

## Developing a PDCA Cycle to Improve Scheduled Bus Services

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**Abstract:** Presently, scheduled bus services in Japan are in a state of decline in which operators are trapped in a vicious cycle owing to demographic and societal shifts compounded by harsh economic realities due to deregulation and the suspension of government subsidies. Therefore, this paper examines the application of a plan-do-check-act (PDCA) cycle to scheduled bus services in order to reverse this trend. We first define the scheduled bus PDCA cycle and then apply it to an operating scheduled bus service in Japan. In addition, we determine if a pre-PDCA cycle is necessary and describe how we define and utilize it prior to the implementation of the subsequently defined PDCA cycle. The findings show that this approach is a useful methodology for optimizing scheduled bus services and that it should be readily adopted by scheduled bus operators.

*Keywords:* PDCA, scheduled bus, timetable optimization

### 1. INTRODUCTION

In recent years, there has been a significant decline in the number of scheduled bus routes in Japan. There are numerous factors that can be attributed for this decline, which include socio-environmental changes, such as the emergence of an automobile-centered society, the gradual reduction in the population, and the breakdown of the cross-subsidization support structure following bus service deregulation. Therefore, this study experimentally examines improvements in fixed scheduled bus services by constructing and employing a plan-do-check-act (PDCA) cycle in order to optimize the scheduled bus operation timetables. More specifically, we propose a method to plan and develop more than one PDCA cycle for timetable optimization, which can then be implemented so that scheduled bus service operators can improve their services. Furthermore, this study utilizes short-haul routes through either urban or suburban areas based on previously established routes and timetables.

### 2. IMPROVING BUS SERVICE

#### 2.1 Constructional bus service problems and research scope

To date, bus services in Japan have primarily operated on so-called “intuition and experience.” For example, once a bus departs the garage, no one is able to control its operating conditions (schedule, number of passengers, etc.) other than the driver him/herself. With the use of bus location systems, it has become possible for operation managers to monitor their buses in real

time, but real-time navigation and issuing commands have not become the norm yet. Moreover, as in other industries, the basic task of any business is to provide a service that meets the customers' needs. However, this goal is not generally met in the Japanese bus industry because few operators collect both operating data and customer needs' data to improve bus service.

Accordingly, operation plans were developed from a bus operator's perspective of "intuition and experience" and not on the basis of bus service data. This management method was initially established when demand was high, but bus services have since fallen into a vicious cycle in which a combination of poor services and a disregard of customers' needs have resulted in the loss of ridership and, ultimately, cancellation of the entire route.

## **2.2 How improvement is defined in this study**

In order to break this vicious cycle, we need to overcome these constructional problems and make scheduled bus service improvements based on operational data. This "improvement" of bus services can be envisaged in various areas, but this study considers two types: "improvement in revenue" and "improvement in quality." If an improvement in revenue is established as the primary goal, then it focuses on cost reductions, such as lowering drivers' wages. Instead, we made "the improvement of methodologies" as the primary purpose of this study in order to maintain and enhance the quality of services that the bus operators can implement for themselves. For instance, this quality encompasses punctuality (defined by whether buses run according to the timetable or not) or connectivity (defined by whether the transfer time at train stations is adequate or not). In addition, riders' service evaluations (degree of satisfaction or dissatisfaction) are defined as the primary evaluation indices and as service quality improves, we can assume that there would be an increase in the number of riders. Therefore, the actual increase or decrease in the number of riders can also be used as an evaluation index.

## **2.3 Timetable optimization**

A bus schedule is what is normally referred to as a timetable that comprises both routes and timings. In general, improving schedule efficiency is similar to the problem of optimally arranging vehicles and drivers on the routes that they have been authorized to operate. However, it is not uncommon that the result is something that differs from the customers' needs. Schedule optimization is not only about improving the efficiency of the schedule based on operational data but it is also about incorporating customers' needs and creating an appropriate schedule. In addition, given that there is an appropriate road network for the bus service, the creation of the routes can be freely completed. However, because the licensing procedure for the relevant authorities requires a period of three months, changing routes in a flexible manner can be difficult. Therefore, as a first step in this study, the routes are fixed so that we can specifically deal with the optimization of the bus schedules running on the routes. It is important to note that, for Japanese scheduled buses, any amendment to the schedules is usually made annually during the spring or autumn.

