Evaluation of GIS-supported Route Selection Method of Hillside Transportation in Nagasaki City, Japan

Kohei Watanabe
Graduate School of Science and Technology, Nagasaki University
1-14 Bunkyou-machi, Nagasaki 852-8521, Japan
nabe@suncv1.civil.nagasaki-u.ac.jp

Keinosuke Gotoh
Ditto
1-14 Bunkyou-machi, Nagasaki 852-8521, Japan
gotoh@civil.nagasaki-u.ac.jp

Kaoru Tachiiri
Department of Civil Eng., Faculty of Eng., Nagasaki University
1-14 Bunkyou-machi, Nagasaki 852-8521, Japan
tachiiri@civil.nagasaki-u.ac.jp

Abstract: In this study, the authors evaluate the suitability of the candidate routes selected by the route selection method, which is developed by the authors, by combination of Geographic Information Systems (GIS) and Analytic Hierarchy Process. To evaluate the suitability of the candidate routes, from the viewpoint of the residents, we have considered element factors such as, population, household, aging situation, elevation, gradient, housing density and the Control Point. The results of this study are expected to assess the suitability of the candidate routes of the hillside transportation for the residents and examine the application limit of the route selection method.

Keywords: GIS, Route Selection Method, Suitability of the candidate routes

1. Introduction

Most of the hillside urban area (HUA) in Nagasaki City, Japan is located in the steep slopes of high elevation areas, although it was formed in the gradual foot slopes in the low elevation areas in the old days. Recently, various problems such as superannuated housing, poor road system, rapidly increasing aging rate etc. are occurring in these urban areas in the steep slopes. Especially, the poor road system causes serious physical burden to the residents in transferring and is associated closely with all of the above-mentioned problems [1].

In this study, the authors evaluated the suitability of the candidate routes selected by the total evaluation of gradient, housing density, distance from the road, aging situation and control point, which is needed to pass or avoid in construction of roads or other transportation facilities. The authors developed the route selection method (RSM), by combination of Geographic Information Systems (GIS) and Analytic Hierarchy Process (AHP) [2]. Using this RSM, three candidate routes were selected in each of seven different HUA in Nagasaki City.

In order to evaluate the suitability of the candidate routes of the hillside transportation, from the viewpoint of the residents, we have considered element factors such as, population, household, aging situation, elevation, gradient, and travel time.

In this paper, the suitability of the candidate routes of the hillside transportation for the residents are assessed. Finally, the applicability of route selection method in the HUA has been discussed.

2. Route Selection Method and Route

The flow of the route selection method (RSM) is shown in Fig.1. The candidate route is selected by five stages.

Firstly, collected and prepared terrain/society information, and inserted these data in form of the grid cell with size of 20 square meter. This size is determined from the installation case of mini-monorail as the rail track width and value considering the rail track including ancillary facilities [3] that is introduction traffic system in this study.

Secondly, the evaluation scores are classifying to the each input data. Thirdly, an aging rate for each household is important factor for the resident transportation, therefore evaluates separately from another data.

Fourthly, weighted score of the each attribute data for each grid is calculated using Analytic Hierarchy Process [4]. Out of four attribute data, the distance from the road to reduce the physical burden of the resident, is considered to be the most important attribute and are also closely related to the main purpose of this study. Second important attribute is a control point that is relater to harmony between new and existing traffic facilities.

Fifthly, total evaluation map is carried out and candidate routes were selected considering the distribution score of high score grids (see Fig. 2) and the validity of the routes are verified from the distribution

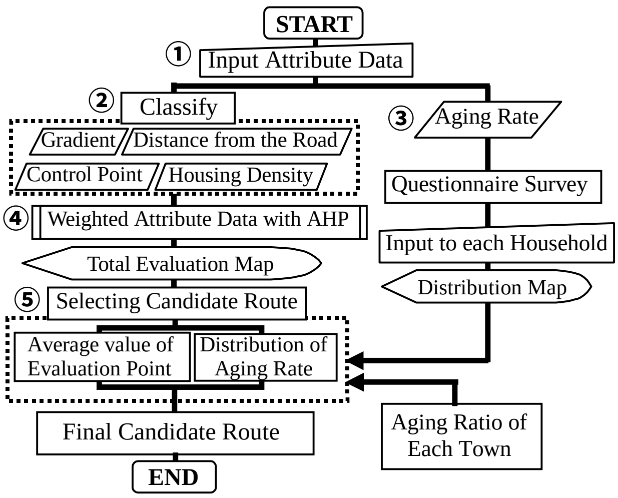

Fig.1. Route Selection Method.

map of an aging rate of household. Additionally, we have used the town aging ratio to interpolate. Finally, routes are recommended by combination of those two types of evaluation.

Table 1 shows the result of candidate routes in each area (A to G) that is the typical HUA in Nagasaki City. For selecting these route, primarily selected from the evaluation map about ten to eleven routes and finally, selected three candidate routes.

