PLANNING A BUS TERMINAL IN A SUBURBAN STATION PLAZA IN JAPAN

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INTRODUCTION

In suburban areas of Japan, space for station plazas is usually very poor, while the number of cars, buses, taxis has increased. Because of such conditions planning process for transportation facility in suburban station plazas has become very important. Especially that for bus terminals might be a serious problem to solve, partly because bus terminals occupy much of limited space of station plazas, and partly because bus service improvement has been one of serious transportation problems in suburban areas of Japan. However, planning process for bus terminals in station plazas has not been established sufficiently yet.

The purpose of this paper is to develop the alternative process for bus terminals in suburban station plazas. The total process of the bus terminal in a station plaza can be divided into three continual stages. which include the stage to determine the number of bus berths, the stage to evaluate the alternative layouts for the bus terminal and other transportation facilities based on the values calculated at the previous stage, and the stage to determine the operation method of bus berths of the bus terminal based on the layout determined at the previous stage.

In each stage there exist some problems which affect especially on the service level of feeder bus service. At first we review the existing process of planning the transportation facilities of station plazas, and identify the problems relating to each stage in chapter 1. After that, we discuss each stage and show the alternative planning process in chapter 2, 3 and 4, based on the data observed at Aobadai station plaza in Yokohama in 1987. After discussing the planning process of each stage, we take the Aobadai station plaza renewal project, which has completed in april of 1991, as the case study to make sure whether the developed process might be effective or not, in chapter 5.

1.EXISTING PROCESS OF PLANNING THE STATION PLAZA

When planning a station plaza in Japan, all we have to do is to adjust differences of views between two main interest groups, which include the railway operator side and the city hall side. Especially it is important to determine the total space, that consists of the number of bus berths , taxi berths and so on, because the result may influence on how much cost has to be charged to each interest group.

To solve this problem, one calculation method was proposed by the Ministry of Construction , Ministry of Transport and Japan National Railway in 1953. This method only shows the linear relationship between the total passenger volume and the total space. Although this method is very simple and doesn't consider other related factors, even now the result calculated by this method is thought to be valid officially.

In 1968 Konami developed a new method to calculate the space based on the supposed amount of the facility needed for each transportation mode. This method shows the clear relationship between the amount of the facilities and the space, although it doesn't mention the relationship between the passenger demand and the amount of the facilities.

Based on this proposal the newest method was developed by the Ministry of Construction and others in 1973. This method takes a lot of variables into consideration in order to deal with various situations. But it has caused the very complicated structure to handle with. Moreover, because it doesn't show the relationship between space and the service level for each transportation mode more than the previous methods do, to calculate by this method is not appropriate when we must consider the service level of the facility, which can be an important factor if the planned space is limited or thought to be insufficient for the ideal amount of the facilities.

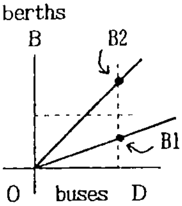
Anyway, with these methods, we cannot mention the relationship between the calculated amount of the facilities and the service level, the layout of the facilities, the operation way of the facility, all of which must be important factors when we consider the importance of the service level of the railway feeder transportation system.

2.THE STAGE TO DETERMINE THE NUMBER OF BUS BERTHS

2.1 The Total Structure of the Method

In this stage, referring the manuals for planning ordinary bus terminals published in U.S.A. and other European countries, we proposed the alternative method to determine the number of bus berths, with which method we can mention the service level of the facility if the planned space is limited and insufficient to acquire the ideal number of the berths corresponding to the demand. This relationship concept can be shown in figure 1. The figure shows that we need a kind of coefficients to derive two values from the one demand value. Considering those, we proposed the calculating flowchart.