In order to optimize the schedule, in addition to data observation and accumulation, it is important to consider how a plan can be developed to first deal with the various problems encountered and then make continued improvements by using PDCA cycles that lead to further optimization. For this reason, this study first constructs a PDCA cycle for scheduled bus services.

### **3. A PDCA CYCLE FOR SCHEDULE BUS SERVICES**

As a methodology for enhancing feasibility, the use of PDCA cycles has long been cited in the improvement of operations. In addition, PDCA cycles have been generalized in many fields and are not limited to any particular industry. According to a review of scheduled bus services under local government operation in Japan, less than 30% of municipalities are revising their plans with an awareness of PDCA cycles and nearly 60% of municipalities are unaware and undecided about the next step.

#### **3.1 Possibilities for the Hidaka–Hannou route**

The bus service that runs between Hidaka in the Saitama prefecture and Hannou consists of 14 lines (the longest route is approximately 12.6 kilometers), which connect three railway stations (JR line Musashi Takakagi, JR line Komagawa, and Seibu line Hannou) and two residential estates within Hidaka City (Hidaka and Komagawa housing complexes) using a per-distance fare system (a basic adult fare of 170 yen with a maximum of 380 yen). In 2003, after the original contractor withdrew from the partnership, Eagle Bus took over operations and began providing bus service. Although the service immediately following the takeover was running at a loss of roughly 750 users on weekdays and 550 on holidays, it was ineligible for government subsidies. However, the service was within the commuting zone to the heart of Tokyo, and the major means of access from housing to the major railway stations was by bus.

During the first year of operation (from April of 2006 to March 2007), all of the business aspects such as scheduling and fare pricing were maintained. There was absolutely no knowledge of the actual use of the service made by customers or the bus demand requirements of residents living along the routes. Consequently, a questionnaire was distributed in July 2006 to both passengers and local residents along the route. The data collection included 660 persons of commuting and school children and 764 persons of noncommuting and school children. In regard to bus-service quality, the connectivity between the buses and the railway stations was reported to be poor. In addition, people commented that they would also be using buses to travel to a large hospital that was to be built in the vicinity. In addition, an origin/destination (OD) survey showed that there were several sections that included no riders. On the basis of the findings, the subsequent schedule was to include schedule changes that allowed a more uniform bus to train transfer time of 10 min, a reduction in the number of trips in sections with no riders, and the establishment of a route that traveled via the new hospital.

During the second year of operation (April 2007 to March 2008), as planned in the previous fiscal year, the schedule was amended in April 2007. However, even though changes were made to reflect the customers' needs, there was a significant drop in the number of riders. According to the results of a questionnaire administered in December 2007, for the rail stations in which a uniform 10-min period had been established, riders were not satisfied with the transfer time stating that it was still too long. In addition, there were hardly any people traveling to the newly opened hospital. Overall, while the definition of a PDCA cycle was still ambiguous, individual changes were being made to each schedule based only on the results of survey questionnaires.

#### **3.2 Defining the PDCA**

The provisional PDCA used during the exploration period is shown in Figure 1.

