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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 ·Appropriate for radial-circular type and irregular type road networks ·Requires carefully arranged timetables for shared routes
Grid type	·Appropriate for a grid-type road network ·Set up for a route network progressing to an L- or U-shaped type ·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 ·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 ·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.

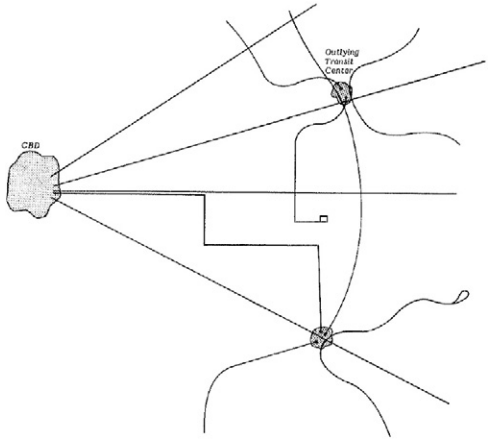

Fig. 1. Conceptual diagram of a timed-transfer type bus network [1].

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.

Fig. 2. Photo of two bus stop signs at the same location (pre-reorganization).

Subsequently, procedures necessary for the operation of a transportation business, such as integrating bus operations and establishing new routes, were completed. Finally, Tokigawa unified the bus system based on the PT Plan commenced in October 2010. The survey research conducted prior to the commencement of the new transportation system will be discussed in Section 3. The period before the commencement of the Tokigawa unified bus system will be referred to as pre-reorganization and that after the commencement as post-reorganization.

2.3. Understanding the actual situation and issues to be resolved

2.3.1. Research for understanding the actual situation

The content of the survey conducted by the Panel for examining the approach of the new transportation system is presented in Table 3. In addition, the town of Tokigawa organized the basic requirements, such as providing projections on the town's future population based on the Tokigawa statistical data.

2.3.2. Operation expenditure and fiscal burden

First, the operation expenditure of Tokigawa town municipal buses for a period of one year, from October 2008 before the reorganization to September 2009, was analyzed. Although the operation expenditure was approximately ¥55 million per year, the operation revenue (fare revenue) was approximately ¥17 million per year, which is approximately 30% of the expenditure. The difference (approximately ¥38 million) becomes the deficit coverage for the year, which the town pays to the bus operators commissioned to run the buses. The operation expenditure for a single passenger is ¥520, with operation revenue being ¥162. This yields a deficit of about ¥360 for each passenger transported. The Panel judged that although the current scale of deficit could continue to be covered, a fiscal burden that greatly surpasses the current state could not be accepted for the new transportation system.

Table 2
Reorganization assessment history.

Date/meeting	Content and subject of discussion
July 9, 2008 1st Regional Public Transportation Panel	Selection of officials and discussion on the current state of transportation policies
October 29, 2008 2nd Regional Public Transportation Panel	Hearing with welfare transportation operators and examination of the survey research execution
November 2008 Conducting survey research concerning public transportation	
March 26, 2009 3rd Regional Public Transportation Panel	Reporting of resident survey analysis, discussion of the direction of the transportation system
September 16, 2009 4th Regional Public Transportation Panel	Examination of the direction and policies of the public transportation system
January 28, 2010 1st Regional Public Transportation Revitalization Council	Drawing of the new PT plan (draft)
February 2010 Residential Briefing Session	Conducting briefing sessions within different areas of the town to receive feedback on the Plan (draft)
February 2010 Public comment hearing	Receiving a significant amount of feedback on the Plan (draft) using the town's Public Comment System
March 1, 2010 2nd Regional Public Transportation Revitalization Council	Drawing of the PT Plan(Final) and Tokigawa unified bus system
October 4, 2010	Commencement of Tokigawa unified bus based on PT Plan

2.3.3. Evaluation of the bus services in the town (Tokigawa town municipal bus and additional scheduled bus)

The public transportation survey revealed that approximately 40% of the townspeople were dissatisfied with the pre-reorganization bus service (Fig. 3).

The reasons for dissatisfaction with bus services were the following: (1) few operating buses (578 respondents), (2) insufficient connection between buses at the railway station and the railway (295 respondents), (3) bus stops located at great distances (82 respondents), and (4) inadequate connections between buses (80 respondents).

Concerning (1), few operating buses, which was the most cited reason for dissatisfaction, the frequency of operation before the reorganization was about one bus every hour for busy lines and one bus every 3 h for the less busy lines. Since this bus route runs in a low-population-density area, this situation is perhaps unavoidable; however, it must be noted that this was the aspect with which the townspeople were most dissatisfied. Furthermore, the interviews with drivers and results of the bus boarding and alighting research revealed that the number of users for one line was only around 10, even during the morning and evening rush hours (excluding the usage of buses as school buses for elementary and middle schools). This result revealed that it is difficult to directly link an increase in bus operation frequency (the number of vehicles) with an increase in profits.

(2) Insufficient connections between buses at the railway stations and the railway, the second most cited reason, indicates that the town's connectivity with a total of four railway stations that can be reached by the buses is an important issue. In the public transportation survey, the usage of rail station bus stops when using the bus was investigated. The results showed that the four bus stops at the railway stations were the four most used stops (Fig. 4). Ogawamachi Station, which lies outside

Table 3
Research conducted by the Regional Public Transportation Panel.

Research period/topic	Objective	Scale
November 2008 Survey on public transportation	To ascertain the actual bus usage of the residents and their demands for public transportation	Subjects: 11,797 residents Retrieved copies: 4584 (38.9%)
March 2009 Interview with for-profit transportation service providers	To ascertain the actual usage of disadvantaged users and their demands for public transportation	Special transportation service providers: 4 organizations
July 2009 Interview with bus drivers	To obtain opinions on users in a daily life setting	Three drivers of Tokigawa town municipal buses
November 2009 Bus boarding survey	To ascertain the usage of town bus routes	Researching the number of people boarding and alighting at the Tokigawa town municipal bus stops (in a day)

the town, was within the top four (159 respondents), but if the Nisseki Hospital (44 respondents) in the Ogawamachi peripheral area is also included, this would surpass the Myokaku Station stop (189 respondents), which lies within the town, and becomes one of the top three spots. Further, the survey showed that most commuters used the railway stations outside the town.

