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CASPT 2018 Extended Abstract

Passenger Route Choice and Assignment Model for Combined Fixed and Flexible Public Transport Systems

Jishnu Narayan · Oded Cats · Niels van Oort · Serge Hoogendoorn

Abstract The recent technological innovations have given rise to innovative mobility solutions. Public transport systems combining such services need novel models for the design of services. We develop a multimodal route choice and assignment model for combined use of line/schedule based public transport systems (fixed public transport) and demand responsive services (flexible public transport). The model takes into account the dynamic demand-supply interaction using an iterative learning model framework. Flexible public transport can be used to perform any part of the trip, ranging from a first/last mile service to an exclusive direct door-to-door connection. The developed model is implemented in an agent based simulation framework. The model is applied to the test network of Sioux Falls. Results, in terms of modal split, fleet utilization, and passenger waiting times are analysed for scenarios in which fixed and flexible public transport are offered as competing modes as well as potential complementing modes.

Keywords: Agent-based simulation, Multi modal path choice, demand responsive transport, demand responsive public transport, public transport

1 Introduction and Motivation

The recent emergence of innovative mobility solutions in the form of demand responsive services is changing the way public transport systems are designed. It is

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believed that such demand responsive services can potentially address the problems inherent to line/schedule based public transport systems (e.g. long waiting time, lack of accessibility for demand from low demand density regions). Hence, designing a public transport system which combines line/schedule based services and demand responsive services, can potentially increase the overall efficiency. However, in order to design an efficient public transport system combining line/schedule based and demand responsive services, it is important to understand the dynamic interaction of demand and supply. The integration of line/schedule based public transport systems (fixed PT) and demand responsive services (flexible PT) has been studied in the literature, e.g. via analytical approaches including IDARP (Integrated Dial-a-Ride Problem) modelling. This approach includes optimal assignment of real time requests to a fleet of vehicles (considering coordination with fixed services) and thereby maximising/minimising certain user/operator objectives subject to some constraints (Posada et al. 2016 and Hall et al. 2009). Of the studies that have combined fixed and flexible services, most of the works have modelled flexible pt as access/egress modes or as first/last mile modes (Uchimura et al. 2012, Hall et al. 2009, and Posada et al. 2016). Combining fixed and flexible PT within MaaS (Mobility as a Service) framework has also been studied in which passengers essentially choose from a set of choice alternatives (Atasoy et al. 2015).

The integrated iterative learning and route choice modelling of users (enabling users to choose flexible services as first/last mile service as well as exclusive door-to-door service from their origin to destination) has not been considered in literature to the best knowledge of the authors. This paper fills this research gap by developing a model for multimodal route choice of users allowing combinations of fixed and flexible PT on a given trip. This is done by considering the iterative learning of users in which users learn from the service experienced and alter their travel plans. From a practical perspective, this work enables practitioners and policy makers to investigate the implications of combining fixed and flexible services on system performance when fixed and flexible services act as competing and complementing modes.

2 Methodology

2.1 Multimodal Route Choice and Assignment

A multimodal route in this study refers to the trip a passenger makes from their origin to their destination using public transport services. Depending on the type of service and the number of modes used by the passenger in the route, the different types of multimodal routes are illustrated in Figures 1-2.