From the table, lengths of the routes are included between 127 meter and 417 meter. The score of each route, fifteen out of twenty-one routes are over1.50 and seven are over 2.00, having score range between 1.24 to 2.56.

These results show the routes which are selected and enabled us to determine the width of evaluation score which were utilized as the standard for selecting the candidate route.

For the result of the aging rate analysis around each route, it was evident that 25% of the entire population is aged residents, while 45% of the entire households contain aged residents and 10% of the households are composed of only aged residents. This result presented the candidate routes, which are very important for the aged resident residing in HUA.

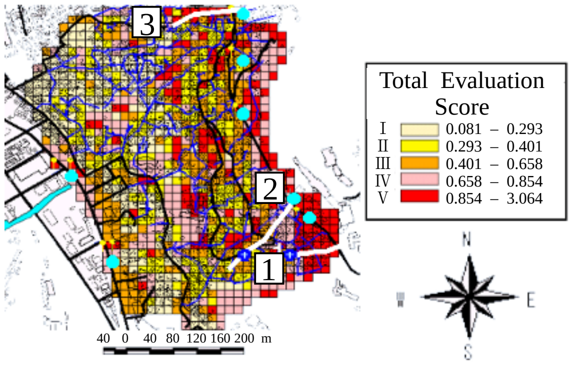

Fig.2. Total Evaluation Map (Area D).

Table 1. Result of Each Candidate Routes.

Area	Route	Length (meter)	Score	Aging Rate (%)
A	1	217	1.01	24.0
	2	274	1.18	23.5
	3	286	1.53	25.4
B	1	255	1.98	27.0
	2	280	1.92	24.5
	3	180	1.73	24.5
C	1	417	1.38	24.0
	2	220	1.51	23.2
	3	240	2.32	23.2
D	1	127	2.79	23.8
	2	213	1.81	25.7
	3	133	2.38	22.3
E	1	308	2.56	25.4
	2	147	2.53	19.3
	3	383	1.61	25.0
F	1	144	1.80	23.3
	2	300	1.32	26.5
	3	183	1.98	26.5
G	1	160	1.28	31.3
	2	184	1.42	30.0
	3	280	1.58	31.3

Table 2. Elevation and Gradient Situation.

Area	Elevation (meter)			Gradient (degree)	
	Avg.	Max	Vertical Distance	Avg.	Max
A	92.8	136.8	71.4	15.2	22.6
B	100.9	155.9	72.9	18.9	22.8
C	42.8	82.3	38.9	14.7	21.5
D	87.7	108.5	36.1	17.2	21.8
E	83.8	127.1	40.4	14.9	21.1
F	74.3	105.3	29.4	17.7	23.9
G	65.4	120.0	62.0	14.9	18.8

3. Assessment of the Candidate Route

Table 2 shows the elevation and gradient situation of each route. From the table, for the gradient, average value of route is about 16.2 degree and maximum value is 23.9 degree for twenty-one routes.

This result shows that mini-monorail could respond to various gradients from steep slope to slight slope. For the elevation, maximum value is between 82 meter and 156 meter. Converting this result into the vertical distance, it is between from 29 meter and 72 meter. At present, most of the movement in HUA is stepping the stairs by walking. Therefore the candidate route could reduce the physical burden of the resident.

Table 3 shows the household and population situation of each route. The authors carried out the buffer analysis of 80 meter from the route centerline in order to realize the effective area of the route.

From the result, it was proven that population and household which are included in the area were 20% to 30% for the one route from each area.

We hold that since the route extension became longer, the effect area of the route is expanded and the number of households and population will increase. Though, the result of the candidate routes has not necessarily brought such a result.

Table 4 shows the road and traffic condition. As the result, most of the routes are connected to the road in the lower and upper side of the HUA that are the origin or the end of the route. Additionally, each route is connected to more than two existing bus stops. Meanwhile, the problem is the long distance to the bus stop for the residents to move smoothly. However, these results show that the candidate routes have good traffic

Table 3. Household and Population Situation.

Area	Route	80 meter Buffer Area (rate:%)	
		Household	Population
A	1	652 (85.2)	1506 (67.8)
	2	364 (36.4)	841 (37.9)
	3	332 (33.2)	767 (34.5)
B	1	232 (39.9)	490 (24.4)
	2	190 (32.6)	401 (20.0)
	3	185 (31.8)	390 (19.5)
C	1	276 (33.1)	640 (29.3)
	2	202 (24.2)	469 (21.4)
	3	415 (49.8)	963 (44.1)
D	1	149 (9.6)	319 (6.5)
	2	248 (16.0)	531 (10.7)
	3	204 (13.2)	437 (8.8)
E	1	514 (29.2)	1172 (26.7)
	2	140 (8.0)	319 (7.3)
	3	199 (11.3)	454 (10.3)
F	1	209 (40.4)	458 (15.8)
	2	231 (44.7)	506 (17.5)
	3	300 (58.0)	657 (22.7)
G	1	181 (21.4)	393 (25.5)
	2	129 (15.3)	280 (18.2)
	3	327 (38.7)	710 (46.1)

Table 4. Road and Traffic Condition.