As for the third most cited reason (3), bus stops located at large distances apart, the opinions greatly differed depending on the residential district. In the western (mountainous) area, approximately 24% of the respondents said that the bus stops were located too far apart, approximately twice the response rate in the eastern (Satoyama) area. This may be because in the mountainous area, the population density is even lower than the average and the roads are narrow and thus not well suited for buses. Moreover, 38 people (approximately 1% of the total respondents) responded by saying that it takes them over 20 min by foot to reach the closest bus stop from their homes. Notably, more than half of the respondents are from the western area, in which the population-aging rate is high. Thus, the survey indicated the importance of resolving the problems of those areas that lack in public transportation.

Concerning reason (4), regarding the connectivity between buses, since a different operator was running the buses before the reorganization, inadequate connections with buses operated by another company were not considered in general. Such situations are commonplace in Japan, where operation efficiency is prioritized over the convenience of bus users. The research results highlighted the importance of securing connectivity between buses to improve user convenience with the new transportation system.

2.3.4. Clarifying issues that need to be resolved

Following the above current state analysis, the coordinated plan had a budget restriction that prohibited any significant increase in the number of buses in consideration of the town's financial condition. Thereafter, the following four objectives were set as the plan's missions (Fig. 5): 1) securing multi-directional mobility for the townspeople to destinations located outside the town, 2) securing operation frequency, 3) securing mobility for residents living in low residential density areas, and 4) implementing convenient bus systems (e.g., unified fee systems). Securing both operations in the various directions as well as operation frequency are considered easy to achieve without budget restrictions, as they simply require an increase in the number of bus vehicles. However, from the usage records heretofore, even if the initial cost of increasing the number of vehicles is covered by the government subsidy based on the coordinated plan, the drivers' labor cost and other expenditures will remain after the termination of the subsidy period (three years). Therefore, increasing the fiscal burden without giving careful consideration is not possible.

2.4. Basic policies of the new transportation system

After conducting the analysis of the current state, as described in the previous section, the Panel and its working committee created the basic policies and objectives of the new transportation system, as listed in Table 4. Naturally, these policies are bound by the budget restriction that prohibits a significant increase in the number of bus vehicles.

3. Bus planning that realizes the new transportation system

3.1. The menu of bus reorganization

After receiving the basic policies proposed by the Panel, the Council drew up PT plan. This plan includes a specific policy menu after conducting resident briefing sessions and public comment hearings. This specific menu is organized below in accordance with missions 1–4 mentioned in Section 2.3.4.

Mission 1: Secure mobility to multi-directional destinations outside the town for the townspeople

- Menu (1) Adapting bus routes to the hub and spoke topology
  All bus routes in the town were reviewed. Thereafter, Seseragi Bus Center (hereafter "Seseragi BC") was equipped as a connection base; enabling buses to run radially (spoke) from the three out-of-town railway stations to two areas within the town (Fig. 6). Even if the operation frequency is low (one bus/hour), in order to secure connections, buses arrive at Seseragi BC within the same timeframe as a

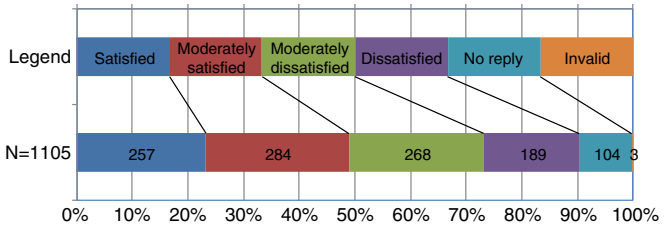

Fig. 3. Satisfaction levels for Tokigawa town municipal bus and additional scheduled bus services (pre-reorganization).

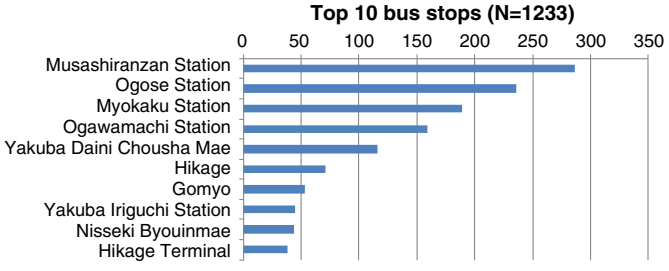

Fig. 4. Bus stop usage.

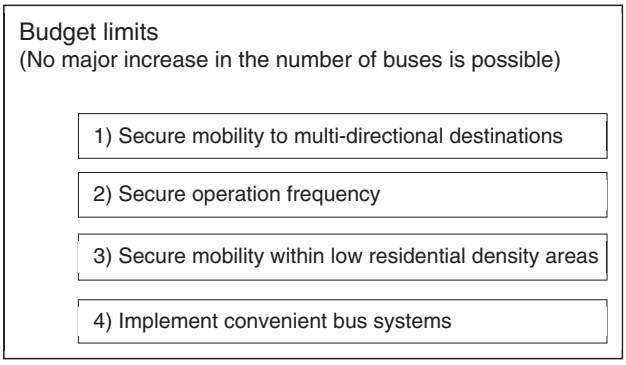

Fig. 5. Missions to be resolved with the coordinated plan.

general rule. Furthermore, all buses leave at the same time after making their connection.

Mission 2: Secure operation frequency

- Menu (2) Increasing the number of operating buses
  By integrating complex operating systems in order to decrease the length of routes, the number of operating buses was increased in most areas. For example, concerning travel from the western area to the three railway stations outside the town, an operation frequency of one bus per hour, as a rule, was secured. Therefore, the number of operating buses was secured at 9–14 per day.