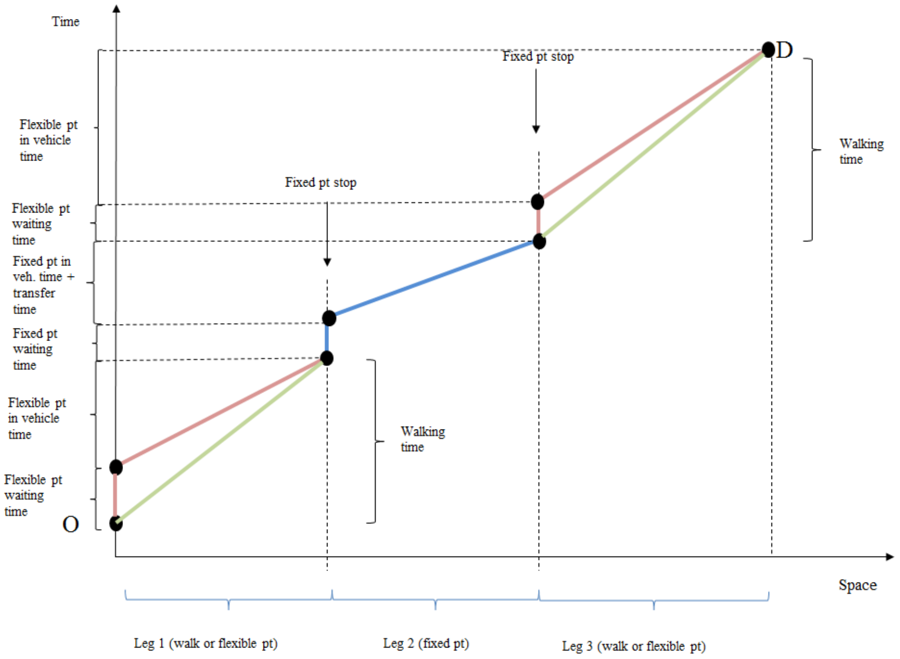

Fig. 1 Three leg route representation using flexible pt/walk and fixed pt

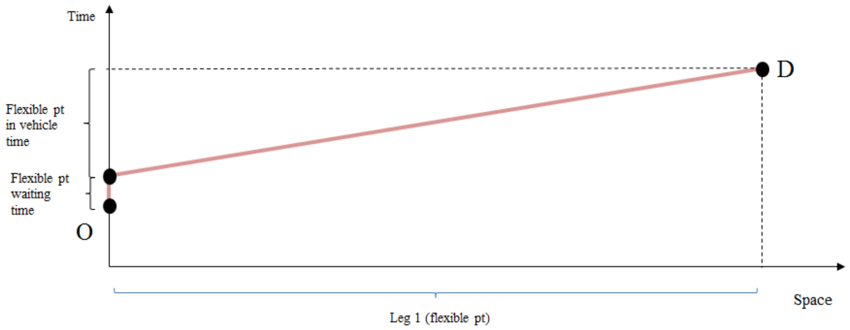

Fig. 2 Single leg route representation using flexible pt

For each origin destination pairs, first a set of possible transit journey options (choice set) are generated as part of the Choice Set Generation step. The choice sets are generated for each user by searching fixed PT stops from origin and destination within an acceptable search radius. The trip from the origin to a fixed PT stop or from a fixed PT stop to their destination is covered by modes of flexible PT or walk depending on the distance of the stop from the origin or destination. Then for each of these options, a utility value is computed-which is a function of attributes of that particular choice-in the module Scoring of choice alternatives. The utility function deployed for evaluating travel alternatives is given in the following equation.

$$U_i = \beta_{walk} . t_{walk} + \beta_{transfer} . N_{transfer} + \sum_{m=fixedpt,flexiblept} [\beta^{m}_{wait.} t^{m}_{wait.} + \beta^{m}_{in\,veh.} t^{m}_{in\,veh.} + \beta_{money} . p^{m} . d^{m}] \quad (1)$$

Where, p^m and d^m represent the fare of service *‘m’* per unit distance and total distance travelled by mode *‘m’* respectively.

Finally, the origin destination demand is assigned to the generated routes based on the computed utility values in the Assignment module. A stochastic assignment is employed where the probability of each choice alternative is calculated by the Logit model.

2.2 Modelling framework

The overall methodology is illustrated in Figure 3. The input to the model consists of the network represented by nodes and connecting links, mode specific origin destination demand data, and transport services. The transport services include modes of public transport, car, and walk. The public transport services comprise of both fixed (characterised by line and schedule based services) and flexible (characterised by a fleet of vehicles operating as demand responsive services offering door-to-door service based on real time requests) services. The daily dynamics of the system are modelled in the Multimodal Route Choice and Assignment and the Network Loading modules in Figure 3. The day-to-day dynamics entail the evaluation of the experienced services and re-planning of the travel plans by users.