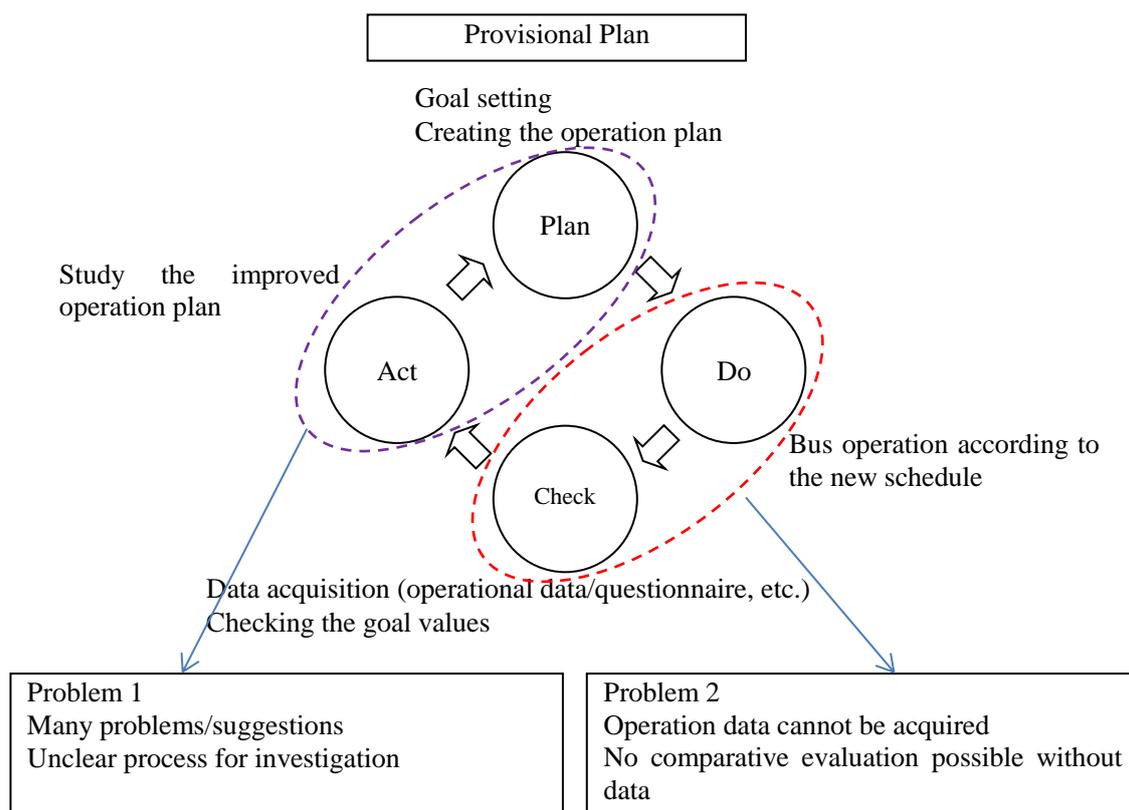


Figure 1. Provisional PDCA for a scheduled bus

Because improvements could not be seen using this PDCA, a new PDCA was defined as given below:

Plan:

- 1) In the goal-setting process, goals are set for improvements, which are based on the evaluation of current routes and the direction of an improvement prior to the cycle. For the goals, there are two settings for both improvements in quality and improvements in revenue. The quality improvement goal extracts those parts that do not meet the customers' needs with the current schedule, and the users' needs are incorporated as far as possible within the constraints of the cost conditions. The revenue improvement goal extracts and reviews wasteful services from the operational data in which there are no riders, and cost reductions are made by changing to smaller-sized vehicles.
- 2) In the creation of the bus-operation plan, a schedule is created that incorporates the customers' needs as discerned from the operational data and questionnaire, which is also within the range of the cost-constraint conditions (the vehicle, the driver, etc.). To create this schedule, the establishment and correction of partial routes (not simply the creation of timetables for each line) is undertaken.
- 3) In the creation of the business plan (policies toward tourism, MM, etc.), events are considered to increase passenger numbers, and policy planning includes collaboration with tourism authorities.
- 4) In the design of evaluation methods (questionnaires, etc.), questionnaires are

distributed during bus operation.

Do:

- 1) Bus operations run exactly as written in the planned schedule.
- 2) The business plan is executed as formulated in the plan.
- 3) Thorough data collection (operational and business) is required in order to implement the PDCA cycle. For “operational data,” we can list spatiotemporal information (GPS) and the number of people getting on and off (boarding and alighting sensors, or passenger OD surveys). For “questionnaire data,” we can list awareness and evaluation data of bus users or residents who live along the routes, etc.
- 4) Information is provided to the riders with details about service improvements and information regarding revenue.

Check:

- 1) In the operational plan evaluation (operation visualization, customer needs, and cost), the operating details for the new schedules are evaluated by accumulating and analyzing the data from both questionnaires and operational data collection.
- 2) By acquiring information about any improvements that are gained from extracting the problem issues, we can accordingly work out any new issues that should be improved upon by means of an operation visualization system and pertinent questionnaires.
- 3) In the business plan evaluation, two points are required, that is, evaluating the degree of success in the planned business policies and searching for new points that should be improved upon.
- 4) Examining changes on the periphery of the routes that could possibly influence the number of bus riders, such as the location of new facilities.

Act:

- 1) When selecting improvement information from the evaluations, information that is to be adopted in the next schedule amendment is determined on the basis of the constraint conditions. The reason(s) why certain improvement information cannot be employed is noted.
- 2) When deciding on the improvement policies for the following year (operational plan, business plan, and external environment), the details of the improvements that have been studied by monitoring changes in the external environment are organized, and a decision is made as to exactly what improvements are going to be implemented.