Mission 3: Secure maximum mobility for residents living in low population density area

- Menu (3) Operating demand responsive transport (DRT)
  We established a DRT phone reservation system to operate in the sparsely populated western area. To provide this service, we created a new bus stop and used smaller DRT vehicles to access these narrow roads, on which regular buses could not travel. This reduced poorly supplied public transportation areas (defined as residential areas that are 500 m or more away from railway stations or bus stops) where bus transportation access was previously difficult for residents (Fig. 7).
- Menu (4) Introduction of free travel sections
  Implement a "Free Travel Section" in the western area, where passengers can alight in places other than bus stops for the Tokigawa unified bus in order to make it more convenient for users.

Mission 4: Create a convenient to use bus system

- Menu (5) Integration of bus routes:
  Integrate Tokigawa town municipal buses with additional scheduled buses to become a Tokigawa unified bus in which fares, getting on and off the bus, and bus stops are unified.
- Menu (6) Introduction of zone-based fares
  Fares were changed from a distance-based to a zone-based system. The town area was designated as Zone 2, while areas outside the town were designated as Zone 3. Traveling within the same zone costs ¥200, and ¥100 is added to the fare each time the passenger travels to a different zone. The maximum fare is ¥400. Connection fares were set so that connections at the Seseragi BC did not impose any additional charges as long as the passenger was not traveling to a different zone upon connection.
- Menu (7) Eliminate some existing bus stops and create new stops
  Bus stops were newly installed in districts with poor transportation (five locations). More bus stops were installed in places where the distance between bus stops was significant (nine locations). Furthermore, five bus stops were abolished in conjunction with the route reorganization.
- Menu (8) Change the ways users get on and off buses
  The systems were unified so that passengers board the buses by the rear door and leave using the front door, with the fare being paid afterward.
- Menu (9): Change Saturdays to a weekend/holiday timetable.
  To match the railway time schedules, Mondays to Fridays were changed to a weekday timetable, while Saturdays, Sundays, and national holidays were changed to a weekend/holiday timetable.
- Menu (10): Introduce a senior's bus ticket
  A senior's bus ticket (¥2000 for a monthly ticket and ¥20,000 for a yearly ticket), which can be used in all zones (all Tokigawa unified bus areas), was introduced for those aged 65 years and above.
- Menu (11): Improve school season tickets
  School season tickets (e.g., ¥4500 for a monthly ticket and

Table 4
Basic policies and objectives of the PT Plan.

Basic policy 1: Implementation of a transportation system that supports the elderly (and others for whom transportation is constrained)	For the elderly, the act of walking to the bus stop itself is difficult, and therefore some have abandoned using bus service. Moreover, it is presumed that the number of people who will have difficulty driving a car due to advancing age will increase. Therefore, transportation methods that address these situations should be established.
Basic policy 2: To minimize the number of buses and designate detailed routes	Buses that run only along the main roads will be minimized due to road circumstances, and routes along narrow roads will be designated. By doing so, buses will become accessible to areas that lack transportation.
Basic policy 3: Responding to the demands for multi-direction stops by adopting a hub and spoke transportation network topology	To respond to the demand for more directions and varieties, users should be gathered together in one location and then transported to different directions. Therefore, the geographically central bus stop should be given the function of a hub.
Basic policy 4: Unification of scheduled buses	By dissolving the overlapping operations of the town route and privately run buses, a bus route network that is convenient to users will be organized.
Basic policy 5: Introduction of a zone fare system and yearly all-access tickets	To resolve the current difficulties in understanding distance-based fare systems, the introduction of a yearly all-access ticket will lessen the burden on users. This aims to secure fare revenue by increasing users.
Basic policy 6: Ascertaining the demand trend and advocating the necessity of public transportation	By conducting surveys and research into the boarding and alighting passenger counts per bus, the status of users will be ascertained accurately, which will be used as data for future reviews. A briefing session should be conducted locally in order to directly obtain feedback from the community and users, as well as to raise awareness among residents and highlight the necessity of public transportation.
Basic policy 7: Enhancement of tourism transport	In addition to the research on everyday transport, studies should be conducted on the necessity for tourist transport, and when necessary, such a transportation system should be implemented that corresponds to the balance of supply and demand.

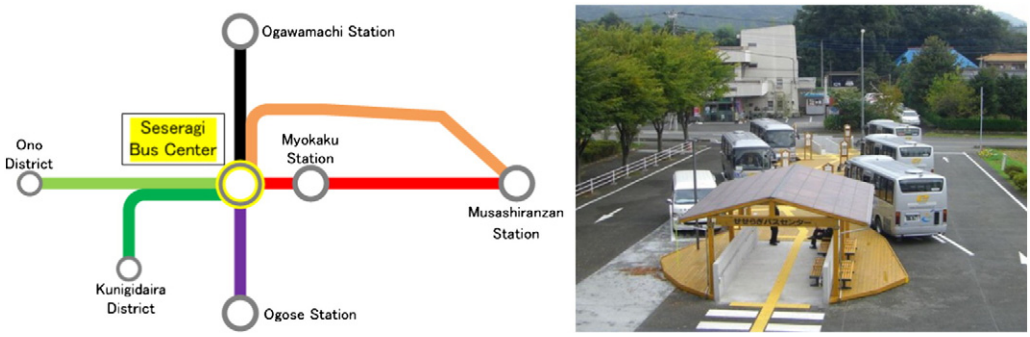

Fig. 6. Diagram of the hub and spoke system bus routes (left), and the Seseragi Bus Center that serves as a hub (right).

¥12,000 for a quarterly ticket) were introduced for school commuters, which can be used in all zones (all Tokigawa unified bus areas).

- Menu (12): Improve season tickets
  A season ticket with zone-based fares for commuters was introduced. With this ticket, holders can alight in a different zone if they pay the additional fare when getting off the bus.
- Menu (13): Introduce a bus support ticket
  Support tickets sold to townspeople were introduced. By purchasing these tickets, residents can help with the bus operation costs, even if they do not often ride the bus (i.e., purchasing the ticket is much like a donation). For ¥1000, one person can ride the bus for 4 days or four people can ride the bus for 1 day.
- Menu (14): Trial ticket
  Free trial tickets were distributed at events so that the residents could become familiar with the new transportation system.

3.2. Comparison between the pre- and post-implementation periods of the new transportation system

The comparison between pre- and post-implementation periods is presented below.

