

# CONSTRUCTION ON DECISION SUPPORT SYSTEM FOR ROUTE LOCATION BASED ON GIS

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## WG II/4 Spatial Planning and Decision Support Systems

**KEY WORDS :** Route Location, Decision Support System, GIS, Vertical Slope

### ABSTRACT:

This study presented the route location method by applying AHP and evaluating quantitatively. This study developed the program that can be easily applied to this kind of road design, and built the decision support system for route location. The study results are summarized as follows ; We could quantitatively evaluate the appropriateness of existing routes by applying the AHP based on GIS. If we apply this to the roads that will be newly constructed, we can make the objective and reliable route location when making road plans and basic designs. We improved the technique of route location by applying the decision support system with third-dimensional data, which considers even the vertical alignment plan, to the existing decision support system with second-dimensional data. And, since we can set those data such as vertical slope, earth-volume, structure size, location and construction cost to independent variables, we can make road designs more scientifically and reasonably.

### 1. INTRODUCTION

Generally speaking, roads are provided as a part of a nation's financial business. In most cases, local developments are planned in connection with the locations of roads, or necessarily accompany the constructions of roads. Therefore, in determining the road alignments, we should very carefully consider various factors such as local roadside environments, social effects, balanced land developments, efficient uses of land, maintenances and managements of land. Various determining factors and variables influence the selection of road alignments, which requires experts' skilled experiences and special theories, massive data, as well as much time and economic efficiency. Using these elements and data, many recent researchers are actively studying reasonable selections of road alignments(Xu et al., 1995 ; Cheng et al., 2001 ; Hyung - Suk, Lee, 2001). But it has turned out that, when they are based on a decision making, the selections of road alignments have been made mostly in relation to horizontal alignments and therefore vertical alignments have hardly been considered. The goals of this study are to analyze not only horizontal alignments chosen as the analytic hierarchy process based on GIS, but also the designs of vertical alignments in various ways, focusing on changes in vertical inclinations. This study also aims at providing and evaluating reasonable but quick ways to select road alignments.

### 2. FACTORS AFFECTING THE SELECTIONS OF ROAD ALIGNMENTS

To select road alignments is to align traffic flows which run through a road network and to determine the locations of passage points on the way. In determining and evaluating road alignments, we should evaluate social, economic, and technical

factors, and should determine the best road alignments according to the results of those evaluations.

Regarding social factors, researchers evaluate the significance of improving road traffic networks in local societies, and examine its social effects on local communities, along with the considerations of other development projects.

As for economic factors, it is econometrically estimated whether road plans are reasonable with respect to their investment issues such as construction costs or maintenance and management costs, and with respect of the economic benefits of investments in those plans. Technical factors of road plans are divided into traffic-technical and structure-technical aspects, which are separately examined. While the former are for managing the traffic flow of automobiles, the latter are for adapting it to natural conditions and then structurally stabilizing it.

### 3. THE ANALYTIC HIERARCHY PROCESS

The analytic hierarchy process was developed by Tomas L. Saaty in 1960s. Having been developed on the basis of the fact that when human beings make decisions their brains utilize the analytic process in a gradual or hierarchical way, this theory is the method to arrive at a final decision making by decomposing the whole process of analysis into several sub-processes and then analyzing them independently step by step (Saaty, 2000). The analytic hierarchy process helps us consider multi-dimensional variables including both objective and subjective factors, as we evaluates alternatives available for a certain purpose in the process of decision making. It also helps us simultaneously use both qualitative and quantitative standards and objectify the decision goals by means of mathematical rationality. In other words, the analytic hierarchy process is a

tree-shaped decision making system which is designed to achieve a final goal by gradually breaking down factors into smaller sub-factors for a certain purpose. There are usually three principles which can be applied to the analytic hierarchy process.

#### 4. THE SELECTIONS OF ROAD ALIGNMENTS

##### 4.1 Methodology and Scope

In order to determine details and items necessary for the selections of road alignments, this study collects and examines related data. It also identifies items and factors to be considered. Items and factors identified as qualitative data have been converted into quantitative data for the purpose of applying the decision method to choose road alignments to the analytic hierarchy process. In the next step, this study selects the target regions of the research. In order to use these regions as data based on GIS, it collects data such as topographical maps, detailed soil maps, geological maps, land use maps, and land feature maps, etc., which are related to the selections of road alignments. These theme maps are constructed by classifying relative importance weights with respect to each item and each factor constituting the analytic hierarchy process. This study uses these constructed data to select and visualize vertical alignments by means of ArcView, a GIS program. It chooses and comparatively analyzes vertical alignments, with the focus on the changes in the vertical inclination caused by the chosen horizontal alignments. It also draws the best road alignments by estimating the volume of earthwork. Last but not least, this study examines the effectiveness of this system by comparing it with the already designed and established road alignments. Figure 1 presents a series of these processes.

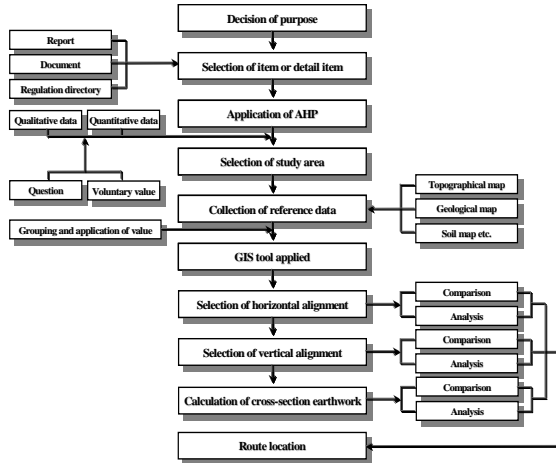


Figure 1. Flow chart of a study

#### 4.2 Data Classification

##### 4.2.1 The Structure of the Analytic Hierarchy Process

The process of designing horizontal alignments is structured through the analytic hierarchy process, as is illustrated in Figure 2. First, this study creates a hierarchy of items and factors imposed upon the goal of selecting horizontal alignments. Second, as for each item constituting the hierarchy, priorities among them are determined and their relative importance weights are selected. Third, this study examines the coherence regarding the determination of priorities and relative importance weights. If it turns out that there is little coherence, priorities among items and their relative importance weights

should be reset in order to make data classifications coherent. Through these steps, we can get some results regarding the final goal.

