主 論 文 の 要 約

論文題目　**Exploring Subscribing Behavior and Spatiotemporal Evolution in Demand of Customized Bus Service**
（カスタマイズドバスサービスのサブスクリプション行動と需要の時空間進化に関する研究）

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論 文 内 容 の 要 約

With the rapid development of information and communication technologies in the past decade, various types of demand-responsive mobility services such as dial-a-ride and flexible transportation services have been entering the life of the public all over the world and contributing to improving the satisfaction of mobility. The customized bus (CB), as one of its main developments, has been rapidly spread in major cities across China in recent years, holding the promise of establishing more attractive and diverse public transportation (PT) services and thereby reducing urban traffic congestion especially during peak hours. The CB services are designed to cater for a group of specific travelers with analogous travel requirements in space and time, aiming at providing high-quality transit services (albeit at a higher cost) for a relatively small number of passengers with specific travel demand. However, a drastic decline in the number of CB service users in some cities of China thereafter and the huge waste of resources resulting from the cancelation of launching routes and subscriptions drive us to attach more importance to the demand of CB system.

The first chapter introduces the background of my studies and proposes the research problems that are urgent and important in the development of CB systems. The objectives of this study are to 1) explore the role of CB services in the transportation system, 2) ascertain the mechanism of determinants on passenger loyalty and the effects of the built environment on the subscribing behavior, and 3) investigate the spatiotemporal evolution patterns of CB demand.

Regarding these three key questions, Chapter 2 provides a detailed review of the existing studies from four viewpoints: 1) transit performance evaluation, 2) passenger loyalty, 3) built environment effects on the subscribing behavior, and 4) travel demand modeling. Although CB systems have been developed for several years, there is still no consensus on the role of CB services in modern transportation systems. Additionally, the ridership retention in CB systems is still a challenge for almost all operators, and previous studies barely investigated the built environment effects on the travel behavior in on-demand transit systems. More attention has been paid to temporal adjustments using time-series and dynamic panel data models but the spatial dependence effects that arise in the demand for transit services, particularly in the travel-sharing systems such as CB systems, have barely been addressed. However, the existing literature provides us an important foundation on the factor selection and methodology adoption for the studies in this dissertation.

Chapter 3 introduces the study area, Dalian, China. The Dalian CB system has been operating for 6 years and is known as one of the successful CB systems in China, over 200 bus routes serving more than 4,000 passengers per day. Actual subscription records (for 28 months) of the Dalian CB system have been collected and employed to investigate the three key issues of this dissertation.

The first problem addressed in the dissertation, i.e., in Chapter 4, is the assessment on the practical performance of CB services based on an empirical study on a successful CB system. To investigate the actual performance of the CB services, a series of metrics including route and service characteristics, reliability, and travel costs were chosen and calculated based on the route generation/planning module of online maps and the subscription records. The directions on the utility function of these metrics were determined using a multinomial logit model excluding alternative-specific constant. The results illustrate that the CB service is an eclectic choice that can balance service quality and costs between traveling by PT and private cars/taxis. Comparison of performance metrics for all available transportation modes shows that the CB service significantly improves the service quality (in terms of the travel time, travel speed, number of stations, and differential arrival time) compared to traditional PT services, even though with an increased travel expense. In particular, the costs increased by shifting from PT to CB is significantly lesser than that of shifting from CB to private cars and taxis. The temporal coverage reveals that the period of peak travel with the CB services falls exactly in the rush period of the road network in Dalian. The CB service mainly acts to complement traditional PT services in areas with poor coverage levels of PT services, while it serves as the main bus transit service in several areas without PT service within 500 m.

The second issue in this dissertation focuses on CB subscribing behavior, including Chapter 5 and 6. In Chapter 5, a shared frailty survival model was employed to model the subscribing behavior and ascertain the mechanism of determinants on passenger loyalty. The results indicate that male passengers are more sensitive (negatively) than female passengers to the number of intermediate CB stations due to the potentially increased uncertainty in the waiting time. Even though the long-term subscription has a significant advantage on price, it also increases the cost of not complying with the contract. A more flexible service subscription strategy will be beneficial for strengthening user loyalty, such as weekly subscription and a subscription on several specific days of a week. The travel time saved in a CB trip (in contrast to a PT trip) is tested as the most important factor that contributes to passenger loyalty. Therefore, route optimization should pay more attention to travel time minimization. On the other hand, the PT users who have longer detours and more interchanges in PT trips are the potential loyal passengers of CB services. The results of our models will provide references for designing new CB routes and optimizing old routes by minimizing the subscription termination hazards of users. As the survival model developed and calibrated in this study was demonstrated to be well fitted, it indicates that the fundamental framework also provides an empirical foundation for other types of demand-responsive transportation (DRT) systems to investigate and model the passenger loyalty. It will help service operators identify and quantify the risk factors caused by the flexible nature of DRT systems, and on the other hand, it is beneficial for understanding the seemingly irrational behaviors from the aspect of the utility maximization theory. For users who use DRT as a way of commuting, travel time should be assigned as a greater priority in route design relative to travel costs to increase the ridership by enhancing their loyalty levels. Moreover, more flexible subscription strategies will increase passenger loyalty.