In the pre-reorganization period (Fig. 8), bus users from the western area had to change buses at the "Town Hall Annex" bus stop when they wanted to reach the bus stops of their destinations such as the railway stations outside the town. For example, residents of the Kunugidaira District would at times travel up to the "Town Hall Annex" bus stop by C-line, then head toward Ogawamachi Station after making a connection with A-line. However, changing buses was extremely inconvenient because connections between buses could take more than an hour or the passengers had to cross the road to go to the bus stop on the opposite side of the road.

Fig. 7. DRT vehicle.

Furthermore, although residents living along A-line, such as the western area including the Ono District, were able to go to Nisseki Hospital near Ogawamachi Station without changing buses, this route took a long detour around the entire town area, resulting in a traveling time of more than 70 min (for just over a 20-km distance). Thus, commuting time remained an issue. Residents living along B-line, C-line, and D-line (such as the Kunugidaira District), were unable to go to the Nisseki hospital without changing buses at the "Town Hall Annex" bus stop, which had poor connectivity.

Moreover, to get to Musashiranzan Station, which is convenient for western area residents wishing to travel toward central Tokyo, it was necessary to first take the town municipal bus and then change to an additional scheduled bus. Therefore, passengers had to pay the base fare once again after making the connection owing to the two different fare systems. This situation was seen, for instance, when residents of the Kunugidaira District traveled to the "Town Hall Annex" bus stop by C-line and then headed to Musashiranzan Station by changing to X-line. Furthermore, since roads in the western area are narrow and houses scattered, there were many areas without a bus stop within a convenient walking distance from one's home.

Please note, route names such as A-line and B-line used in this paper are not actual names but rather are used only for explanation purposes.

Under the new transportation system (Fig. 9), the routes of the two bus services, Tokigawa town municipal buses whose routes were within the town, and the additional scheduled buses whose routes connect to Musashiranzan Station, were integrated into the Tokigawa unified bus routes. This is an accomplishment made by the town of Tokigawa, represented by the Council members and the privately run bus operators' compromises in order to achieve the common goal of reconstructing a sustainable bus transportation system.

Furthermore, by newly installing the Seseragi BC, which functions as a hub, in the parking lot of the general gymnasium near town hall annex, bus routes that extend like spokes to the three railway stations located outside the town and to the two mountainous areas in the town were established. A-line, a long route, was divided into a-line and e-line, whose distances are shorter. C-line was also similarly divided into b-line and c-line. Consequently, bus users heading to the stations outside the town from the western area are invariably required to change buses at the Seseragi BC. However, the convenience of making connections was secured by adopting a time schedule such that buses going to the stations depart at more or less the same time. The waiting space installed in the Seseragi BC enabled users to communicate with each other and wait comfortably for their bus connection. By having the schedule of either d1-line or d2-line, which connects the Seseragi BC to Musashiranzan Station,

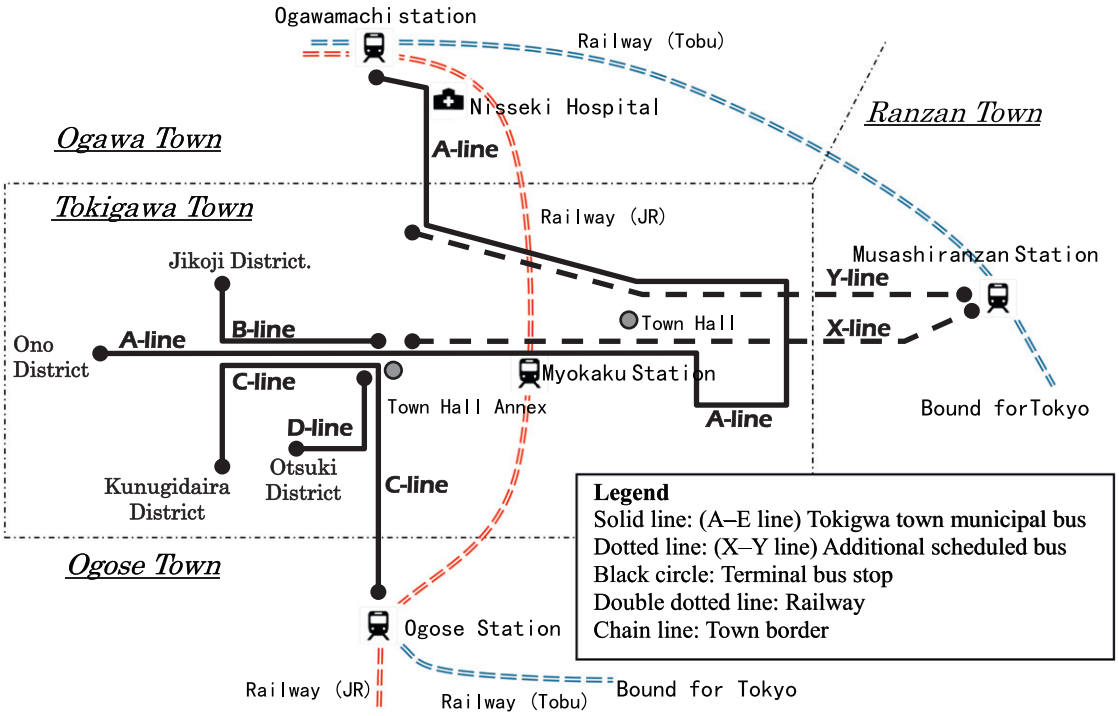

Fig. 8. Conceptual image of the bus routes before the new transportation system was implemented.

match the simultaneous arriving and departing times, the operation frequency between the Seseragi BC and Musashiranzan Station became one bus per hour.

Although Myokaku Station, located in the town center, was also a possible hub candidate, establishing it as a hub would have been difficult owing to the narrow area in front of the station. Moreover, since the Seseragi BC is located at the cross section of main roads that link the surrounding towns to one another (two-way prefectural road), the hub was established in an ideal location in terms of road networks.