The proposed total process is shown in figure 2. To function this process, firstly we investigated the structure and



OB1:the highest LOS
OB2:the lowest LOS

Figure 1. Relationship between buses and berths (↑)

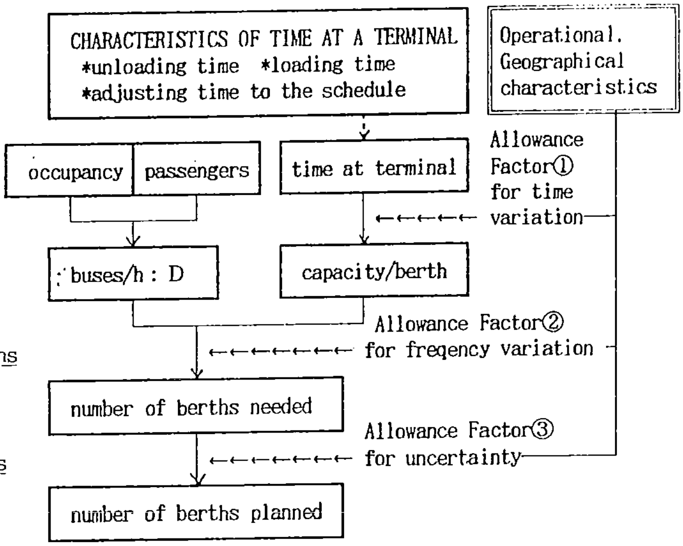


Figure 2. Total process for calculating the number of berths (→)

characteristics of the loading and unloading time at a bus terminal. And secondly we determined the special coefficients which we call allowance factors.

2.2 The Structure of the Loading and Unloading Time

We investigated the characteristics about the loading time and unloading time for bus passengers at a bus terminal at first through a video-recording survey at the bus terminal of Aobadai station plaza.

The following characteristics have been identified. Firstly the unloading time can be significantly influenced by the bus body type (the number and width of doors, the height of the floor and so on) , the volume the bus conveyed (i.e. congested or not), the time period (morning peak or not), the bus operator and the waiting time at the station for the rapid commuter trains to Tokyo (table 1). And secondly the Loading time can be significantly influenced only by the ticketing type (using commuter pass or not) (table 2).

Considering the characteristics mentioned above, we identified time for buses to turn back at the terminal, including unloading time, loading time, and adjusting time to the schedule. would be stable. The capacity per berth, which means how many buses can turn back at one berth during one hour, can be easily calculated by that stable value. In this sense, in the calculating process, we supposed the time buses staying at the terminal should be 4 minutes, following the experiences of the bus operators.

Table 1. Characteristics of unloading time

Factors		number of samples	average unloding time	(S.D.)	Correlation coefficient	T-test for groups
All samples		314 buses	2.59sec	(7.93)	0.295	***
Number of doors	1	20	2.42	(1.90)	0.962	***
	2	265	1.67	(1.39)	0.542	***
	3	21	0.94	(0.77)	0.447	***
Time period	mo	158	1.21	(1.02)	0.449	t=6.04
	ev	148	2.15	(1.62)	0.647	1% sig.
Bus operator	X	207	1.55	(1.42)	0.553	t=1.97
	Y	99	1.90	(1.41)	0.552	5% sig.

mo:morning
ev:evening
sig.: significant

Table 2. Ceristics of loading time

Number of samples		15 buses	Regression model		
Loading time	average	2.37sec.	r^2		0.785
	s.d.	0.83			
	c.v.	0.35	Parameters	Pass user	1.85 (6.23)
				Non-pass user	3.39 (4.42)
Correlation coefficient		0.837	(t-value)	Constant	-3.37 (0.44)

Table 3. Values of allowance factors (cf. Figure 2.)

No.	meaning for	values
①	variation of time at a terminal	$0.8 \leqq \alpha_1 \leqq 1$
②	variation of freqency and operation way	$0.75 \leqq \alpha_2 \leqq 1$
③	uncertainty or planning allowance	$\alpha_3^* \leqq \alpha_3 \leqq 1$ $(0 < \alpha_3^* < 1)$

α_3^* should be determined by the planners.

