放射状都市におけるシェアードモビリティーと公共交通の運営戦略に関する研究

Shared and Mass Transit Operational Strategies for Profit and Social Welfare Maximization in Radial Cities

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1. Introduction

Shared modes have been showing an explosive growth worldwide. Amongst these, there are multiple ride pooling services that has attracted demand from various different modes. In most developed countries, considering the aging problems, and those who do not own a car, a service that stands in between taxi and bus would be ideal as an alternative mode of versatility. In developing countries, though not robust enough and are mostly constrained to locals who have abundant experience in the place, ride sharing has been much longer established.

In this thesis, operational strategies of ride share and transit will be compared, against various scenarios of commuter towns, including "competition", "cooperation", and "combination", where the city scale and population differs. The resulting optimal fare settings of shared mode and the station spacing as well as transit network design in terms of station location are the key aspect we aim to understand, focusing on interactions between the three parties including passengers, shared mode operator and transit service.

2. Literature Review

Chen et al. (2018) mentioned that in radial cities, a supportive mode burdens transit less, indicating the possibility of collaboration, while an addition of choice relates to competition between them. Similar to the other new modes introduced to the system, shared modes trigger or are affected by the mass effect. To be more precise, passengers are even more heavily affected by others in shared mode than any other conventional transits.

Existing literatures mostly discuss about the current status of shared mode and passengers' modal choices separately and neglect the interactions between them and the transit operators, the "dynamics" that connect them and trigger further changes. Other contributions discuss the addition of alternative modes and provide a general insight on the interactions between new modes and conventional ones, but do not consider the effects resulting from the attributes of sharing economy that has been a significant issue, or focus on either party's perspective in operations instead of social optimization.

The model in this thesis is aimed at specifying where and how shared mode should exist and how transit should be designed so that all three parties, government, shared mode operators and individual passengers' benefit, when considering an area where demand origins are widely distributed but focused on a single destination as is typical for the morning traffic in commuter towns.

3. Methodology

We propose a town network as below, where the figure on the right is one eighths of the one on the left, for detailed analysis since the town is considered to be symmetric.

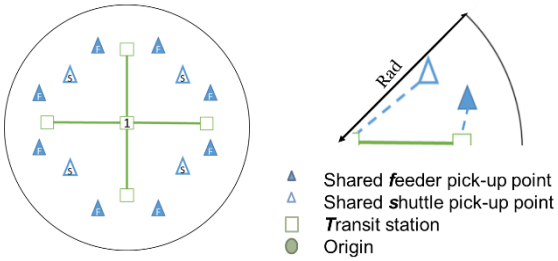

Figure 1. Network Settings

We consider feeder for "1st mile travel" to transit station and shuttle as a service for travels between transit blank area and the city center. Consequently the passengers have four choices, to travel from origin to the center s: walk to shuttle; f: walk to feeder to transit; t: walk to transit; w: walk only.

The analysis is done in three levels, to compared the domination of government policy and private party as well as passenger's reaction towards it. In the lower level, decision makers are passengers, each aiming to minimize his/her cost (DUE). In the middle level, alternative shared mode operators can make decisions that maximizes feeder mode operators' revenue. In the upper level, urban planners designs the whole structure with the objective of minimizing total travelling cost (Transportation social welfare) with constraints (Regulations).

We consider that the demand is uniformly distributed around the area, thereby with such aggregation, we can determine the waiting time for the shared modes to fill up, in turns affecting the passengers' choices. Individual passengers are assumed to follow

a logit model distribution in modal choices based on the expected travel cost of each choice they are given.

We compare four scenarios of the three levels, traditional, competition, collaboration and combination, correspondingly having none, shuttle only, feeder only, and both of the shared modes added into the original system. The scenarios helps to provide insights and indices in shared mode planning in commuter towns. The city parameters are taken from Goyang City nearby Seoul, which is a major commuter town around Seoul, and is varied to observe the sensitivity regarding city characteristics.