DRT bus areas were also established in the mountainous region in the western area, and vans were used to provide transportation between the Seseragi BC and the DRT areas upon request. Several DRT new bus stops were created along narrow roads on which a

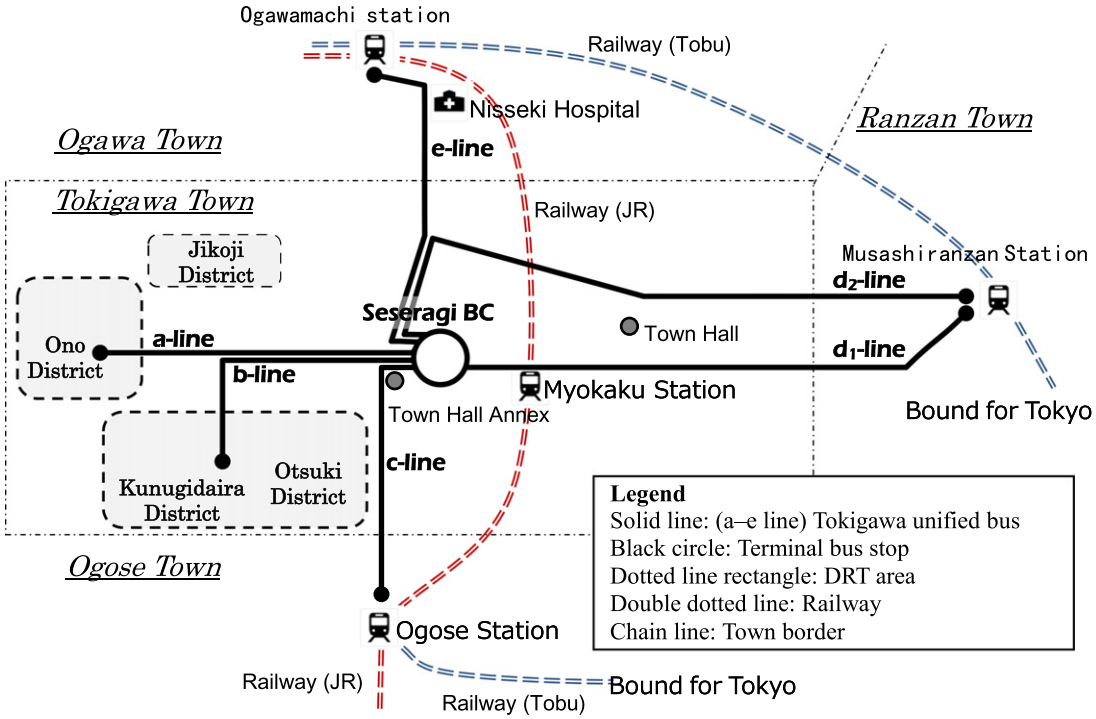

Fig. 9. Conceptual image of the bus routes after the new transportation system was implemented (post-reorganization).

Table 5
Number of vehicles and drivers used pre- and post-reorganization.

	Weekdays	Weekends/holidays
Pre-reorganization scheduled bus (before October 2010)	6 vehicles/12 drivers (Monday–Saturday)	4 vehicles/4 drivers (Sundays, holidays)
Post-reorganization scheduled bus DRT (since October 2010)	6 vehicles/12 drivers 1 vehicle/2 drivers (Monday–Friday)	5 vehicles/5 drivers (Saturdays, Sundays, holidays)
% Increase	17%	20%

van can navigate, with boarding only allowed at DRT bus stops. The time schedule for DRTs was set in advance, based only on the times requested. However, only the normal scheduled buses were in operation during the morning rush hours. During the daytime period from 10:00 am onward, when many users travel by bus to go shopping or to visit hospitals, normal scheduled buses and the DRT buses operated alternatively. For example, along the a-line, which goes to the District, a normal scheduled bus operated (a-line) from 10:00 am to 11:00 am, a DRT bus (Ono District) operated from 11:00 am to 12:00 pm, and a normal scheduled bus (a-line) was operated from 12:00 pm to 1:00 pm. By establishing a method by which the DRT bus stops located near one's home became available for use once every 2 h after securing an operation frequency of one bus per hour, the system became more convenient for the elderly living in places far from the normal bus stops or children who use the van as a school bus. Furthermore, in the pre-reorganization period, users had frequently commented that it was inefficient for buses to run without any passengers. By introducing a DRT bus system, unnecessary running of these buses ceased, leading to a possible reduction in fuel costs.

4. Evaluation of the new regional public transportation plan and discussion

4.1. Comparison of the numbers of vehicles and timetables

The new bus service commenced in October 2010. Prior to this, a weekday schedule was used from Mondays to Saturdays and a weekend/holiday schedule was used for Sundays and national holidays. Post reorganization, the weekday schedule was changed and applied from Mondays to Fridays and the weekend/holiday schedule was applied to Saturdays, Sundays, and national holidays.

The number of vehicles operating in the pre-reorganization period was six vehicles during weekdays (five medium-sized and one small-sized), and four vehicles on Sundays/national holidays (three medium-sized and one small-sized). Five small-sized buses and one van were introduced during the reorganization after five medium-sized buses used in the past were discarded. Thereafter, seven vehicles (six small-sized buses and one van) ran on weekdays while five vehicles (small-sized buses) ran on the weekends and national holidays. This means that the number of vehicles used on weekdays increased by 17% while that on weekends/national holidays increased by 20% (Table 5). Incidentally, the new vehicles were purchased by the town of Tokigawa after receiving government subsidies and were then loaned to the bus operator free of charge.

Moreover, the number of bus drivers for a day's operation prior to the reorganization was 12 for weekdays and 4 for Sundays/national holidays. Post-reorganization, this number increased to 14 for weekdays and 5 for weekends/holidays (the increase rate was the same as that for the number of vehicles). In both pre- and post-reorganization periods, two drivers operated a bus alternatively on a weekday, with one driver operating one bus during the weekends/holidays. Since there is only one driver for weekends/holidays,

Table 6
Changes in the number of services operated between the pre- and post-reorganization periods (weekdays).

