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# Efficacy of bus service reorganization utilizing a hub-and-spoke topology and DRT to meet community needs: A case study of Tokigawa town

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ABSTRACT

The purpose of this study is to verify the efficacy of a route/timetable reorganization methodology focused on a hub-and-spoke schedule bus architecture as well as the introduction of demand responsive transport (DRT) in suburban or underpopulated areas in Japan to accommodate local requirements.
We selected Tokigawa town for our reorganization trial and there were many local characteristics that needed to be addressed, including town residents' demands for origins and destinations that were linearly arranged within the town but also scattered outside of the town, geographically far flung, and in this scenario, route reorganization utilizing a hub-and-spoke architecture proved effective. Particularly, by changing the timetable whereby long routes running longitudinally and across the town connected with spoke-style short routes, service frequency was increased considerably without significantly increasing expenses.
Also, by implementing a system to alternatively operate regular route buses and DRT with a fixed schedule and area for routes in the mountain area, bus availability for residents living in low traffic areas was successfully increased due to increased efficiencies.


## 1. Introduction

The survival of privately run bus services is fraught with difficulties in regions where transport demand is sparse, such as in suburban and rural areas. In these regions, bus routes are generally longer, and thus, bus times are infrequent.

In Japan, scheduled bus services are generally run by private companies that carry out all the planning, management, and operation of the buses. Only exceptionally is the injection of public money into their operation considered. Adding to the paucity of demand for buses in suburban and rural areas, it has become easy to withdraw services from loss-making routes following the deregulation of the 2000s. As a result, more local towns have resorted to operating public bus services to make up for the shortfall. However, since these routes were unprofitable in the first place, this has put pressure on public finances and has led to less frequent operation. Also, since the year 2000, there has been an active merging of municipalities in Japan, and the concerted attempt to develop adequate bus services throughout these newly formed regions has unfortunately created many bus routes that are both long and infrequent.

This study examines the concept of bus route topologies in these kinds of regions in a practical way.

TRB in the United States systematically studied how to set up bus routes in the 1970s [1]. According to the review by Nakamura [2], the bus routes shown there can be classified into four forms (Table 1). Among these, the timed-transfer type is particularly noteworthy as being appropriate for rural areas and suburban outskirts where demand is low. The timed-transfer type is different to the outgoing radial type, in which all routes lead straight to the CBD, in that it utilizes transport centers in the suburbs to facilitate transfer from a suburban route to a radial route (Fig. 1). By this means, the need to make routes longer can be avoided, and it is more feasible to guarantee a constant operational frequency even in regions with low demand. The results obtained in several cities using such a system, for example Edmonton, indicated an increase in the number of users.

To minimize transfer times, buses on each route need to arrive at the transport centers at approximately the same time, and this entails close adherence to an operational plan.

Analogous to the timed-transfer type, a hub and spoke concept has been employed for airline routes. This concept is a route form, assuming transfer at the transport centers, with the major radial routes connecting the CBD and the transport centers in the suburbs, and each

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**Table 1**
The four bus route topologies according to their special characteristics [2].

| Bus route form | Characteristics |
|---|---|
| Outgoing radial type | ·Typical route network<br>·Appropriate for radial-circular type and irregular type road networks<br>·Requires carefully arranged timetables for shared routes |
| Grid type | ·Appropriate for a grid-type road network<br>·Set up for a route network progressing to an L- or U-shaped type<br>·Easily understood route network, but care is required in the design of transfer facilities |
| Arterial feeder type | ·Utilized depending on topographical constraints and development status<br>·The arterial portion is for orbital or express bus services |
| Timed-transfer type | ·Operational pattern so buses arrive together at specific transfer points to facilitate transfers<br>·Careful planning necessary to align operating intervals |

of the routes connecting the low-demand regions with the transport centers as spoke routes.

As examples incorporating the hub and spoke principle, we can cite the Singapore case [3], and studies like the one concerning mainline buses in Taiwan [4]. Some approaches have also included an aim to make these hub facilities not merely transfer facilities but also attractive spaces with a commercial function [5].

The InterConnect initiative in Lincolnshire in the UK, for example, is well known as an approach being used in rural areas with low transport demands [6].

Similar concepts to these can be found which use such terms as "Integrated Line-Haul and Collection Distribution [7]," and "Trunk-feeder services [8]."