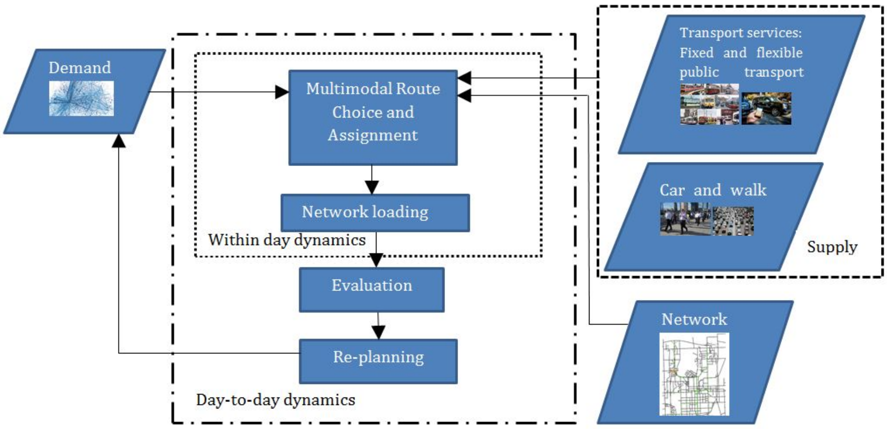

Fig. 3 Overall modelling framework

4 Implementation and Results

The proposed model is implemented in MATSim, a multi-agent based traffic simulation framework with day-to-day learning of users (Horni et al. 2015). The test network used for the application of the model is based on the city of Sioux Falls (Chakirov and Fourie 2014 and Horl 2016). The flexible PT system comprise of a fleet of vehicles controlled by a central dispatching unit that assigns travel requests to vehicles in real time. A vehicle that has been assigned a request by the dispatching unit, drives to the pick-up location, picks up the passenger, drives to the drop-off location, and drops the passenger. It then stays at the drop off location till further requests are assigned. The vehicle dispatching algorithm used in this paper has been adopted from Maciejewski 2015. The scenarios considered are shown in Table 1. The scenarios are based on the type of public transport services offered and whether the combination of fixed and flexible services in a single trip is possible. In the Base scenario, the modes available to the user are car, walk, fixed PT. In scenario Fixed or flexible PT a fleet of vehicles is introduced which serve as flexible

PT. Fixed and flexible services are mutually exclusive in this scenario. Finally, in scenario Fixed + flexible PT, in addition to the modes available in the previous scenario, users can combine fixed pt and flexible pt for travel from their origin to their destination.

Table 1 Scenario description

Scenario	**User Choice**				
	Car	**Walk**	**Fixed PT only**	**Flexible + flexible PT**	**Flexible PT only**
Base scenario	Y	Y	Y	N	N
Fixed or flexible PT	Y	Y	Y	N	Y
Fixed + flexible PT	Y	Y	Y	Y	Y

Results are reported for a sampled down population of 1% of the original population of the Sioux Falls network. Table 2 shows the modal share for each of the three scenarios when a fleet size of 1% of the sampled population is available for flexible PT operations in the second and third scenarios.

Table 2 Mode share for the three scenarios

Scenario	**User Choice**				
	Car (%)	**Walk (%)**	**Fixed PT only (%)**	**Flexible + flexible PT (%)**	**Flexible PT only (%)**
Base scenario	66	<=1	33	NA	NA
Fixed or flexible PT	62	<=1	23	NA	15
Fixed + flexible PT	61	1	9	15	14

Results show that the introduction of a fleet of vehicles as flexible pt in the second scenario caused a shift in mode share of approximately 4% from car and 10% from fixed PT towards the new mode. In the third scenario, when the same fleet size is used and flexible services can be used for part of the trip, it can be seen 15% of the trips involve a combination of fixed and flexible services. However, the mode share of fixed PT in the second scenario and the combined mode share of fixed PT and fixed + flexible PT in the third scenario remains almost unchanged. The share of fixed + flexible PT in the third scenario results thus of users shifting from fixed PT to fixed + flexible PT, rather than attracting additional demand from non-PT modes.

