequencies for transit lines. SVs are vehicles that have a capacity of around ten passengers. Trip refers to one entry in the origin-destination matrix. Feeder services are all services that transport passengers to fixed transit lines.

The price of shared transport should decline with the introduction of autonomous vehicles, which would lead to decrease in transit usage. The situation for transit could be improved by building feeder services. Hence, the main motivation for this work is to keep transit relevant and to improve its overall its quality by modifying TNDP to integrate SV as a feeder service.

This problem lies between TNDP and feeder services, leaning more towards TNDP. Due to combinatorial nature of TNDP many approaches in the literature use metaheuristics to solve the problem (Ibarra-Rojas et al., 2015). Hence, as a starting point for solving the problem we used metaheuristic method developed by Nikolić and Teodorović (2013), which we extend to answer a different question. The idea of zoning for feeder services is not new (Aldaihani et al., 2004; Li and Quadrifoglio, 2009), and it's conceptually similar to this work.

Currently missing in the literature is an approach for simultaneous design of transit network with small capacity shared vehicles. This deficiency will become even more evident, once SV become competitive in price to transit and can be used as cost effective feeders on very short distances.

In this paper, we solve the transit network design problem, when shared vehicles are used as feeders. As a constraint, SV can be used only when starting the trip and can operate only on adjacent nodes.

2 Methods

To solve the problem we modify the bee colony optimization algorithm for TNDP proposed by Nikolić and Teodorović (2013). Bee colony optimization is a metaheuristic that belongs to the family of swarm-based optimization methods. Originally, two types of modifications are performed by the "bees" on the transit network, and in both cases, transit lines are randomly chosen for modifications. The first type of modifications randomly changes the position of a line terminal to any other position. The second modification extends or shortens the line, one edge at the time, from either terminal of the line. For this problem we extend the algorithm, to perform the third type of modifications on SV distribution. Before the algorithm starts, we assign a fixed number of SV in a network. Modification is then performed in each iteration by randomly choosing one node in which SV are positioned, and SV are moved to another node, also chosen randomly.

Shared vehicles are only allowed to move to adjacent nodes, e.g. in Figure 1 vehicles which are positioned in node 5 can only perform the following movements: 5–2, 5–3, 5–7, 5–14. In addition, shared vehicles can only be used when starting the trip and *not* when ending the trip. The underlying hypothesis is that changing transport mode, in a short distance, and at the beginning of a trip wouldn't be counted as a transfer. Therefore, if the beginning of a trip begins with SV and continued with transit, it is not counted as a transfer.

3 Results

For this experiment, we use Mandl's network with its demand (Mandl, 1980), cf. Figure 1. The network was originally used in a case study in Switzerland and is frequently used for benchmarking TNDP.

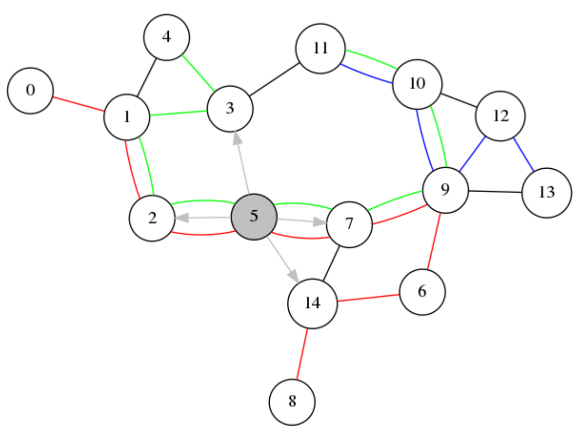

Figure 1: Left: Network with 3 transit lines and 1 SV node. Right: Network with 4 transit lines and 1 SV node (in gray). Directed gray edges are allowed movements for SV. Black edges represent street network. Other colors represent different transit lines.

Table 1 shows best results obtained by using the proposed methodology. The accompanying graphs are shown in Figure 1. We can see that performance is slightly worse when using SV, namely total travel time (TT) is larger by 16%. Also, there are 2% more trips that have one transfer (t1)

Table 1: Performance analysis

	4 lines, 0 SV nodes	3 lines, 1 SV node
t0	95.38%	93.51%
t1	04.30%	06.49%
t2	00.32%	00.00%
tu	00.00%	00.00%
TT	1502h	1749h

and 2% fewer trips with no transfers (t0). In both networks, there are no cases with three or more transfers (tu). We see that the performance difference is not very large but in the case with one node served by SV we have one transit line less.

4 Discussion & Conclusion

Most current approaches observe shared transport modes and transit as separate entities which can work together. In this work, they are seen as a singular entity. The proposed approach offers a similar level of transit performance with a smaller number of transit lines. This was achieved by adding small capacity shared vehicles at certain nodes to act as feeders to transit. Since fewer lines have to satisfy the same demand, lines must have a higher frequency. This is a desirable property for a transit line. Increasing the demand for a smaller number of lines was the main concept that guided this approach. Furthermore, method is at a very high level and more details can be added, which indicates that it is possible to have tight integration of SV and PT to further improve the performance of the transit in the future.

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