2.3 The Values for the Allowance Factors

As seen in figure 2, we set the 3 types of allowance factors in the process. Referring to the experiences in other countries, we figured out the ranges of values of the two allowance factors (table 3). In the process of calculating the number of berths, these values can represent the level of service at the terminal.

3. THE STAGE TO DETERMINE THE LAYOUTS OF THE FACILITIES

In this stage we treated the layout of the transportation facilities in a station plaza, including bus terminal, taxi terminal, and kiss-and-ride facility. The total process of this stage is shown in figure 3. At this stage the most important step is that to evaluate the alternative layout. In this step, we introduced the framework method, which has been used originally for the appraisal of major road schemes in England.

3.1 Evaluation Groups and Items

In the process we set evaluation groups and items as is shown in table 4. In the previous planning experiences, pedestrian movement over the plaza has not been considered sufficiently, although drivers for each mode have been considered. But when thinking that one of the most important functions of the station plaza is the interchange between different transportation modes, we have to regard pedestrian movement as important ones.

3.2 Derivation of the Alternative Layouts

In this step, at first intentions stated by each interest group, including bus operator, bus user, and so on, have to be recognized. Then, using the result calculated at the previous stage, we set the target space location and figure out the conditions relating to the target space, such as the gradient in the space, traffic volume on the road along the area, and the possibility of constructing decks or multistoried terminals. Considering those mentioned above, we derive the alternative layouts as much as possible. In this step we only need rough

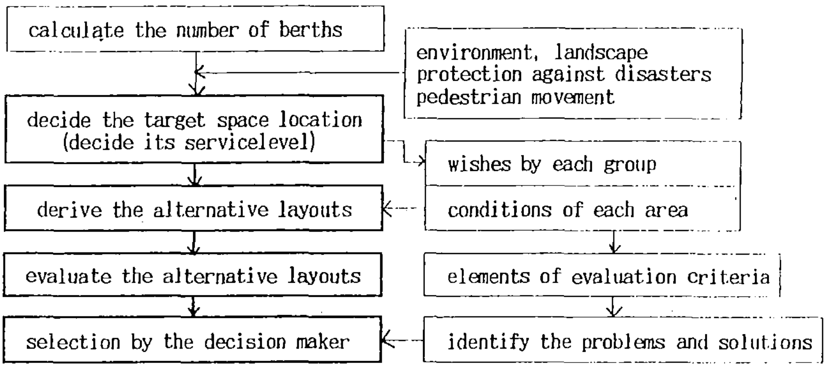


Figure 3. The total process fir determining the layout

Table 4. The evaluation groups and items ※ k-&-r : kiss-and-ride

evaluation groups		sub groups	items	
plaza user	passengers	bus user, taxi user k-&-r user, bicyclist	transfer movement	distance, up and down crossing the road
		pedestrians	spaces	comfortable, light
	drivers	each mode	movement	in and out, conflict
user and manager of facilities around the plaza		shop user and manager	direct access	
		road user and manager	road congestion	
		residents	noize, vivration	
effect on operator and society	operator	each mode	convenience improvement, extendability	
	social benefit	catchment area	road congestion condition	
		local area	landscape and environment	

layout and precise location of each berth is not necessary.

3.3 Evaluation of the Layouts

In this step, we set the criteria for evaluation corresponding to the evaluation elements, as is shown in table 5. Based on those criteria, the decision maker can select the final layout of the plaza. The decision maker has to take a lot of condition into consideration. However, even so, the final layout may have some deficits. By using this process we can easily know the deficits and the solutions to overcome the deficits. In this sense to evaluate based on those criteria before selecting the layout is important.

