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Editorial

On the urban-rural bus transit system with passenger-freight mixed flow

1. Introduction

Providing low-cost, accessible transportation systems connecting rural to urban areas is essential for creating a richer rural-urban partnership. Low density rural populations, coupled with low trip frequency and larger geography makes bus-based travel the only reasonable transit option for rural residents to access critical services (e.g., hospitals, schools, markets, and parks), many of which are largely situated in urban areas.

The urban-rural bus transit link has two salient features that make it unique from the typical urban bus transit system. First, almost all passengers traveling from rural areas to the urban area share one common destination (usually the urban area's central bus station) and on the return trip, almost all rural passengers travel from one common origin (usually the urban area's central bus station). Rural bus riders rarely travel between two rural bus stops and transfer between rural bus routes is almost non-existent. The second notable feature is that passenger flow is highly imbalanced: morning peaks consist largely of rural to urban travel and in the afternoon peak, the predominant travel is urban to rural. Partially as a result of the imbalanced passenger demand, rural buses often serve as last mile small package delivery (Cochrane et al., 2017; Elgart et al., 2019). Currently, this service is mostly on an ad-hoc basis, for example, on a passenger transport trip where the need for small cargo transport can utilize unused bus capacity, which mainly results from an imbalanced passenger flow.

In this discussion, we explore how these two features can facilitate the planning and operation of urban-rural bus transit systems. Tighter linking between the rural passenger-cargo delivery needs and urban centers can help to reduce travel and expedite package delivery.

2. Common origin/destination of passengers

Nearly all passengers traveling on urban-rural bus routes share one common destination or origin; this is usually the urban area's central bus station. This facilitates transit network planning. Consider a bus whose route includes stops $1, 2, \ldots, N$ sequentially, where N represents the urban area's central bus station, and the number of passengers who travel from stop $i = 1, \ldots, N-1$ to stop $j = i+1, \ldots, N$ is d_{ij}. Then, we have $d_{ij} = 0$ for all $j = i+1, \ldots, N-1$ with the highest bus passenger load on the leg from stop $N-1$ to stop N. The number of passengers onboard on this leg is $\sum_{i=1}^{N-1} d_{iN}$, which is the bus capacity required. In contrast, for an urban bus route, the required capacity will be the maximum number of passengers on legs $k = 1, \ldots N-1$ (leg k is from stop k to stop $k+1$), that is, $\max_{k=1,\ldots,N-1}\left\{\sum_{i=1}^{k}\sum_{j=k+1}^{N} d_{ij}\right\}$. Thus, there is a reasonably easy estimation of the unused passenger capacity on rural to urban routes.

3. Imbalanced passenger flow and mixed passenger-freight flow

If we assume that a bus traveling from an urban area's central bus station and stopping along a rural route will deliver few goods between rural stops, then it is relatively straightforward to estimate the amount of cargo that can be added[1]: min{amount of available cargo[2], bus capacity – number of passengers onboard}. Even if there are passengers that debark along the rural route, this capacity is not available until after the bus leaves the urban central station.

Conversely, for a rural bus traveling to the urban area's central bus station, the cargo to be delivered from the rural stops, $i = 1, \ldots, N-2N-1$, to the central bus station depends not only on (i) the bus capacity that is already used (i.e., the total number of passengers who board the bus at stops $1, \ldots, i$ and the total amount of cargo loaded onto the bus at stops $1, \ldots, i-1$, (ii) the amount of available cargo at stop i, but also (iii) the amounts of available cargo at stops $i+1, \ldots, N-1$, (iv) the numbers of passengers who would like to board at stops $i+1, \ldots, N-1$, and (v) the ratio of the benefit of transporting one unit of cargo and the cost of rejecting a passenger. Information (i) and (ii) is known to the bus driver/bus system manager. Information (iii) is generally also known, because the total trip duration of a bus route is usually less than 2 h; requiring cargo to be ready for delivery at least 2 h in advance is not a restriction for practical purposes.

The numbers of passengers (iv) who would like to board at subsequent stops, is uncertain. Historical data, machine learning models, and local knowledge can be of great help in predicting this information. In particular, we stress the value of local knowledge in this urban-rural context: drivers and passengers generally know how many or few passengers take the bus at a particular time on a particular day. For instance, there may be days of high agricultural activity, days in which festival-related travel is high, or school start days (as students living in rural areas return to schools in urban areas).

Factors such as these and others interact to affect cargo capacity. For instance, it is possible that rain will significantly affect the number of people traveling to the urban area for shopping but will not affect the

[1] This is similar to the case of passenger aircraft carrying air cargo when capacity is available.

[2] The unit of the amount of cargo is “passenger seat”.