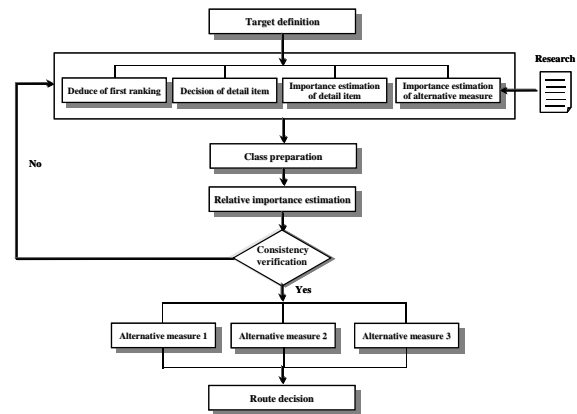


Figure 2. Structure chart of AHP

##### 4.2.2 The Application of the Analytic Hierarchy Process

In order to apply the analytic hierarchy process, this study draws a connection map of details and items, as is depicted in Figure 3. Major items to be considered consist of economic, technical, and environmental factors. In terms of economic aspects, the details of each item includes the construction cost, the price of land, the operation cost and time of transportation system, the maintenance cost of road networks. The sub-items of technical aspects includes an appropriate combination of alignments, an easiness of construction, a soft ground, and the safety of operation. Social and environmental aspects consists of the details such as cultural properties, the connecting points of bridges, traffic noises, and nature protection areas.

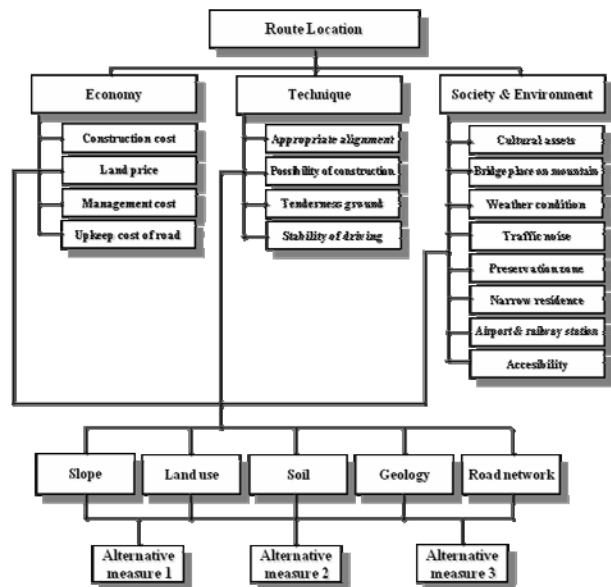


Figure 3. Application map of AHP

##### 4.2.3 The Data Construction of the Analytic Hierarchy Process

Qualitative data should be converted into quantitative data, which aims at applying the item-related data based on GIS. Accordingly, in this study, the economic aspects are applied, as Figure 4 demonstrates. Figures 5 and 6 respectively illustrated the applications of the technical aspects and of the social and environmental aspects. It should also be noted that relative

importance weights, which are intended for the comparison of each item in the analytic hierarchy process, are provided on the basis of documents, reports, and research literature.

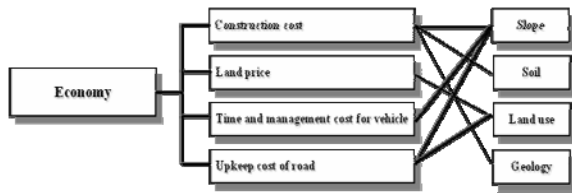


Figure 4. Economy of class structure

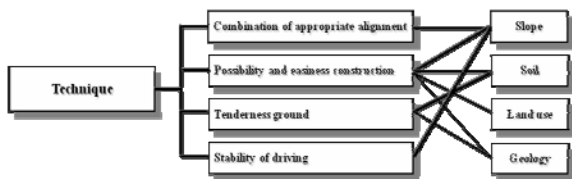


Figure 5. Technique of class structure

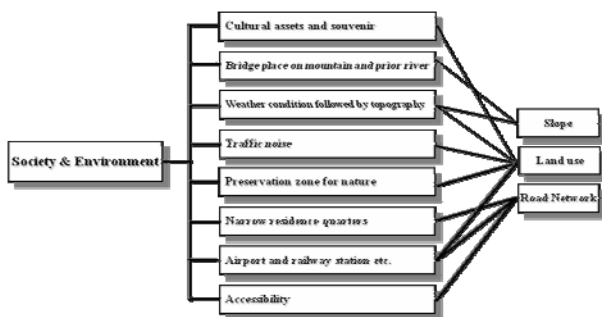


Figure 6. Society and environment of class structure

**4.2.3.1 Inclination**

Inclination both directly and indirectly affects many factors such as the volume of earthwork, vertical alignments of road network, constructability, etc. Therefore, the item of inclination is regarded as a factor influencing the economic, the technical, and the social and environmental aspects.