Additionally, in Chapter 6, the effects of the built environment on subscribing behavior are examined using a random-effect negative binomial regression, based on multi-sources geographic data and operational data. The high subscribing frequency is associated with a higher population but lower employments density. Subscribers who live in areas with less balanced and less compact land-use are more likely to subscribe to the CB service frequently. In particular, areas with more residential land-use concentrated and less administrative facilities distributed are potential marketing direction for frequent subscribers. As the poor connectivity to the road network and fewer parking lots are not conducive to the development of PT service and are not friendly to private car owners, the CB services in these areas have a higher level of substitutability in terms of the mode of commuting. The CB plays the role of complementing the PT service, therefore the distance to transit is found to have positive impacts on the subscribing frequency. Additionally, the subscribers who reside in residential areas with complete supporting facilities but far from city centers are more likely to subscribe to the CB service frequently. The findings derived from this study give important empirical references to identify high-frequency users of CB services and are even valid for other DRT systems. The users who reside in urban areas that have a high population level, low employment density, poor connection to the road network, less parking lots distributed, and are far from PT stations and city centers, are potential high-frequency passengers. Therefore, the corresponding areas with enough high-frequency passengers identified are suggested to be targeted with intensive strategies to improve service efficiency, for instance, dispatching vehicles in advance of peak periods to reduce service response time.

Chapter 7 investigates the spatiotemporal evolution patterns of CB demand. A spatial dynamic panel model is employed to simultaneously accommodate dynamic adjustments, spatial dependence and spillover effects, and unit-specific heterogeneity. Endogeneity caused by blending spatial dependence effects has been solved by extending the moment restrictions of the estimator of the generalized method of moments to a spatial autoregressive dynamic panel. The results suggest a stronger time dependence than that of the spatial. The increments (or decrement) in demand rather than the amount of demand itself in neighborhoods contribute to the significant spatial dependence effects in CB demand. In particular, an increment in the demand of neighborhoods in the current month relative to the previous month will generate approximately 43% of that value in demand of a given unit for the current month. This finding provides important orientation for potential marketing based on the expectation that matching demand will be generated in an area when the demand in its neighborhoods increases. As with other modes of transportation, a lower price is more attractive. A ¥0.1 decrease in the unit price will increase the CB demand by approximately 0.3 units. Consistent with the previous studies, the CB services are found more attractive for passengers with distant trips. Longer CB routes will pass through more spatial areas and therefore have more opportunity to actively absorb potential demand. Thus, increasing the focus on long-distance trips is one possible strategy for increasing the ridership of CBs. Additionally, spatial units where the passengers depart from have a lower boarding order position and a higher alighting order position are significantly associated with a larger amount of CB demand.

Lastly, Chapter 8 summarizes the key conclusions achieved from the studies mentioned above and provides recommendations to the general DRT systems as well as the limitations and possible future topics. First, the successful CB services should provide a high-quality, convenient, and easy-to-use transit service and are able to 1) complement the regular PT services (share the pressure of original PT demand), 2) attract more private car drivers (increase the modal share of the public transit services), and 3) provide enough mobility services for travelers who reside in areas with poor levels of regular PT services. Local authorities are suggested to subsidize the CB users living in areas where public transport is underdeveloped and having long-distance commuting trips as these users have been found to subscribe to CB service more frequently. Secondly, the operators of DRT routes which mainly serve commuters are suggested to put more effort to reduce the travel time of passengers in route design so as to increase the ridership by enhancing their loyalty. On the other hand, the PT users who live in areas with poorer quality of PT services (longer detours and more interchanges, indicated by larger differences in travel time between CB and PT) are the potential loyal passengers of the DRT systems. Additionally, the users who reside in urban areas that have a high population level, low employment density, poor connection to the road network, fewer parking lots distributed, and are far from PT stations and city centers are potential high-frequency subscribers. Therefore, the corresponding areas with enough high-frequency passengers identified are suggested to be targeted with intensive strategies to improve service efficiency, for instance, dispatching vehicles in advance of peak periods to reduce service response time. Finally, I suggest the DRT service operators to 1) consider the spatial dependence effects in demand modeling and forecasting, 2) design a limited number of fixed stations nearby the areas with significant demand risen to increase the ridership, and 3) strengthen focus and strategy on long-distance commuting trips.