Departure		Arrival	West area				Railway stations outside the town					
			Ono District		Kunugidaira District		Ogawamachi Station		Musashiranzan Station		Ogose Station	
			Pre-R	Post-R	Pre-R	Post-R	Pre-R	Post-R	Pre-R	Post-R	Pre-R	Post-R
West Area	Ono District	Number of bus runs	–	–	–	–	5	10	5	13	12	14
		% Increase	–		–		100%		160%		17%	
	Kunugidaira District	Number of bus runs	–	–	–	–	5	10	4	13	11	14
		% Increase	–		–		100%		225%		27%	
Railway stations outside the town	Ogawamachi Station	Number of bus runs	6	11	5	11	–	–	–	–	–	–
		% Increase	83%		120%		–		–		–	
	Musashiranzan Station	Number of bus runs	5	15	2	15	–	–	–	–	–	–
		% Increase	200%		650%		–		–		–	
	Ogose Station	Number of bus runs	10	15	11	15	–	–	–	–	–	–
		% Increase	50%		37%						–	

Pre-R: Pre-Reorganization, Post-R: Post-Reorganization. Before the reorganization, a condition was set such that if making a connection became necessary, connection had to be made within 30 min. Post reorganization, although making a connection is invariably required in the above travel pattern, a connection is made within 15 min at most.

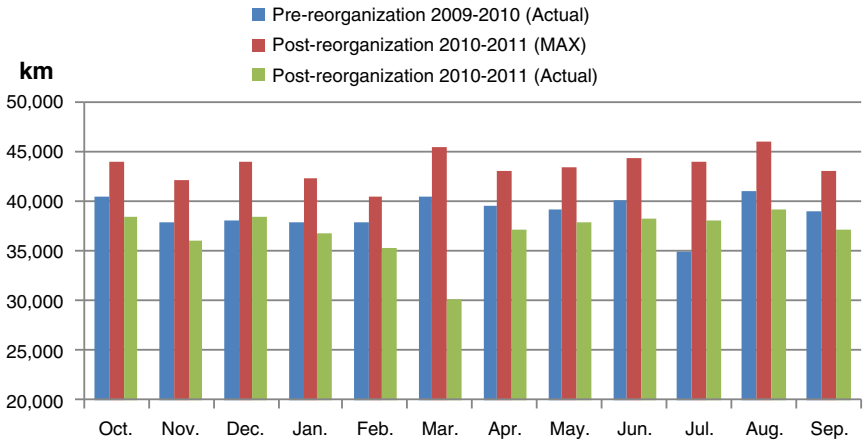

Fig. 10. Comparison of the total distance operated between the pre- and post-reorganization periods (km/month). The values for post-reorganization (MAX) show the distance traveled if DRT vehicles were booked 100%.

the starting time was delayed with reduced afternoon operations, and the service terminated earlier. However, this is deemed unavoidable owing to the small number of users.

4.2. Improvement of service levels and operation optimization

The following changes to the bus service levels between pre- and post-reorganization periods were confirmed.

4.2.1. Increase in operation frequency and response to multi-directional movement demands

As mentioned in Section 2.3.3, the changes in the bus operation frequency between pre- and post-reorganization periods were analyzed to confirm the extent of improvements made regarding the "lack of operating services," (the issue with which people were most dissatisfied pre-reorganization). Table 6 presents changes in the operating services for one weekday for the main travel patterns. Prior to the reorganization, the number of buses running from two locations within the western area to the three railway stations located outside the town was extremely small: only two–six services ran per day, with the exception of the route to Ogose Station. However, post reorganization, at least 10 services per day were secured for all travel patterns. Rates of increase between the pre- and post-reorganization periods show that the number has increased greatly by 27%–650%. The total number of operating services increased from 83 buses (pre-reorganization) to 156 buses (post-reorganization), an increase of 73 buses.

Following the elimination of the long routes and reorganization of routes into a hub and spoke system, passengers had to always make a connection when passing through the hub. However, operation frequency (Mission 2, as assumed by the Council) and mobility toward multi-directional destinations (Mission 1) were simultaneously improved and secured.

4.2.2. Optimization of operations

After the reorganization, the number of vehicles increased by one for both weekdays and weekends/holidays. Preliminary calculations showed that the total distance operated for all vehicles based on the post-reorganization plan would increase by 10% from pre-reorganization because of the increased number of vehicles. Since this is directly linked to fuel cost, an increase in operation costs was an issue of concern. However, since approximately half of the buses operating in the western area, in which the usage frequency was low, were replaced with DRT buses, bus service ceased to operate for services that were not requested. Therefore, it was also anticipated that the actual distance operated would decrease. The total distance operated by month for the pre- and post-reorganization periods is shown in Fig. 10. Although the total post-reorganization distance operated has become larger than that operated prior to the reorganization, this is a preliminary calculation with a 100% DRT bus operation rate. The operation rate of DRT buses for the first year post-reorganization was approximately 27%. Therefore, the actual total distance operated in the first year post-reorganization was approximately 442,654 km,

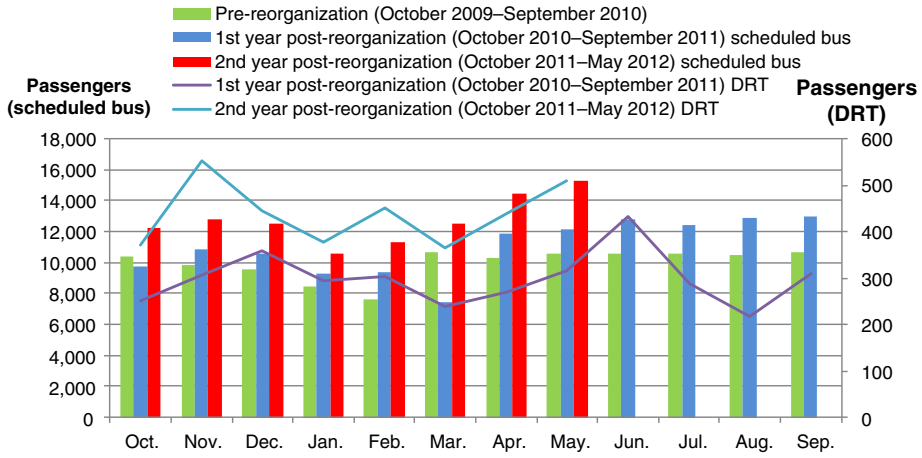

Fig. 11. Number of users pre- and post-reorganization.