The standard value of vertical inclination is standardized according to the design speed, whose maximum is set to 16%. But it is prescribed that it can be increased by 1%, if it is judged to be necessary in consideration of the geographical conditions and of the economic efficiency of surrounding obstacles. Consequently, in this study, inclination is classified on the basis of the standard value of the vertical inclination, which is estimated according to the design speed designated by the Ministry of Construction and Transportation.

As Table 1 presents them, the relative importance weight of  $\pm(0 \sim 17\%)$  inclination is set to 1, and the  $\pm(18 \sim 34\%)$  importance weight to 1/3. In case of the 17% increase, the each relative importance weight is respectively set to 1/5 and to 1/7. Of the values provided by Saaty, the one considered most universal is applied as the weight. As the result of applying this importance weight, RIW is estimated according to the inclination and the consistency rate turns out to be 0.004.

Slope type	Weight	RIW	CR
$\pm(0 \sim 17)\%$	1	0.57	0.04
$\pm(18 \sim 34)\%$	1/3	0.26	
$\pm(34 \sim 51)\%$	1/5	0.12	
$\pm 52\%$ Over	1/7	0.06	

Table 1. Weight estimated by inclination

**4.2.3.2 Soil**

Soil affects the relation between constructability and soft ground, and the condition of drainage, etc.

Accordingly, the item of soil is judged to be a factor influencing the economic and the technical aspects. Regarding the soil classification, this study sets the relative importance weight according to the condition of drainage, compares the classification standard of SCS in the United State with that of the Rural Development Administration in Korea, and uses the standard to classify the soil series of the detailed soil map into A, B, C, and D, which are the hydrological soil groups suggested by SCS.

As for the level of drainage condition, the level A means "excellent," the level B "good," the level C "poor," and the level D "terrible."

As Table 2 shows, the importance weight of excellent soil is set to 1 and the importance weight of good soil is set to 1/3. In this way, the relative importance weight is estimated according to the drainage level of soil condition.

Soil type	Weight	RIW	CR
A	1	0.57	0.04
B	1/3	0.26	
C	1/5	0.12	
D	1/7	0.06	

Table 2. Weight estimated by soil

**4.2.3.3 Geology**

It is judged that the conditions of geological features influence the relation between constructability and soft ground, the suitability of foundation, and the economic efficiency of blasting at the time of construction. Consequently, it is considered a factor of the technical and the economic aspects. As Table 3 demonstrates, this study classifies rocks into volcanic rocks, metamorphic rocks, and sedimentary rocks, and estimates the relative importance weight. The calculated value of technical aspects is classified according to the strength of rock, and the importance weight of volcanic rocks is set to 1. The computed value of the economic aspects is divided according to the economic efficiency of blasting at the time of construction, and the importance weight of sedimentary rocks is set to 1. The consistency rate is estimated at 0.03.

Geology type	Weight (Technique)	RIW	CR	Weight (Economy)	RIW	CR
Igneous rock	1	0.637	0.03	1/5	0.105	0.04
Metamorphic rock	1/3	0.258		1/3	0.258	
Sedimentary rock	1/5	0.105		1	0.637	

Table 3. Weight estimated by soil

4.2.3.4 Road networks

Although the construction or extension of a road is important, the accessibility to another road should also be considered. Therefore, this study estimates the relative importance weights of road networks with respect to the accessibility of road by classifying roads into express highways, national highways, and general highways. In this context, road accessibility is judged to be a factor affecting the social and environmental aspects. Accordingly, road accessibility is judged to be a factor which has an influence on social and environmental aspects. The classification standard follows the road classifications of the road act. The relative importance weight of highway is set to 1, as is shown in Table 4.

Geology type	Weight	RIW	CR
Highway	1	0.637	0.03
Road	1/3	0.258	
Local road	1/5	0.105	

Table 4. Weight estimated by road networks

4.2.3.5 Land use

Land use is considered a factor which affects the economic aspects and the societal and environmental aspects. In this study, the classification of land use consists of the classifications by environmental effects and by land price, which in turn affects the estimation of the importance weight of land use.

(1) The Classification by Environmental Effects.

The conditions of land use are classified by environmental effects in three ways. This classification is applied on the basis of the principal business projects of the Ministry of Environment. In these business projects, "regions to be protected" are distinguished from "regions to be developed," in order to environmentally and deliberately preserve, develop, and use national lands. As Table 5 demonstrates, this study reflects social and environmental aspects by setting the relative importance weight of the forest areas to 1/5, the minimum value that keeps the environmental destruction at the lowest possible level.

Land type	Weight	RIW	CR
Urban area	1	0.637	0.03
Farming area	1/3	0.258	
Forest area	1/5	0.105	

Table 5. Weight estimated by effect of environment

(2) Land Prices by Land Categories

Land prices by land categories vary from region to region. The land price of the same land category has wide differences even in the same region. In this study, land prices by land categories are estimated by using the Land Price Index Table. The Land Price Index Table is a simplified land price calculation table econometrically designed to help conveniently calculate the price of large land. Therefore, as Table 6 illustrates, land prices by land categories are estimated on the basis of the Land Price Index Table. If it is not on this Index Table, an item is reflected in the economic aspects by estimating land prices of city planning facilities according to the Land Price Index Table, as is shown in Table 7.