4.THE STAGE TO DETERMINE THE OPERATION METHOD

At the last stage, given the number of berths and the layout of the bus terminal in the station plaza, we determine the operation method for buses at a bus terminal. Usually we planner don't have to think about the operation method. But considering some cases where the ideal amount of the bus berths has not been acquired, we need to select the suitable operation method in order to treat the demand. This stage can be divided into two steps as is shown in figure 4. According to the flowchart, we have to set the conditions, and then develop the simulation model which can describe the movement of the buses in the terminal and can calculate some values which is useful in the evaluation process. Also we derive the criteria for evaluation.

4.1 The Conditions

To execute this stage, the following conditions must be considered.

1)The terminal is the origin of all the bus routes: In Japan, in most cases this condition is appropriate, and by this condition calculation becomes simple.

2)Other vehicles than buses are prohibited to enter the terminal: We don't have to worry about any conflict between bus and other vehicles or walking passengers.

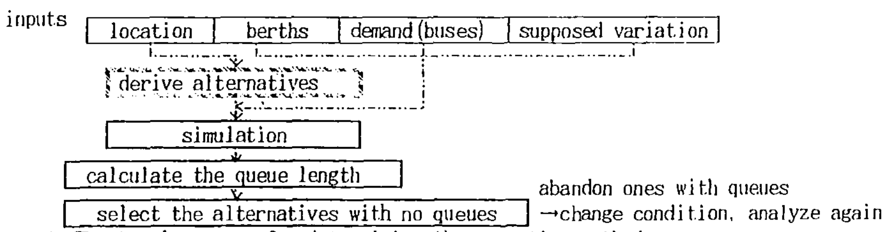


Figure 4. The total process for determining the operation method

3)Buses only do unloading, adjusting to the schedule and loading, and in the morning peak very few get on buses at the terminal:
4)The time when buses stay at the terminal is stable and drivers don't have long rest for breakfast at the terminal:
5)The bus system has the bus location system which can give the driver and passengers appropriate informations:
6)The shape of each berth in the terminal should not make buses to move backwards: That causes longer time for departures.
7)The bus body type and the ticketing system should be the same in the target period (which is the morning peak when the passenger volume is the largest).

4.2 Derivation of the Alternative Method

There must be two isolated operation type, including 'share' type and 'split' type. In the 'share' type, some multiple berths are assigned to unloading, and buses are assigned to each berth in order of arriving. In the 'split' type, some berths are used for only unloading and some are for only loading. Considering those basic operation types, we can acquire 4 basic patterns of operating, as is shown in table 5. When deriving the alternatives, we consider the number of routes and the number of berths, and then assign the route or the pattern into each berth or some group of berths.

Table 5. The typical operation patterns ※○→applying that type ×→not

Type No.	Applying types share	/ split	role of each berth	route assign	conditions
(00)	×	×	off, wait, on	fixed	
(10)	○	×	off, wait, on	share	share berths≦4 /continuously placed
(01)	×	○	off or on only	fixed	off for all berths/ wait at any ones
(11)	○	○	off or on only	share	same as above two patterns

Table 6. Random variables

variables	supposed value
headway range	3, 5, 10 or 15 0, ±1, ±2, ±3 minute
occupancy range	40, 30 or 20 ±5 or ±10 passengers/bus

Table 7. Evaluation elements for operation

group	evaluation elements
bus user	①time for transferring to trains
bus driver	②time spended at the terminal ③driving terminal in the terminal ④movement conflict
bus operator	⑤safety allowance if buses delay
neighborhood	⑥noize , environment (≒ ③)

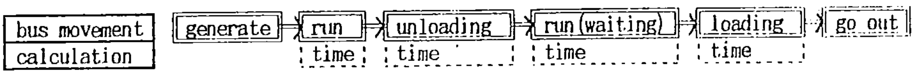


Figure 5. The simulation flowchart

4.3 Development of the GPSS Simulation Model

To describe the movement we developed the simulation model by using the GPSS model, which is ordinarily used in queuing theory problems. In the model we considered the distribution of the arrival time and the number of passengers as the random variables shown in table 6.