In addition, one year can be considered as a suitable PDCA cycle period. The reasons for this include the relative certainty of rider habits observed over a one-year period and the fact that we can synchronize the data with the annual schedule amendments made by the railways.

Conversely, there are details that need to be improved upon in the short term without waiting for the one-year PDCA cycle. The reality of scheduled bus services is that various problems arise during day-to-day operations or, alternatively, many opportunities for obtaining new riders arise. Accordingly, the chance to make improvements may be lost if we attempt to only deal with these issues during a one-year cycle. Therefore, distinct from the

PDCA cycle period for basic operational improvements, a short-term improvement cycle must be established for making timely day-to-day improvements.

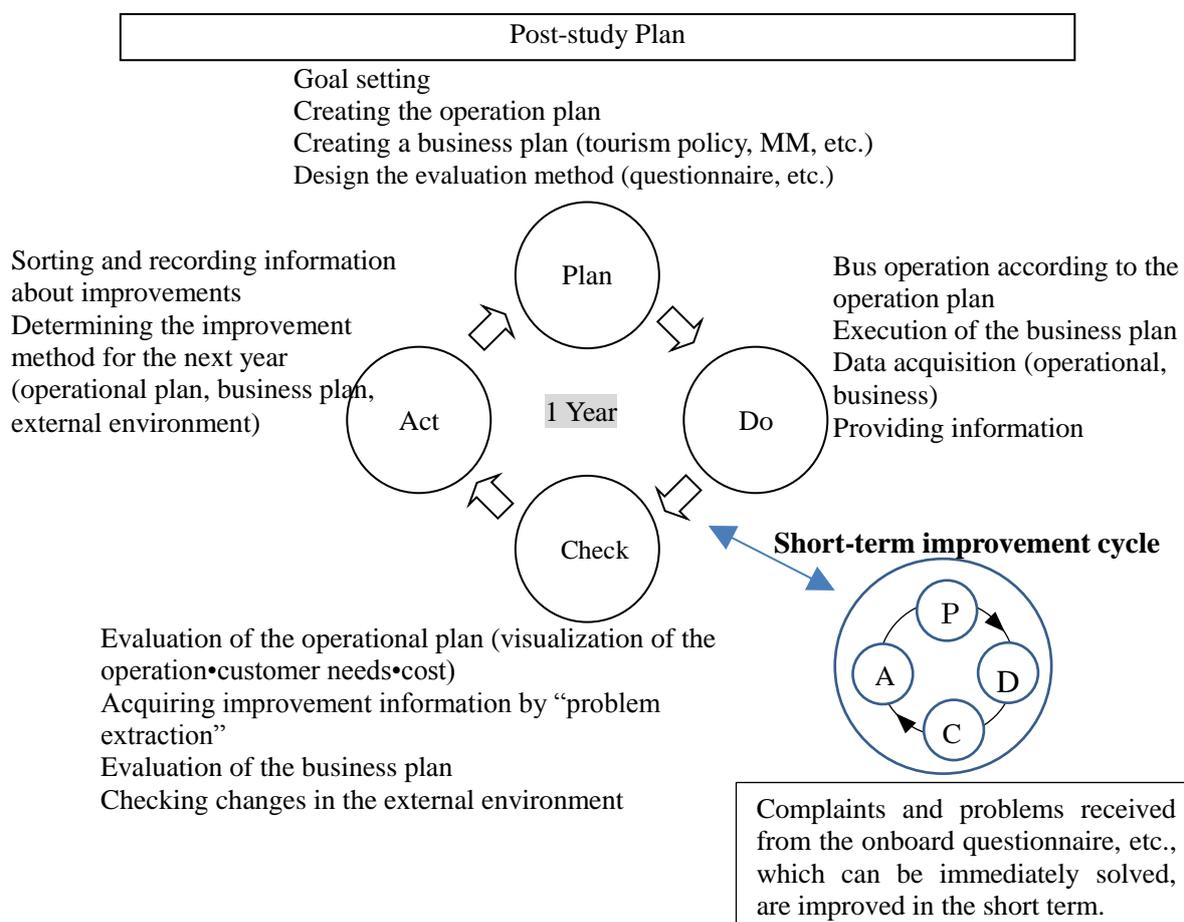


Figure 2. The concepts of the bus service PDCA cycle and the short-term improvement cycle

Furthermore, when improvements are made to operating routes (Do), an incomplete cycle occurs in which preoperational plans (Plan) are missing. In addition, as long as there is no data acquisition (Do), it is impossible to assess the operational plan (Check). Therefore, the first step of collecting data is to “visualize” the bus service and then apply a normal PDCA cycle after completing the “PDCA introductory cycle” that begins from Do.