Land type	A	B	C	D	E	F	RIW	CR
Farm	A	1.000					0.161	0.00
Rice field	B	0.980	1.000				0.158	
Stock farm	C	0.940	0.960	1.000			0.151	
Forest and field	D	0.920	0.940	0.980	1.000		0.148	
Factory region	E	1.250	1.280	1.330	1.360	1.000	0.201	
Hybridity site	F	1.130	1.150	1.200	1.230	0.900	1.000	

Table 6. Weight estimated by land price(classification of land category)

Land type	A	B	C	RIW	CR
Urban amusement park	A	1.000		0.408	0.00
Waterway, Railway, Road	B	0.85	1.000	0.346	
River	C	0.60	0.71	1.000	

Table 7. Weight estimated by land price(classification of urban facilities)

4.3 The Selection of Research Target Areas

The target areas of this research include Chulma-myun and Jeungkwon-myun, Gijan-gun, Pusan Metropolitan City. These areas have both steep and gentle slope areas, and some areas adjoin the sea. The construction of data requires numerically expressed data, and therefore data yet to be numerically expressed should be converted into numerical data. These data are converted in consideration of the index ellipsoid and the projection standard. The conversion into numerical data should be performed by means of scanners, so that we can correct errors in constructing data. Also, vector data should be converted into raster data. The size of the raster data constructed in this study is set and converted to 20m×20m. Table 8 presents the types of constructed data, their scale, and the goal of extracting data, etc. Figures 8 to 11 presents the numerically expressed data produced through these extractions.



Figure 7. Study area

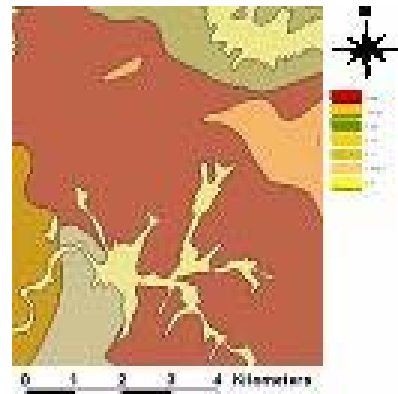


Figure 9. Geology map

Classification	Scale	Purpose of extraction	Remark
Topographic map	1/5,000	Contour Elevation Slope Road network etc.	
Geologic map	1/50,000	Rock of distribution	
Cadastral map	1/500 1/600 1/1,200	Classification of land category Land price Number of a lot of ground Boundary of ground	Scanner Digitizing
Land property map	1/5,000	Situation of land use	
Soil map	1/25,000	Situation of soil	

Table 8. Data classification and extraction

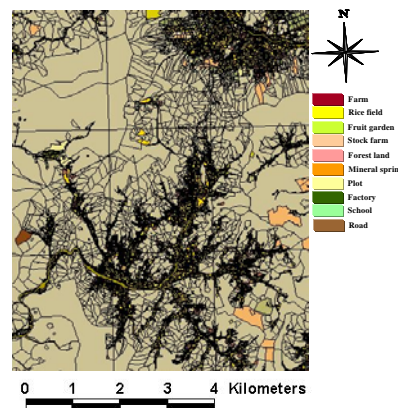


Figure 10. Land property map

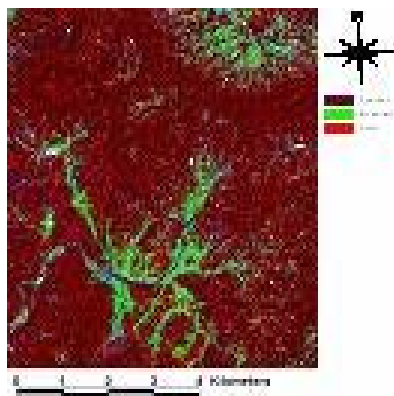


Figure 8. Topographic map

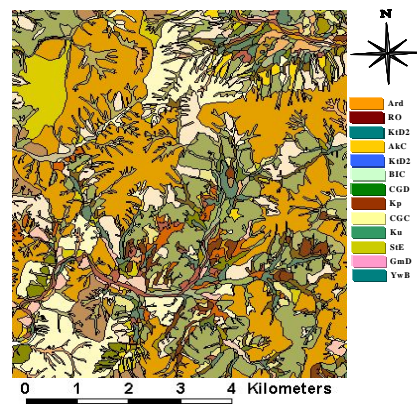


Figure 11. Soil map

#### 4.4 The Selection and Analysis of Horizontal Alignments

This study classifies the selection condition of horizontal alignments into five factors, as is described in Table 9. Emphasizing each of the technical, the social and environmental, and the economic aspects, this study sets the relative importance weight of the selection condition to the ratio of 6:2:2. This ratio is applied because it is considered unreasonable to choose a certain item at an extremely large rate. This study also classifies both the conditions in which the relative importance weight of each item is set to the same value and the conditions in which the importance weight is suggested on the basis of the results of the survey targeted to exports engaged in actual designs. The results are described in Figures 12 to 17. Making comparisons between the selected five horizontal alignments, we have found that the length of road

alignments selected in consideration of technical aspects is 6.272km, which is the shortest one, and the length of road alignments selected in consideration of social and environmental aspects is 6.561km, which is the longest one.