The rough flowchart of the simulation model is shown in figure 5. With this flowchart we can find whether the given number of berths can afford to deal with the demand. It means that indirectly we get the range of the number of berths under the given demand by iterating the calculation with the variable numbers of berths. So we assured that the calculated value in the model might not be inconsistent with those calculated in the first stage under some supposed conditions.

4.4 Evaluation of the Alternative Layout

In the evaluation step, all we have to consider are the elements shown in the table 7.

5.CASE STUDY

We applied this total process into Aobadai station plaza renewal project.

5.1 The Calculation of the Berths

The existing layout is shown in figure 6 and the original demand and conditions are shown in table 8 and figure 7. Before the project was begun, each of the interest groups had had the intentions written in table 9. Based on table 8, the numbers of berths were calculated as is shown in table 10.

5.2 The Evaluation of the Alternative Layout

Figure 7 shows there are 5 areas where each facility can be set and theoretically we can derive a lot of layout alternative. However, because some combinations have serious problems shown in table 11, we were able to derive only 6 alternatives shown in figure 8. The result of the evaluation was in table 12. The decision maker selected the layout of No.6, although other alternative also had the possibility under different conditions.

Because the layout of No.6 was selected, the following problems were figured out to be considered in the next stage. Firstly the less number of bus berths means the necessity of the high dense operation. Secondly inhospitality to the kiss-and-ride users means the need of bus service improvement which encourage them to shift the mode or the special information system for the kiss-and-ride users in order to prevent unnecessary congestion from the streets around the station plaza.

According to the selection and the discussion about some problems which must be solved, the precise layout was designed. The layout in the bus terminal is shown in figure 9.

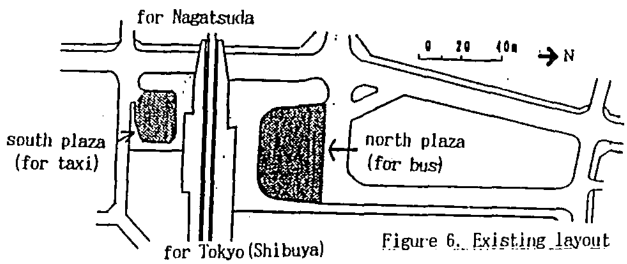


Figure 6. Existing layout

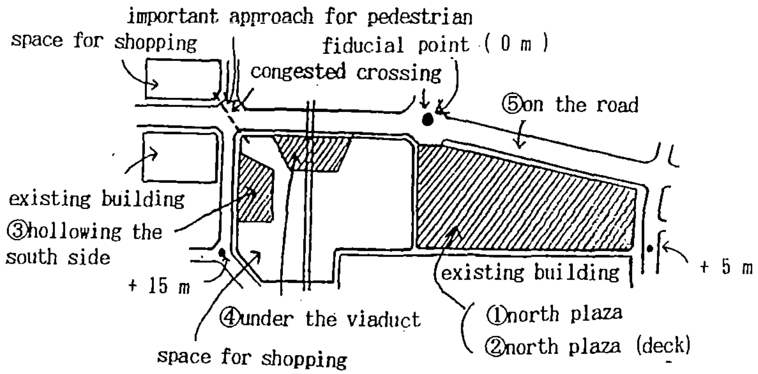


Figure 7. Conditions

Table 8. Original demand and conditions

items	conditions
demand in future by each mode (vehicles / peak 1 hour)	· bus : 130 (morning) · taxi : 210 (morning) · kiss-and-ride : 1390 (evening)
conditions (cf. figure 6 and 7)	· viaduct, existing buildings · height, steeps · affect on the front road
adjustment with the related projects (cf. figure 6 and 7)	· keep the space for shops · keep the approachs for buildings.