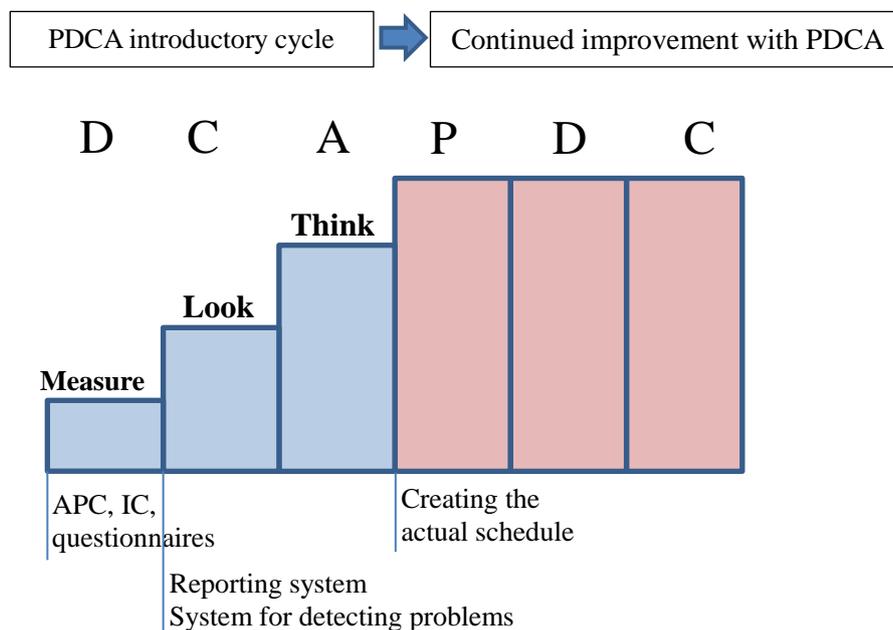


Figure 3. Introductory PDCA cycle

## 4. DEMONSTRATION WITH THE HIDAKA–HANNO ROUTE

### 4.1 The Hidaka–Hannou route

The first year of operation was established as the introductory cycle, and since the second year of operation (April 2007 ~), continual improvements have been made on an annual basis by using PDCA, employing the users' needs obtained from questionnaires, and the operational data from boarding and alighting sensors that were being separately developed during the same period. A summary is provided below:

The first cycle (2007):

Railway connections were adjusted in which there were margins, operating lines were sorted on the basis of the demand by route, and new routes were established where demand could be expected, such as with the new medical center, etc.

The second cycle (2008 fiscal year):

Railway connection time was adjusted to match riders' needs, routes were changed to eliminate cross service, and so on.

The third cycle (2009 fiscal year):

Rail connections were adjusted to correspond with across-the-board changes in the railway timetables, and new routes and express services were added after the operational costs were properly secured with advertisements for the services offered.

The fourth cycle (2010 fiscal year):

Timetables were adjusted with knowledge of delays based on operational data using GPS, and route sections with few riders were identified with data obtained from boarding and alighting sensors.

The fifth cycle (2011 fiscal year):

Timetables were adjusted with the knowledge of delays based on operational data using GPS, route sections with few riders were identified with data obtained from boarding and alighting sensors, and service was increased in sections where more use could be expected.

Adjusting punctuality was the primary function that was carried out each year. According to the annual questionnaire responses, the number of suggestions pertaining to punctuality or connectivity with the railways decreased each year.

Figure 4 below shows an example of the service quality improvement, which was based on GPS operational data during the fourth cycle period. Long delays occurred for some sections, but by adjusting the operation pitch, these delays were significantly reduced.