Classification	Weight			Remark
	T	S·E	E	
Technique	6.00	2.00	2.00	Consideration of technique
Society and environment	2.00	6.00	2.00	Consideration of society and environment
Economy	2.00	2.00	6.00	Consideration of economy
Balance	3.33	3.33	3.33	Consideration of balance
Research	3.05	4.62	2.32	Investigation of question

Table 9. Classification by different weight

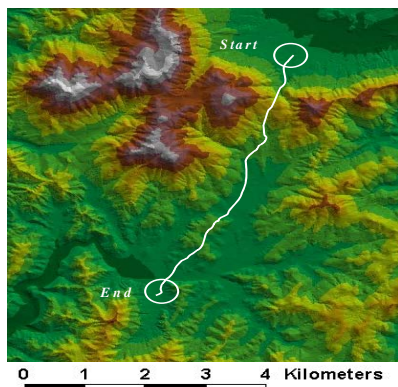


Figure 12. Technique

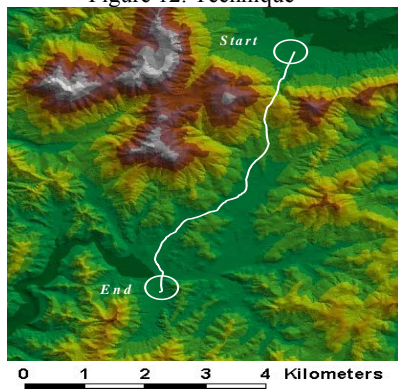


Figure 13. Society and Environment

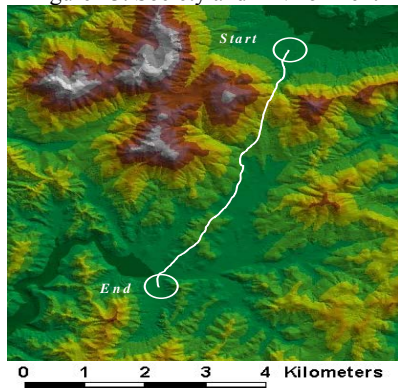


Figure 14. Economy

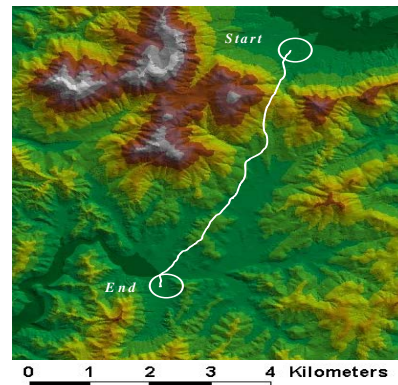


Figure 15. Balance

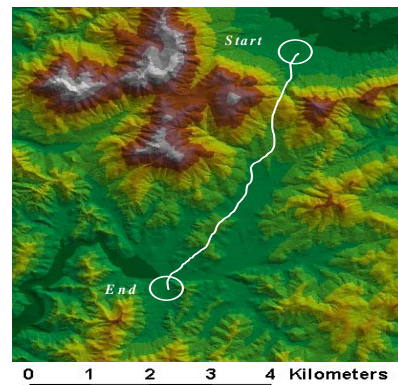


Figure 16. Research

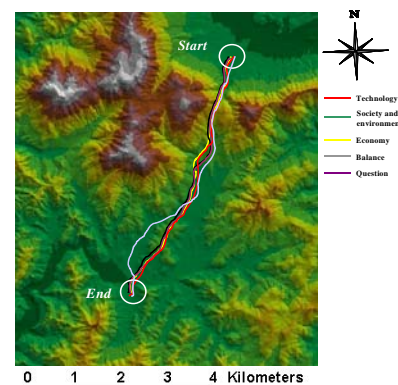


Figure 17. Overlay

Classification	Length of route(km)	Minimum elevation(m)	Maximum elevation(m)	Average elevation(m)
Technique	6.272	70.000	274.078	136.246
Society and environment	6.561	70.000	275.738	125.306
Economy	6.293	70.000	274.596	136.086
Balance	6.295	70.000	274.550	135.016
Question	6.285	69.988	274.436	134.311

Table 10. Comparison of horizontal alignment

#### 4.5 The Selection and Analysis of Vertical Alignments

Strictly speaking, the vertical cross-section chosen in this study is the one displaying the geographical features of terrain. Therefore, the vertical alignments should be planned by using

these data on geographical features. Figure 18 presents the vertical cross-section of geographical features classified into five categories.

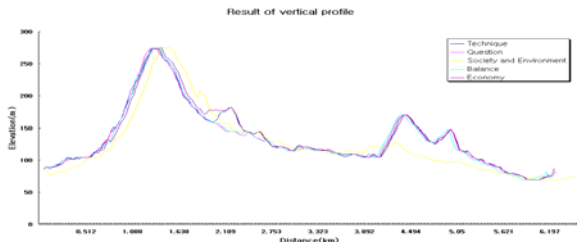


Figure 18. Result of vertical profile

The following rules of order are used to design the inclinations of vertical alignments in the vertical cross-section of this study. The first rule is to set the vertical inclinations according to the maximum geographical inclinations. The second one is to use the geographical inclinations but not to exceed the maximum range of the vertical inclination. The third is to make the planned ground height of the starting point identical with that of the end point. The fourth is that a bridge should be constructed, if the difference of embankment height to the vertical alignment is more than 20m. The fifth is the rule that a tunnel should be constructed, if the cutting height is more than 30m. It follows that, when the vertical inclination is determined according to these rules, the volume of earthwork can be estimated. The estimation method of the volume of earthwork is designed to estimate the volume of earthwork through the application of both-section average method. In order to estimate more approximate volume of the earthwork, each input value should be determined in consideration of the cutting inclination and the embankment inclination. The series of these processes are summarized in Figure 19.

Based on Figure 19, this study has constructed the system which can automatically estimate the vertical alignments by using Visual Basic, which is Microsoft's object-oriented language, and Map Object, which is a GIS tool. As for the contents of this system, the horizontal alignments in various cases selected by the analytic hierarchy process are displayed in the upper right side, and the coordinates the user wants to get are also displayed, as is shown in Figure 20. As for the analysis conditions, it is supposed to select the items of horizontal alignments obtained in the analytic hierarchy process and to input the value of road width which will be considered at the time of design. Based on the vertical cross-section drawn up by the horizontal alignments, it is also to be expected to input the value of inclination the designer wants to get. On the basis of this input value, the locations of bridges and tunnels are identified in the vertical alignment window located at the bottom part of the screen. At the same time, the extension, the volume of earthwork as well as the approximate cost of construction are estimated. Especially whenever the designer varies the vertical inclinations, the locations and the lengths of bridges and of tunnels can also be analyzed according to the corresponding vertical inclination. It means that this system is constructed to design along with the three-dimensional visual effects.