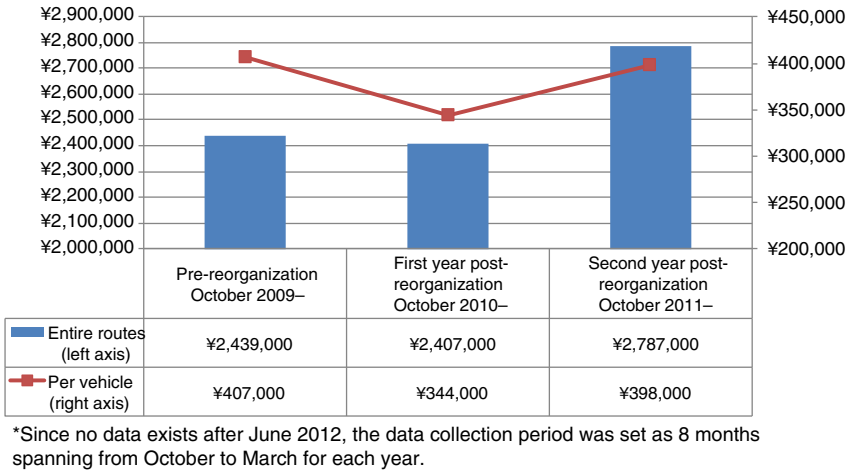

Fig. 12. Comparison of fare revenues (monthly averages).

approximately 85% of the planned distance of 522,708 km. Furthermore, as mentioned in Section 4.2.1, despite the fact that the operation frequency increased significantly, there was an approximately 95% decrease from the total distance of 466,075 km operated for a year in the pre-reorganization period. This shows that sufficiently high optimization was achieved even with the budget restriction that the Council set as a requirement for the mission.

4.3. Increase in bus users and changes in fare revenue

4.3.1. Change in user numbers

The number of average bus users in the first year pre-organization (October 2009–October 2010) was 9975 people per month. The number of average bus users in the first year post-organization (October 2009–October 2010) increased greatly to 11,034 per month, an 11% increase compared to the previous year (Fig. 11). The number of users decreased in March 2011 because the number of operated lines decreased for 4 days and operations stopped for 6 days following the Tohoku Earthquake.

Furthermore, the average number of bus users for the second year (October–May 2011) further increased to 12,708 people per month, a 15% increase from the previous year and a 27% increase from the pre-reorganization period. Since this number does not include DRT users (on average, approximately 300 users/month), the actual number of bus users is even greater. It is extremely rare to see the number of bus users greatly increase for scheduled buses in a remote area with few users.

4.3.2. Changes to fare revenue

By changing the distance-based fare system to a zone-based fare system in the reorganization of the Tokigawa bus routes, most of the user fees became cheaper. For example, the fare from the Kunugidaira bus stop to the Musashiranzan Station bus stop was ¥570 prior to the reorganization, which became cheaper by ¥170 post-reorganization to ¥400. As demonstrated by this example, the bus fares decreased on average. In addition, there was a concern that the fare revenue would decrease owing to the introduction of various cost-effective seasonal bus tickets. However, as mentioned in Section 4.3.1, the number of users increased greatly. Consequently, there was almost no change in fare revenue during the first year post-reorganization compared to the pre-reorganization revenue. However, since one more bus was added, as mentioned in Section 4.1, fare revenue per bus decreased greatly from ¥407,000 (pre-reorganization) to ¥344,000 (post-reorganization). However, in the second year post-reorganization, in which the number of users further increased, the total revenue for all routes increased greatly from approximately ¥2.44 million (pre-reorganization) to approximately ¥2.79 million. The fare revenue per a bus improved to more or less the same level as the pre-reorganization one. The above results confirmed that the budget restriction stipulated by the Council was sufficiently followed (Fig. 12).

4.3.3. DRT operations and costs

Since DRT was not included in the pre-reorganization period, there were no costs or budget values for DRT services at that time. However, since DRT operations were fairly small compared to the overall operations, there was no need to establish a new communications platform to handle user requests and bus dispatch, which helped maintain low logistics operational costs. Accordingly, the government subsidy provided for DRT logistics was set at ¥2,400,000 per year.

4.4. Changes in the bus users' opinions

Pre- and post-reorganization surveys (Table 7) were conducted to ascertain the changes in bus users' opinions. The pre-reorganization survey was conducted by sending a survey form to a randomly selected 500 townspeople in September 2010, right before the reorganization. These were middle school students or older. Since it was just before

Table 7
Pre- and post-reorganization surveys.

Survey name (survey period)			Copies distributed	Copies distributed	Response rate
Pre-reorganization research (September 2010)			500	218	43.60%
Commencement of the new transportation study (October 4, 2010)					
Postreorganization research (January 2011)	Panel survey	Pre-reorganization research respondents	218	113	51.80%
		Unanswered preorganization research	282	50	17.70%
	New distribution		500	161	32.20%
	Total		1000	335	35.50%