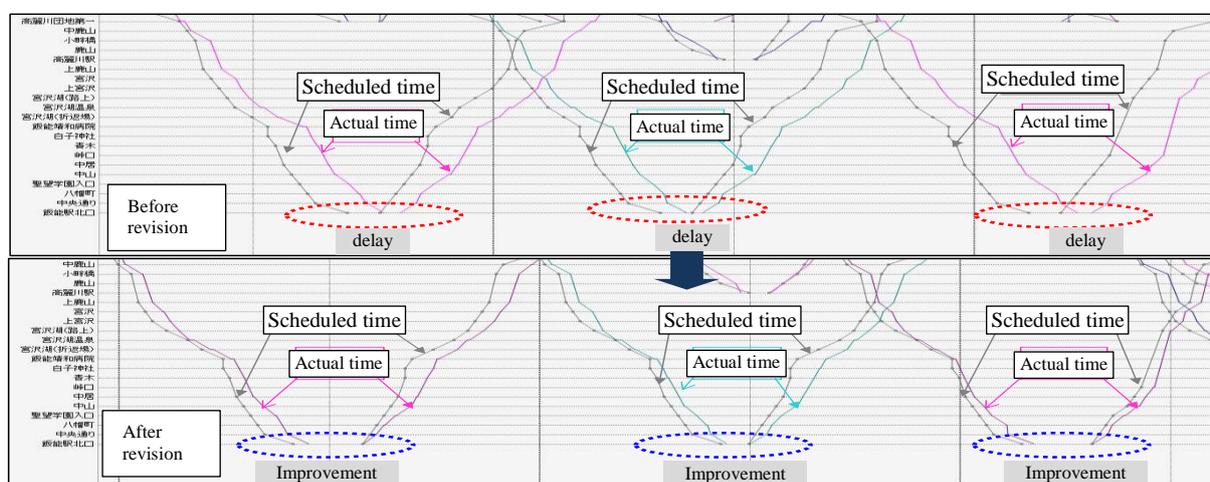


Figure 4. Service quality improvement from GPS operational data

#### 4.2 The number of bus riders

In the first cycle exploratory period (2007), the number of riders significantly dropped compared to the previous year, but from then on, the numbers have steadily increased. Taking into account the tendency for the number of riders to decrease on other bus routes in the same region and the fact that the population around those corresponding routes was also decreasing, these results suggest that the annual schedule amendments matched the riders' needs.

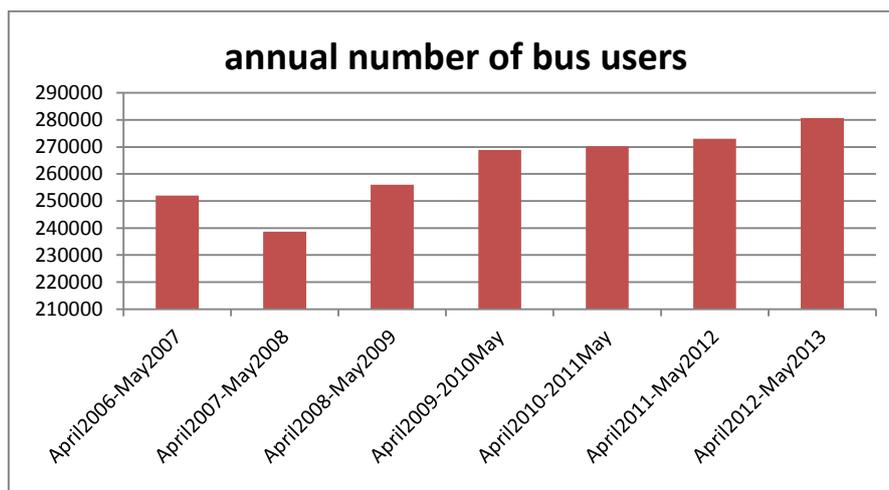


Figure 4. Annual number of riders on the Hidaka-Hannou route

### 4.3 Riders' appraisal

These evaluations cover the periods prior to schedule optimization in 2006 and after improvements made in 2010 and 2011. It is important to note that on account of changes in questionnaire design, whereby questions concerning the quality of the service were omitted from 2007 to 2009, this data does not exist. Before the improvements, 50% of users positively responded to the schedules, while 20% stated that they were either bad or quite bad. In the 2010 evaluation after the continued improvements, 78% of users made positive comments, and that proportion in 2011 had further grown to 80%. Conversely, the number stating that it was quite bad slightly increased, but there was no one who actually believed that the schedule was bad. It is very clear that, compared with the 2006 evaluation, the users' appraisals have dramatically improved, and we can assume that this is a result of the improvements made to the schedules.