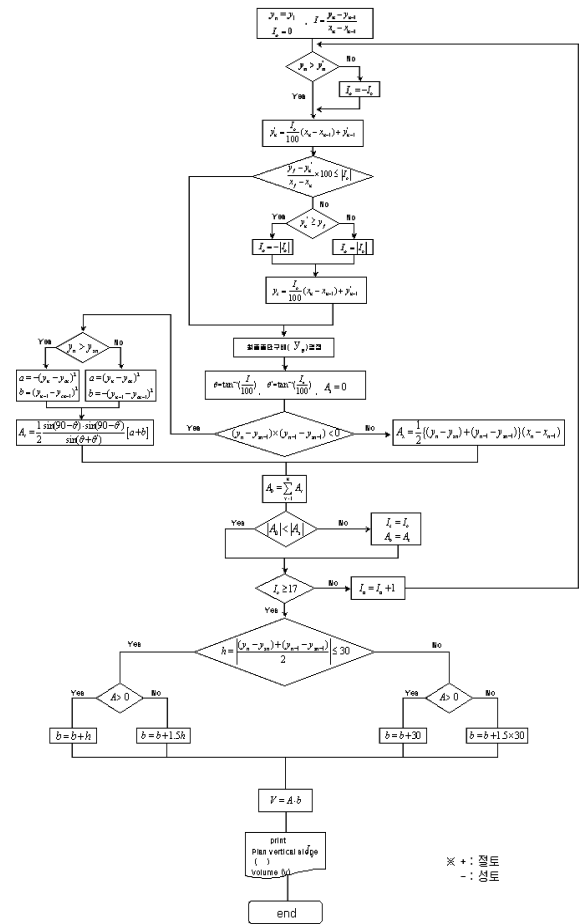


Figure 19. Flow chart for design of vertical alignment

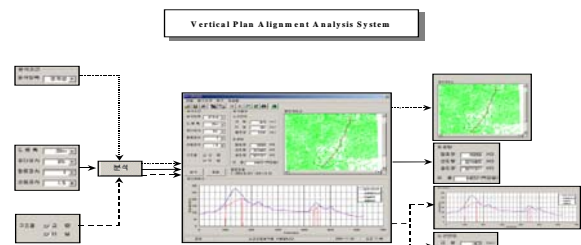


Figure 20. Screen of main

This study planned the vertical alignments by using the vertical cross-sections estimated by the five horizontal alignments selected for designing the vertical alignments. The conditions, under which the vertical alignments, the approximate volume of earthwork, and the construction cost are calculated, are classified as is shown in Table 11. The vertical alignments are selected by applying the vertical inclination regarding the vertical alignment to 5~10%. Although the embankment inclination and the cutting inclination are differently applied according to the nature of the soil, this study applies the general value of 1:1.5 in the embankment inclination and of 1:1 in the cutting inclination. The unit cost of the cutting varies according to earth and sand, blasting rocks, and ripping rocks. But this study estimates the mean value of these unit costs and applies the representative value. The construction costs of bridges and tunnels are calculated by referring to the road business handbook issued by the Ministry of Construction and Transportation in 2003. In this study, the total construction cost is calculated by adding up the total volume of cutting and

embankment to the construction cost of structures (tunnel, bridge).

Type	Condition	Remark
Slope of banking	1 : 1.5	
Slope of cutting	1 : 1.0	
Unit-price of banking	4,241 won	
Unit-price of cutting	7,336 won	
Cost of bridge construction	29,366,000 won/m	PSC-Beam (4 way)
Cost of tunnel construction	11,602,000 won/m	NATM (2 way)
Vertical slope	5 ~ 10%	

Table 11. Condition of vertical alignment

Table 12 and Figure 21 display the results of the vertical alignments designed on the premise of the conditions suggested in Table 11. Arranging the results described in Table 12 and Figure 21 and comparing the construction cost alone, we find that the best condition in the target areas of this study is the alignment selected in consideration of social and environmental aspects. When comparing it with another road alignment, we also find that the net cost of construction has reduced by 20%. But the priorities in designing alternatives varies according as how the vertical inclination is applied, even if all the vertical alignments have the same conditions. It implies that the vertical alignment considering the vertical inclination is important for designing alternatives. In this way, this study can design much better alternatives by considering the vertical alignments at the moment of selecting road alignments through the application of this system and by analyzing the inclination appropriate to the topographical features.