Table 9. The first intentions

interest group	intentions
bus user*	los improve no delay
taxi user*	keep existing los
k-&-r user*	no congestion
pedestrian *	direct approach no conflicts
railway operator	cover future demand
bus operators	near the gate isolate space
taxi operators	wide space
shoppers*	direct approach
road manager	less affect on roads
neighborhood*	less noize from bus
decision maker*	good interchange bus

*…based on the homebased surveys

Table 10. number of berths

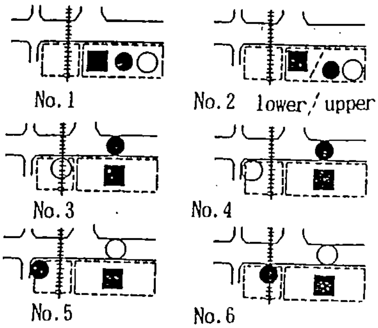
los	bus	taxi	k&r
highest	15	1	7
lowest	12	1	4

※not considered about the allowance factor α_3

Table 11. Problems appeared in some locations

mode	location	problems
bus	①	only 13 berths provided.
	①&⑤	bad affect on congestion
	②	expensive
	③or④	physically impossible
taxi	①	conflict
	②	bad pedestrian approach
	③or④	1)shop space decrease 2)bad vehicle approach
	⑤	long walk distance
K&R	①	conflict
	②	bad pedestrian approach
	③or④	1)shop space decrease 2)bad vehicle approach
	⑤	affect on congestion

※①~⑤: figure 6



■…bus ●…taxi
○…kiss and ride

Figure 8. Alternative layouts

5.3 The Determination of the Operating Method

In this stage, according to table 5 and figure 9, we derived 24 operation alternatives shown in figure 10, with additional conditions such as, 1)the routes with more passengers have priority to use the berths near the entrance of the train platform, 2)in 'split' type operation, unloading berths cannot be set except berth No.2-No.6 because of inconvenience for the passengers, 3)in 'share' type operation, sharing berths must be set as close as possible to the entrance of the train platform.

Among alternatives some 8 alternatives have been abandoned because the queuing of arriving buses occurred in the simulation process. The result of the evaluation about the rest 16 alternatives are shown in table 13. The table shows that 6 alternatives are the best for the bus passengers. With in the 6 alternatives, No.22 is best for bus drivers, No.16 for bus operators, and No.24 for neighborhood residents. When considering the request from the residents and the anticipated condition in the morning peak period, the No.24 should be selected.

Aobadai station plaza project was almost completed. However the proposed operation method has not been introduced because the number of buses is still lower than what was estimated. Actually the station plaza has two problems now. One is the location of the crossing connecting the island with the fringe walkway, which was different from the original plan because of the safety. The other is the lack of bus information service, which is important

Table 12. The result of the evaluation

sub group	evaluation item	sub-item	Alternatives(figure 8) 1	2	3	4	5	6
bus user	pedestrian movement	crossing up & down distance	○ ○ ○	○ ○ ○	○ ○ ○	○ ○ ○	○ ○ ○	○ ○ ○
taxi user	pedestrian movement	crossing up & down distance	× ○ △	○ × ×	△ ○ ×	△ ○ ×	○ ○ ○	○ ○ ○
k-&-r user	pedestrian movement	crossing up & down distance	× ○ △	○ × ×	○ ○ ○	○ ○ ○	△ ○ ×	△ ○ ×
pedestrian	space	comfort lights	× ○	△ ×	○ ○	○ ○	○ ○	○ ○
bus driver	vehicle movement	conflict in & out	× ○	○ ○	○ ○	○ ○	○ ○	○ ○
taxi driver	vehicle movement	conflict in & out	× ○	○ △	○ △	○ △	○ ×	○ ×
k-&-r driver	vehicle movement	conflict in & out	× ○	○ △	○ ×	○ ×	○ △	○ △
shoppers & managers	pedestrian movement	direct approach	○	○	○	×	×	○
road user & manager	road congestion	affect on the road	○	○	×	×	△	△
residents	noize etc.	noize etc.	○	×	○	○	○	○
railway operator	make convenient	convenient extendable	○ ○	○ ×	○ ○	○ ○	○ ○	○ ○
bus operator	make convenient	convenient extendable	△ ×	△ ×	○ ○	○ ○	○ ○	○ ○
taxi operator	make convenient	convenient extendable	○ ○	△ ○	× ×	× ×	○ ○	○ ○
all area local area	traffic landscape	totally totally	○ ○	○ ×	× ○	× ○	△ ○	△ ○