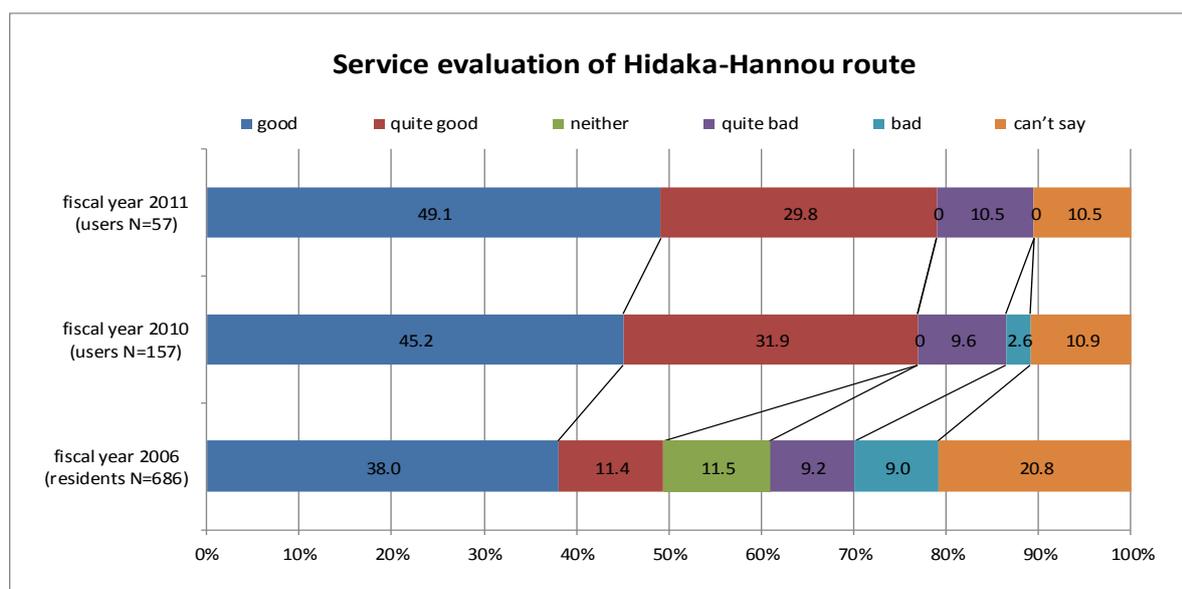


Figure 5. Service evaluation of Hidaka-Hannou route

## 5. CONCLUSION

In this study, a PDCA cycle to improve scheduled bus services was constructed beginning with an exploratory process and then progressing toward a fine-tuned solution. After determining the details of the PDCA for making improvements, we verified the importance of using an introductory PDCA cycle before implementing the first PDCA cycle designed to improve the existing routes. In addition, through improvement of an actual scheduled bus service and by implementing an appropriate PDCA cycle, we verify that not only was it possible to raise the level of user satisfaction but it could also maintain and increase the number of bus riders. Furthermore, it was also found that the vicious cycle of “worsening revenue - drop in the level of service - less users - worsening revenue...” can be reversed by using an appropriate PDCA cycle, and that ridership numbers can return to their former state if the supply side (the business operator) makes the necessary improvements. At the same time, the riders’ needs and opinions are very diverse, and we must live with the fact that all of these problems cannot be addressed through one-time improvements. In recent years, measures taken on the demand side have been highlighted by the means of mobility management (MM), but on the supply side (improving the basic service level in the bus industry), there remain many issues to address. However, we have demonstrated the usefulness of one such option (employing the PDCA cycle), which should be continually implemented in order to improve scheduled bus services in Japan.

## REFERENCES

- National Transit Database, <http://www.ntdprogram.gov/ntdprogram/> (Accessed on April 5th, 2013)
- Furth, G., Peter. (2000) Data Analysis for Bus Planning and Monitoring, *TCRP Synthesis 34*, Transportation Research Board.
- University of South Florida (2010) A guidebook for Using Automatic Passenger Counter Data for National Transit Database.
- Yajima, M., Sakamoto, K., Kubota, H. (2007) Improving the route bus business model using operation data and marketing, *Proceedings of the Eastern Asia Society for Transportation Studies*, Vol. 6, CD-ROM,