Vertical slope		Volume of cutting (m <sup>3</sup> )	Volume of banking (m <sup>3</sup> )	length of vertical slope (m)	cost of construction	Bridge of Tunnel (m)	length of Bridge(m)
5 %	E	521,261	795,581	6,266	36,943	1,246	0
	S	315,723	112,452	6,271	25,810	1,019	0
	T	792,706	690,561	6,280	38,895	1,313	0
	Q	492,127	435,151	6,275	33,535	1,218	0
	B	451,299	413,154	6,223	33,684	1,023	0
6 %	E	484,568	482,831	6,270	29,218	1,018	0
	S	314,379	100,873	6,275	23,227	912	0
	T	589,928	428,437	6,283	28,783	997	0
	Q	504,604	239,432	6,279	28,135	1,045	0
	B	490,973	292,398	6,227	28,207	1,034	0
7 %	E	477,646	276,609	6,274	25,491	924	0
	S	281,684	153,747	6,279	21,705	835	0
	T	477,464	266,874	6,287	26,321	963	0
	Q	497,991	174,317	6,283	25,474	952	0
	B	457,974	232,332	6,231	25,925	960	0
8 %	E	457,119	226,842	6,279	23,354	851	0
	S	275,609	224,896	6,284	19,525	720	0
	T	418,833	192,558	6,292	23,452	873	0
	Q	398,791	159,904	6,288	24,208	920	0

	B	414,388	150,928	6,235	23,808	903	0
9 %	E	418,936	149,309	6,284	21,257	792	0
	S	263,127	190,681	6,289	18,344	682	0
	T	445,117	173,297	6,297	22,963	854	0
	Q	364,925	196,329	6,293	22,534	834	0
	B	389,964	135,273	6,240	23,142	883	0
10 %	E	438,638	121,560	6,290	20,695	773	0
	S	256,214	182,856	6,295	16,921	625	0
	T	360,440	228,144	6,303	22,128	816	0
	Q	398,935	140,774	6,299	21,412	806	0
	B	397,188	153,244	6,246	20,580	766	0

Table 12. Result of vertical alignment

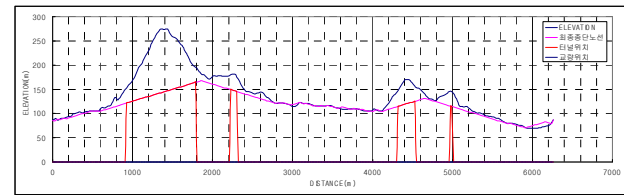


Figure 21(1). Result of vertical alignment(5% - Economy)

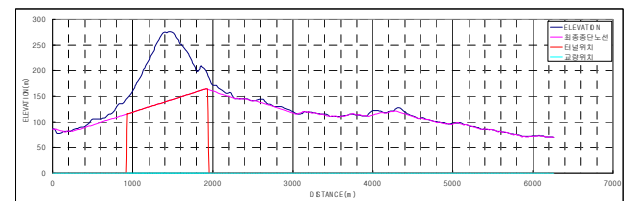


Figure 21(2). Result of vertical alignment(5% - Society)

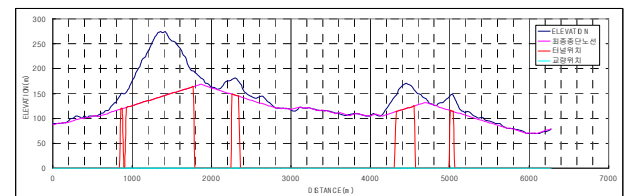


Figure 21(3). Result of vertical alignment(5% - Technique)

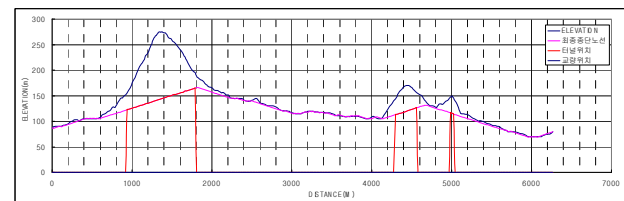


Figure 21(4). Result of vertical alignment(5% - Research)

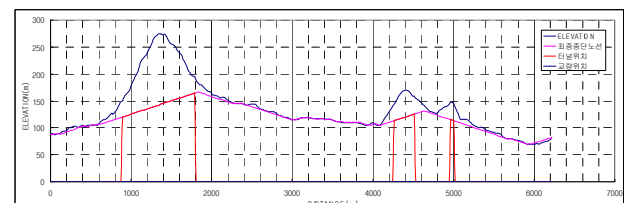


Figure 21(5). Result of vertical alignment(5% - Balance)



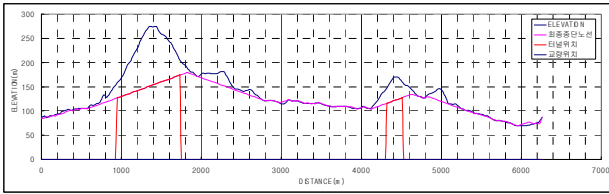


Figure 21(6). Result of vertical alignment(6% - Economy)

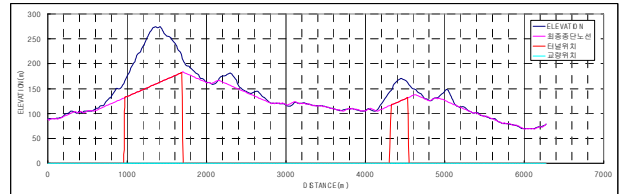


Figure 21(13). Result of vertical alignment(7% - Technique)

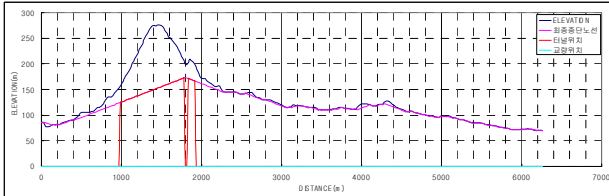


Figure 21(7). Result of vertical alignment(6% - Society)

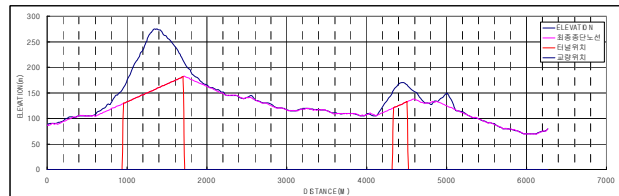


Figure 21(14). Result of vertical alignment(7% - Research)