Area	Route	Road Situation*		Bus Stop Situation	
		Upper Area	Lower Area	Location! (Number)	Nearest Distance (meter)
A	1	1	1	U (2)	28.5
	2	1	1	U (2)	93.5
	3	1	1	U (2)	146.1
B	1	1	1	U (2)	184.8
	2	2	1	L (2)	305.9
	3	2	1	L (2)	350.5
C	1	2	1	U (2)	200.3
	2	1	2	U (2)	20.6
	3	1	2	U (2)	26.6
D	1	1	1	U (4)	77.8
	2	1	1	U (4)	92.7
	3	1	1	U (2)	67.3
E	1	1	1	U (2)	24.5
	2	2	1	L (2)	259.3
	3	1	1	L (1)	641.5
F	1	2	2	U (2)	412.0
	2	2	1	L (2)	186.1
	3	1	2	L (2)	25.9
G	1	1	2	L (2)	265.4
	2	2	1	L (2)	265.4
	3	2	2	L (2)	233.8

*: 1: Connected, 2: Not-Connected,
! : U: Upper Area, L: Lower Area

Table 5. Travel Time to the Existing Bus Stop.

Area	Average Travel Time (minutes)	Travel Time Rate (%)		
		0-5 mins	6-10 mins	Over 11 mins
A	7.1	48.8	29.1	22.1
B	3.7	68.6	21.2	10.2
C	6.1	57.8	34.4	7.8
D	4.6	66.7	21.3	12
E	7.4	60.8	26.9	12.3
F	4.9	73.9	14.1	12
G	4.5	73.0	25.2	1.8

From The Nagasaki Area Person Trip Survey Report (1998)

nodes with existing traffic facilities.

Table 5 shows the average travel time to the existing bus stop by walk and residents rate of taking travel time from the each household by the person trip survey, and Table 6 shows the travel time from the each route effective area to the nearest bus stop. The walking speed limit is 66.7 m/min (4km/h) for calculating the travel time.

From table 5, 70% of the residents take less than five minutes for the travel time. From table 6, the travel time to the nearest bus stop, some of the routes in each area are under survey result. This result shows that the residents of the effective area of the each route can move smoothly by incurring lowest physical burden.

Table 6. Total Travel Time from the Household.

Area	Route	Travel Time to the Nearest Bus Stop (minutes)			
		80 meter effective area	Halfway of the route	To the nearest bus stop from the route origin	Total
A	1	1.2	1.6	0.4	3.3
	2	1.2	2.1	1.4	4.7
	3	1.2	2.1	2.2	5.5
B	1	1.2	1.9	2.8	5.9
	2	1.2	2.1	4.6	7.9
	3	1.2	1.4	5.3	7.8
C	1	1.2	1.5	3.0	5.7
	2	1.2	1.6	0.3	3.2
	3	1.2	1.8	0.4	3.4
D	1	1.2	1.0	1.2	3.3
	2	1.2	1.6	1.4	4.2
	3	1.2	1.0	1.0	3.2
E	1	1.2	2.3	0.4	3.9
	2	1.2	1.1	3.9	6.2
	3	1.2	2.9	9.6	13.7
F	1	1.2	1.1	6.2	8.5
	2	1.2	2.3	2.8	6.2
	3	1.2	1.4	0.4	3.0
G	1	1.2	1.2	4.0	6.4
	2	1.2	1.4	4.0	6.6
	3	1.2	2.1	3.5	6.8

4. RSM in the HUA

In this study, we evaluated whether the candidate routes satisfied the demand of the residents from present state of the area. We used four basic elements which is terrain and society information using AHP for the weighted score of the each attribute data to select the candidate route. For the AHP, it calculated each attribute data for weighting score that is needed to understand the present condition. Additionally, the candidate routes which are selected in each area, shows that to be an important route as a smoothly movement for the residents.

Thus, this route selection method will be the applicability method to plan the new traffic route in HUA and it could be an important method for the redevelopment planning.

5. Conclusions

In this study, the authors assessed the candidate routes which are selected by route selection method and are developed by the authors. Using this method, it can evaluate the main factors, which are needed for the smooth transportation of the residents in HUA.

References

[1] Watanabe, K. and Gotoh, K., 2002. Resident consciousness investigation on traffic environment and disaster prevention on the sloped urban area in Nagasaki City, Nagasaki University, *Reports of the Faculty of Engineering*,32(58): 141-147 (In Japanese).

[2] Gotoh, K., Watanabe, K. and Tachiiri, K., 2002. Application of GIS as a Means of Traffic Introduction at Sloped Urban Area, Center for Environmental Information Science, *Environmental Information Science*,16: 31-36 (In Japanese).

[3] KAHO CO., Ltd. 1998. Fly sheet of KAHO-SLOPECAR (In Japanese).

[4] Saaty, T. L., 1980. *The Analytic Hierarchy Process*, McGraw Hill, New York.