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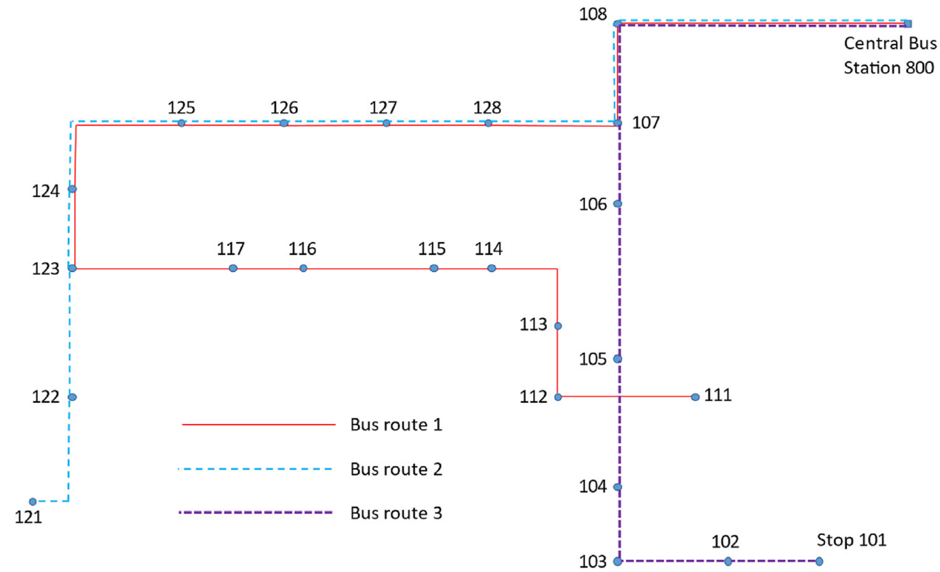

Fig. 1. An illustrative urban-rural bus transit network.

number of people returning to urban schools. In addition to historical data, real-time information may also be very valuable. This might include real-time camera data, turnstile data, and GPS data. These data can be processed in real-time using machine learning models. The other type of real-time information that could potentially be useful passenger boarding numbers at previous bus stops.

Finally, the ratio, (v), of the benefit of transporting one unit of cargo and the cost of rejecting a passenger must be calculated. A passenger who cannot board because the bus is full has three options: waiting for the next bus, taking a taxi, and not traveling at all. The choice and the resulting cost will largely depend on the bus frequency. The frequencies on urban-rural bus routes are usually very low, often ranging between 30 min and 2 h, which means the cost of not boarding is very high.

There is spatial variation that can reduce the potential of losing a passenger. For routes near urban areas, there will usually be some overlap between routes. In other words, passengers who live in close proximity to the urban area may have more than one bus route available. Thus, the cost of not boarding this passenger is less costly than that of rejecting a passenger with only one route available. As shown in Fig. 1, bus stops 111–117 are only served by route 1, bus stops 123–128 are served by route 1 and route 2, and bus stops 107 and 108 are served by routes 1, 2, and 3. Therefore, the bus on route 1 can be much more aggressive when accepting cargo at stop 117 than at stop 116, because refusing a passenger at stops 123–128 is much less costly than refusing a passenger at stop 117. Similarly, the buses on route 1 and route 2 can be much more aggressive when accepting cargo at stop 128 than at stop 127, because refusing a passenger at stops 107 or 108 is much less costly than refusing a passenger at stop 128.

4. Concluding remarks

We have outlined a fairly straightforward framework to begin understanding the trade-offs between pure passenger rural to urban route service and mixed cargo-passenger rural-urban route service. It is important to note that passengers on urban-rural bus routes are generally captive in the sense that they tend to be lower income, non-vehicle households (Yang, 2013). Because they are captive riders, the effects of increased travel time (transporting cargo will increase transit time and potentially affect schedule reliability) and changes in the in-vehicle travel environment (passengers travel with cargo) also bring up equity issues. While passengers will have a higher priority than cargo when bus capacity is limited, unless improvements are made, the ride quality will diminish.

To integrate into the existing multimodal systems, we project that there will be two challenges. The first one is the rural cargo delivery market that traditionally belongs to logistics service providers will be shared by public transit operators. Logistics service providers may strongly oppose the proposal of passenger-freight mixed flow. The second one is the transportation of rural cargo still needs the service from logistics service providers sometimes, e.g., on days when the bus capacity is fully occupied by passengers. The coordination of public transit operations and logistics services can be a barrier. If there are many logistics service providers for the rural cargo market, then both challenges are easy to overcome; however, if it is a monopoly or oligopoly market, then considerable efforts from the government and industry are required to deal with the two challenges.

We notice that, in many countries, freight already travels on buses. Consider, for example, Greyhound in the U.S., which offers courier and express package delivery, or Matkalhuoto in Finland, which generates revenue for rural package delivery on existing transit trips. These routes will sometimes overlap with rural local bus routes and this will need to be factored into the operations and planning of a mixed passenger-cargo rural bus system.

Declarations of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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