Thus, such cases are referred to by many names, but while case studies dealing with the optimization problem of airline hub and spoke routes can be found [9,10], there have been very few case studies concerning bus transport as examples of research into systems with transfer centers in the outskirts to avoid increasing route lengths. However, there are many studies for bus transport in general [11–17]. Further, practical research based on a bus route's actual introduction is almost unknown.

In this study, as a technique to circumvent the problem of increasing bus route length and lower operation frequency in regions of low density, we focus on the timed-transfer type and hub and spoke system (hereafter both of these methods will be referred to as the hub and spoke method) to understand its effectiveness in a practical way. We chose the municipality of Tokigawa for the purposes of our study, which is located in the outlying suburbs in Saitama prefecture in Japan. Tokigawa has expanded following various mergers, and the associated problems of longer and less frequent municipal bus routes have emerged. The objective of this study is to review the Tokigawa bus routes as a whole and then modify them to the hub and spoke type to demonstrate the effectiveness of this method.

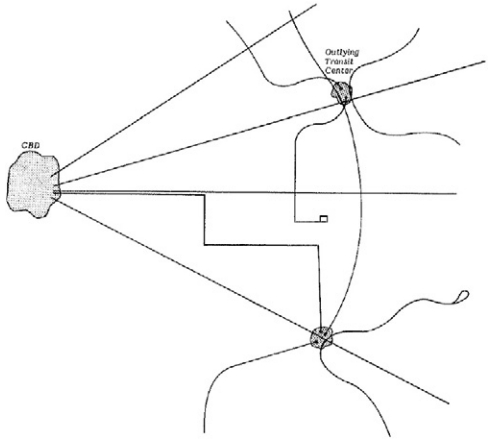


**Fig. 1.** Conceptual diagram of a timed-transfer type bus network [1].

## 2. Case study of Tokigawa

### 2.1. Outline of Tokigawa

The town of Tokigawa was formed by the merger of Tokigawa and Tamagawa villages in February 2006. As of June 2012, the town's population is approximately 12,600; the population peaked in 1995 and has since been declining. The town's population has been rapidly aging, with those aged 65 years and above accounting for 25% of the population, a rate slightly higher than Japan's national average of 23.1%. Tokigawa is located approximately 50 km northeast of central Tokyo. With an area of 55.77 $km^2$, it stretches approximately 13 km east–west and approximately 9 km north–south. A mountainous area in the west and a rural area in the east characterize the town. Much of the town (68%) is comprised of forests.

Even though the town has a Japan Railway (JR) station, the Myokaku Station, public transportation is somewhat inconvenient, as there are only two trains per hour even during the rush hours (the frequency is two trains per 3 h during the day). Furthermore, there is no significant commercial area around Myokaku Station. The town adjacent to Tokigawa has three railway stations, which the townspeople use frequently (Ogawamachi, Ogose, and Musashiranzan Stations). They most commonly use Tobu Railway's Ogose Station or Musashiranzan Station, both of which have frequent service. They also provide service going toward the Tokyo central area, suitable for those commuting to work or school. Moreover, the town has no major medical facility, and therefore, many townspeople use the general hospital located near Ogawamachi Station. Even for grocery shopping and their children's education, the townspeople frequently must go to places around these three stations outside the town. In other words, the movements or destinations of the townspeople are multi-directional, centered on the three stations located outside the town.

Before the merger, bus transportation in the two villages of Tokigawa comprised town-run municipal bus service in lieu of the abolished privately run bus routes. These routes were changed after the merger, however, the changes did not sufficiently consider the entire post-merger town area and left many issues unresolved (the specific issues will be explained in Section 4.2). Furthermore, a private bus operator provided additional bus services. Therefore, both the town-run municipal buses and the privately operated buses ran within the same district. This resulted in having two signs at each bus stop (Fig. 2), two different fare systems, and two separate, non-unified time schedules. This confusing scenario was a pressing issue needing to be resolved.

### 2.2. Planning assessment process

The reorganization assessment history is listed in Table 2. First, the Regional Public Transportation Panel (hereafter "Panel"), a voluntary organization, met four times as a preparatory step. The Panel conducted a resident questionnaire survey (hereafter "survey on public transportation") that included every household in the town. After ascertaining the movement characteristics of the residents and their demands for the transportation system, the Panel proposed the direction of the plan and carried it out. Thereafter, the Regional Public Transportation Revitalization Council (hereafter "Council"), a legally incorporated committee, was established. The Council drew up a new public transportation plan (hereafter "PT Plan") after conducting public comment hearings and residential briefing sessions.