4. Results

In this summary the combined scenario is focus mainly for the base town case, and comparison of different scenarios are done when we confirm the relationship between the city characteristics and the optimal scenario.

Apart from N = 1, f and s demand are rather stable as N changes, where their sum remains close to the same in each level. In this scenario, the upper level has the most t and the least w. These indicates that the shared modes are competing each other, and the major shift is from the walking demand but not the transit compared to the traditional scenario, while what matter is if the mode is shared or not but not how many people are sharing the ride. Regarding total social cost, having a shared mode in any level is much better than traditional scenario, matching with the results in modals split. Lower level has the least and middle level the most social cost, while upper level is slightly lower than middle level. Thus, egulations in need, though the lost happens in travel time and private operators' revenue, and government is powerless if shared mode fare is not regulated particularly in fare.

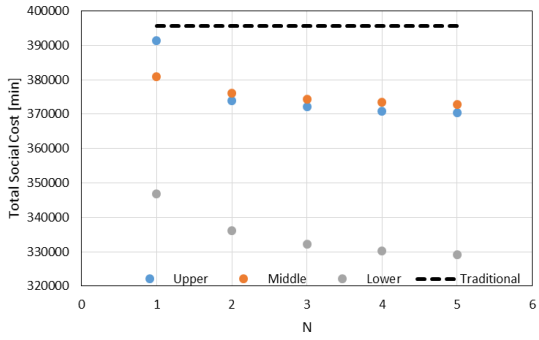

Figure 2. Total Social Cost in Base Town Combined Scenario

The revenue of shared mode operators is accordingly the lowest in the lower level, while being the highest in upper level. The double layered optimization has provided this win-win scenario though it is not the best for the passengers due to the high fare in the shared mode.

When city characteristics are varied, there are different scenario that are preferable. When the size of the city is small, both competition and combination can not provide an effective shared mode whereas collaboration does. Moreover, when the town is also small in demand, no passenger would choose to take the shared mode, hence, a well-designed transit is sufficient.

5. Conclusions and Discussions

The thesis focused on how urban planners should plan the system when shared mode is introduced in the town, if they shall greet them, compete with them or balance between the two attitudes, taking possible mass effects of passengers and operators' adjustments into account.

In general, government is very passive in the relationship, unless they have a strong control over the shared mode fare, to provide transportation as a welfare if they do not have control over shared mode fare, since operators prefer to increase the fare and have less customers to maximize their profit. Either strict regulations or abundant subsidy can help to solve the problem, while the former is more realistic, regarding the budget spent on transportation.

There are optimal scenarios in different kinds of town, a small town with little demand and tiny by area is sufficient with a good transit, a dense town small in size yet holds abundant demand has the lowest total social cost in collaboration scenario, and the other cases usually is good to have the combination as the figure below.

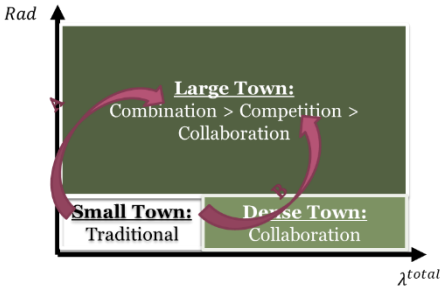

Figure 3. Optimal Scenarios and Developments

Meanwhile, if development of these commuter town is discussed, from a small town where most of them start from, depending on the form of development, they can either follow A or B in pattern. If the town is planned by government, provided with residential facilities first to attract demand, it would follow A, thus it is better to construct a shared mode with transit together at the planning stage, while when the case is that residents concentrated in certain area first and government start to provide better service for them, building up the feeder shared mode is the first priority as B is like.

Key References

1) Chen, P. W., & Nie, Y. M. (2018). Optimal design of demand adaptive paired-line hybrid transit: Case of radial route structure. Transportation Research Part E: Logistics and Transportation Review, 110, 71-89.

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