※ ○=no problem △=some problem ×=serious problem

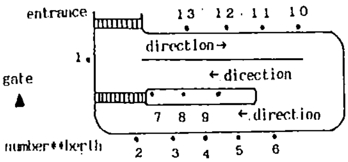


Figure 9. Precise layout of the bus terminal

<table>
<tr><th>No.</th><th>type</th><th colspan="13">role assigned to each berth(1-13 means berth No.)</th></tr>
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<tr><td>17</td><td>11</td><td>○</td><td colspan="5">×</td><td colspan="2">●</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
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<tr><td>19</td><td>11</td><td>○</td><td colspan="5">×</td><td colspan="2">●</td><td>○</td><td colspan="2">●</td><td colspan="2">●</td></tr>
<tr><td>20</td><td>11</td><td>○</td><td colspan="5">×</td><td colspan="3">●</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
<tr><td>21</td><td>11</td><td>○</td><td colspan="5">×</td><td colspan="3">●</td><td>○</td><td>○</td><td colspan="2">●</td></tr>
<tr><td>22</td><td>11</td><td>○</td><td colspan="5">×</td><td colspan="3">●</td><td colspan="2">●</td><td colspan="2">●</td></tr>
<tr><td>23</td><td>11</td><td>○</td><td colspan="5">×</td><td colspan="3">●</td><td>○</td><td colspan="3">●</td></tr>
<tr><td>24</td><td>11</td><td>○</td><td colspan="5">×</td><td colspan="3">●</td><td colspan="4">●</td></tr>
</table>

○…on without share ●…on with share ×…off
△…off and on without share ▲…off and on with share

Figure 10 Operation method alternatives

Table 13. Evaluation result

No.	type	item① sec/p.	item② sec/b.	item③ sec/b.	item④ bus/h	item⑤	item⑥ sec/b.
2	10	139.3	283.3	54.6	0	0.610	54.6
7	10	140.4	281.5	55.0	0	0.605	55.0
10	10	152.4	280.2	53.7	0	0.605	53.7
11	10	136.0	279.0	50.7	0	0.600	50.7
12	10	134.9	279.0	50.7	0	0.600	50.7
13	10	135.0	279.0	50.7	0	0.600	50.7
14	10	134.4	279.0	50.7	0	0.600	50.7
15	10	148.6	279.0	50.7	0	0.600	50.7
16	01	126.9	284.9	135.2	81.0	0.425	135.2
20	11	126.9	282.2	130.3	81.0	0.431	130.3
21	11	126.9	282.2	130.3	81.0	0.431	130.3
22	11	126.9	282.0	131.6	81.0	0.427	131.6
23	11	126.9	282.2	130.3	81.0	0.431	130.3
24	11	126.9	282.3	128.3	81.0	0.437	128.3

①~⑥→evaluation item No. (cf. table 7)
p.:passengers b.:buses

for such a larger bus terminal. Those problems must be solved in near future.

6.CONCLUSIONS

In each stage, through the case study, the developed process was found to be useful under the conditions we supposed. However, as a result, all of these stages can be effective to bus terminal planning in a station plaza. We are sure that by using this planning process developed here we can progress bus terminal planning in station plazas more clearly, although in some cases we may have to make some conditions more complicated.

In Japan, especially in urban areas, most of the station, except those of the JR, don't have the sufficient space of the station plaza. However, some cities, accompanying the redeveloping projects, has begun to investigate the station plaza planning. At that moment we hope that the process proposed and investigated in this paper will be useful.

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