A further analysis was performed by varying the fleet size of flexible PT for the second and third scenarios as 1%, 2%, 3%, 4%, 5%, or 10% of the sampled population. The performance indicators examined are average waiting time of users using flexible PT, empty drive ratio of flexible PT (i.e. the ratio of the drive time spent for picking up passengers out of the total drive time), and stay ratio (i.e. the total fraction of time spent without being en-route to pick up or transporting a passenger). Figures 4-6 shows the variation of these indicators in relation to variation of the fleet size.

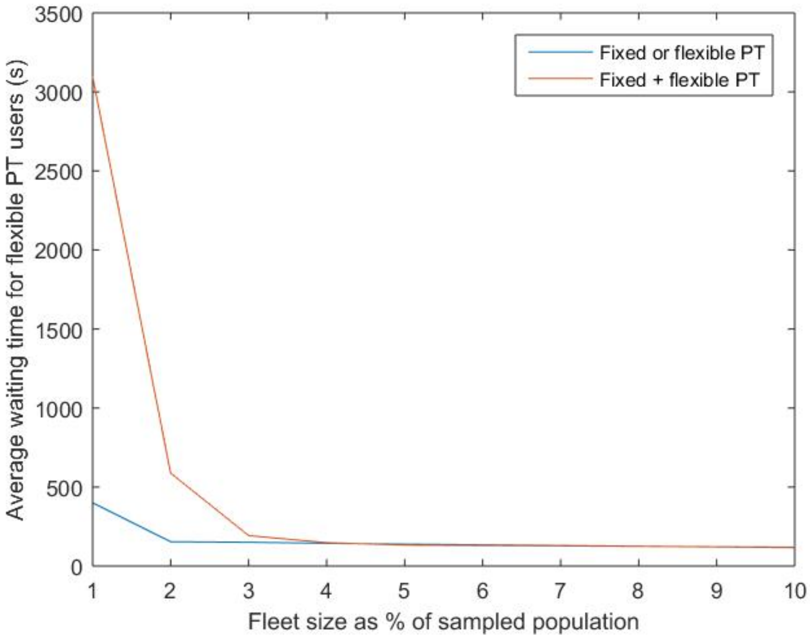

Fig. 4 Average waiting time of flexible PT users versus fleet size

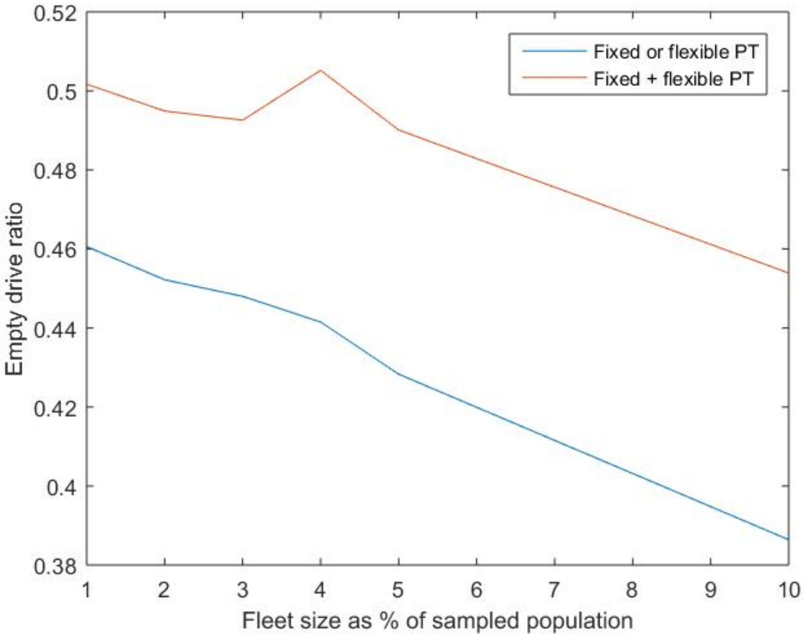

Fig. 5 Empty drive ratio versus fleet size

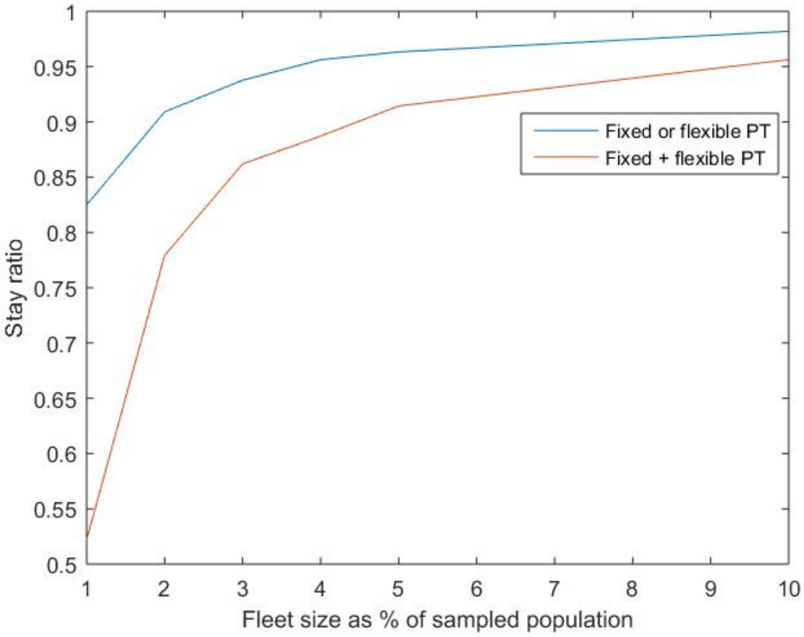

Fig. 6 Stay ratio versus fleet size

As can be seen from Figures 4-6, the average waiting time in the third scenario for a fleet size of 1% of the sampled population, is much larger than that in the second scenario. This can be explained by the additional usage of flexible PT in the third scenario due to the possibility to use it for part of the trip. Interestingly, the reduction in average waiting time is not so prominent when the fleet size surpasses 4% of the total demand. This indicates that the demand for flexible PT as a mode and as combination with fixed PT, is well served by 4% of fleet size in both scenarios. The empty drive ratio shows steady decline with increasing fleet size for both scenarios as can be seen from Figure 5. The spike from 3% to 4% in the third scenario can be explained by the fact that the fleet size is not sufficient to handle the corresponding increase in mode share. Results from Figure 6 indicates that for both scenarios the fleet size remains largely underutilized for larger fleet sizes.

4 Conclusion and scope of full paper

This study developed a multimodal route choice and assignment model for combined fixed and flexible public transport services. The model was applied to the test network of Sioux Falls. Results indicate that the mode share of fixed + flexible PT comes as a result of mode shift of users from fixed PT and that the effect of varying fleet size on waiting time is not so prominent beyond a certain value and that the fleet remains largely underutilized at higher fleet size. Further addition to the model includes implementing a path size factor for each choice alternative to take into account the overlap between choice sets, especially for variants of transfer locations between fixed and flexible services. In terms of implementation, the model will be applied to different demand distributions for the city of Sioux Falls and also for the city of Amsterdam, the Netherlands. The implementation results of these additions will be presented in the full paper. Future research includes developing a modelling framework which optimises the fixed and flexible pt services.

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