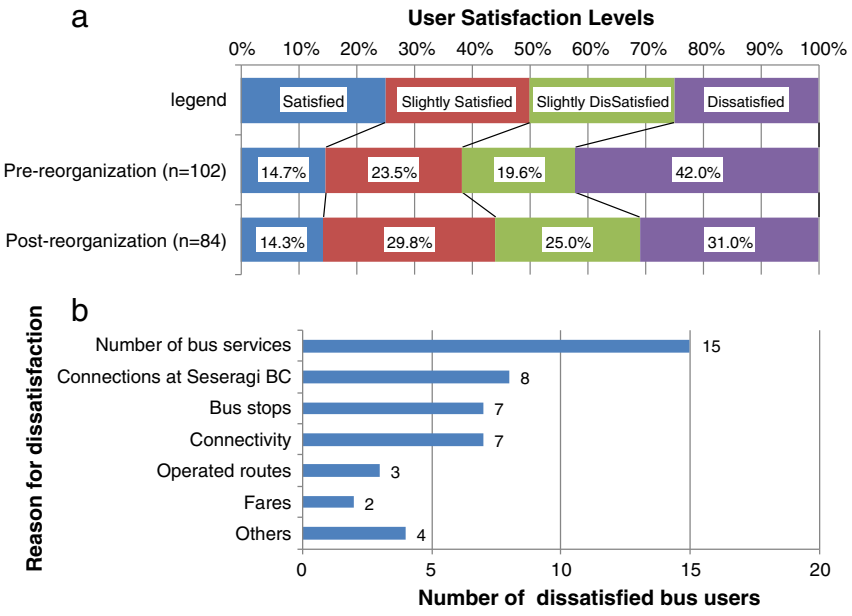

Fig. 13. a. Pre- and Post-reorganization bus user satisfaction levels. b. Reasons for bus user dissatisfaction.

the reorganization, the retrieval rate was high at 43.6%. The post-reorganization survey research was conducted in January 2011, four months after the reorganization. For this research, the survey was sent not only to the 500 participants of the pre-organization survey but also to an additional 500 new townspeople selected randomly.

A comparison of valid responses (excluding no responses and responses where satisfaction levels could not be evaluated) in the pre- and post-reorganization surveys yielded results that showed that the satisfaction level of the town as a whole had increased (Fig. 13a). When the responses of "satisfied" and "slightly satisfied" were combined, there was an increase of approximately 6 points from the pre-reorganization (38.2%) to the post-reorganization (44.1%) period. In addition, negative responses such as "dissatisfied" decreased by 10 points. The most common reason for the response of "satisfied/slightly satisfied" was the number of operating services and route settings. In this survey, there were also many remarks concerning operation frequency (Mission 2) and mobility to multi-directional destinations (Mission 1).

On the other hand, as shown in Fig. 13b, the biggest reason for post-reorganization dissatisfaction was the number of operational services, which was also the biggest reason prior to the reorganization. This confirmed that many townspeople still felt dissatisfied with the one-bus-per-hour service interval as decided by the Council. Furthermore, many respondents were dissatisfied with making connections at the Seseragi BC; implying the need for further improvements.

Next, results of the Panel survey on the satisfaction levels pre- and post-reorganization are shown in Fig. 14. The number of respondents who cooperated in the two research studies conducted pre- and post-reorganization and whose responses were valid for the Panel data was 49.

Judging by the fact that over 60% of the people who responded by saying that they were "slightly dissatisfied/dissatisfied" pre-reorganization later responded by stating that "service improved," major improvements were implemented for users who had earlier found the transportation services difficult to use. On the other hand, over 60% of those who answered that they were "satisfied/slightly satisfied" prior to the reorganization responded by saying that the "service become worse" post reorganization. This could be attributed to the fact that those respondents were forced to change their familiar bus routines because of major system changes resulting from the reorganization. This confirmed the necessity of continuous assessment, including on users' familiarity and behavior changes.

An additional survey will be conducted in the future to directly verify Missions 3 and 4. However, since the comment section in the survey contained comments on how the buses became convenient

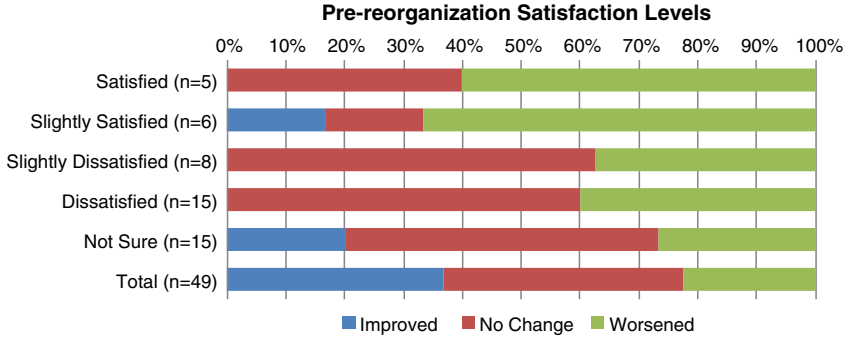

Fig. 14. Results of the survey on users' satisfaction levels.

and some positive feedback was given by DRT area users, it is believed that these missions have been achieved to a certain extent.

5. Conclusion

By using the town of Tokigawa as a case study, the following conclusions were successfully drawn on the effect of bus route and timetable reorganization with the introduction of a hub and spoke system that corresponded to the regional characteristics of low population density as its nucleus.

- This reorganization of bus routes was done to resolve the travel demand of "many destinations to many destinations" (increasing options for bus users), as proposed through an analysis of such regional characteristics as regional conditions and residents' movement characteristics. It was confirmed that the reorganization led to a change in which long routes became shorter. By doing so, it was possible to increase operation frequency without significantly increasing operation costs (number of vehicles). By greatly improving the community's mobility without significantly increasing the fiscal burden, this reorganization was able to improve the residents' satisfaction.
- By installing a system in which the regular scheduled buses and DRT buses operate cooperatively, the operation costs were reduced. At the same time, bus transportation was provided in low population density areas and operation frequencies were maintained. We also found that the best approach for DRT implementation in this instance was to use a private bus operator owing to the greater flexibility and cost benefits. However, the biggest lesson learnt here was that a team effort involving private and government entities, with significant community involvement, is essential to deliver a successful DRT operation.

The adoption of a hub and spoke transportation topology in this case study led to major improvements in the convenience of the residents of the mountainous regions in the western area, for whom bus travel was previously inconvenient. However, the adoption did not sufficiently consider the movement patterns of the residents of the eastern region that has a high residential population. A continual modification of transportation services for the town as a whole is currently being examined. Furthermore, strengthening the hub function of the Seseragi BC needs to be examined as well. By doing this, the center will not only be a facility for bus transfers but also become a center for community activities, once such measures are taken as moving facilities necessary for the residents' daily lives to within the vicinity of the bus stop hub area. In addition, various research studies will also be conducted continuously to ascertain the achievement of each mission.

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