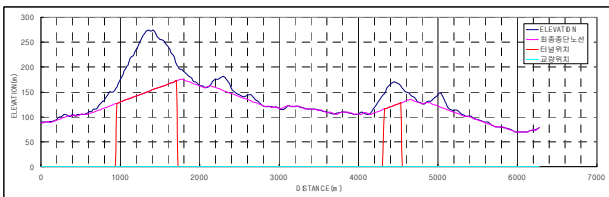


Figure 21(8). Result of vertical alignment(6% - Technique)

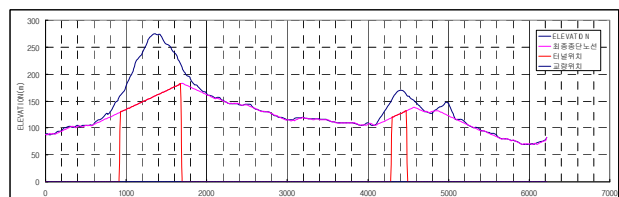


Figure 21(15). Result of vertical alignment(7% - Balance)

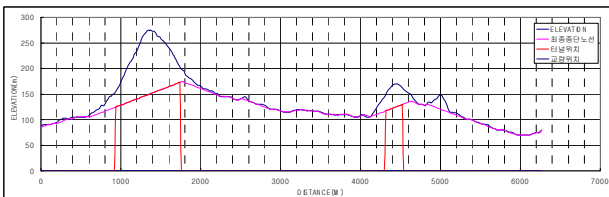


Figure 21(9). Result of vertical alignment(6% - Research)

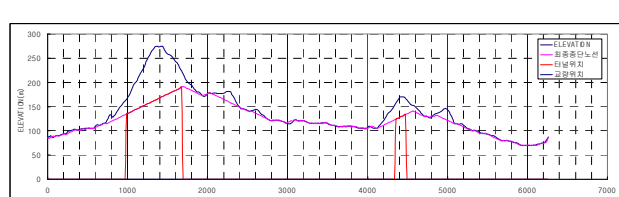


Figure 21(16). Result of vertical alignment(8% - Economy)

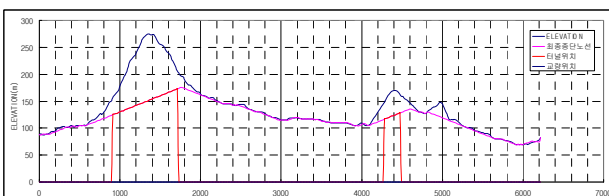


Figure 21(10). Result of vertical alignment(6% - Balance)

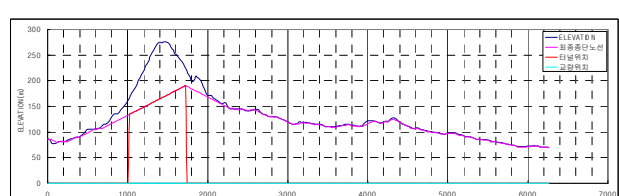


Figure 21(17). Result of vertical alignment(8% - Society)

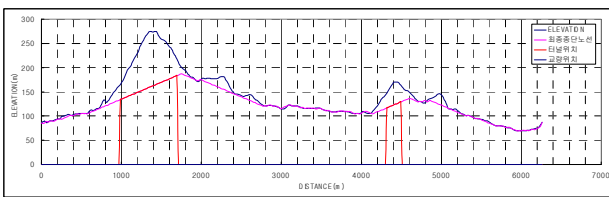


Figure 21(11). Result of vertical alignment(7% - Economy)

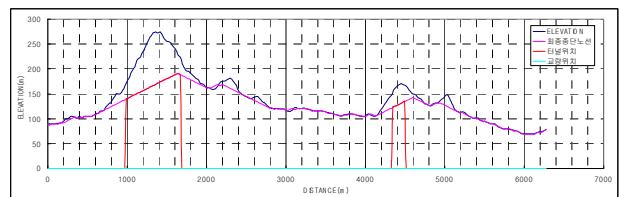


Figure 21(18). Result of vertical alignment(8% - Technique)

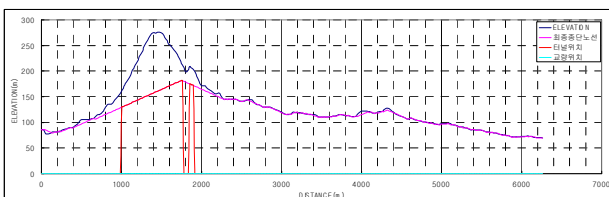


Figure 21(12). Result of vertical alignment(7% - Society)

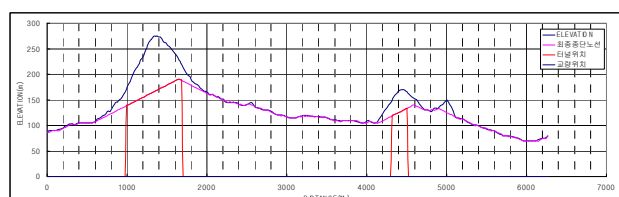


Figure 21(19). Result of vertical alignment(8% - Research)

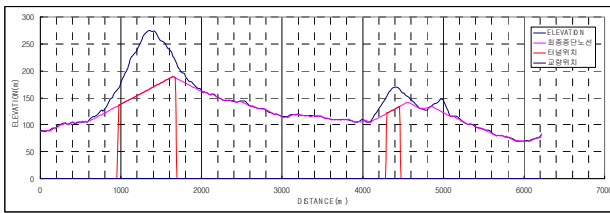


Figure 21(20). Result of vertical alignment(8% - Balance)

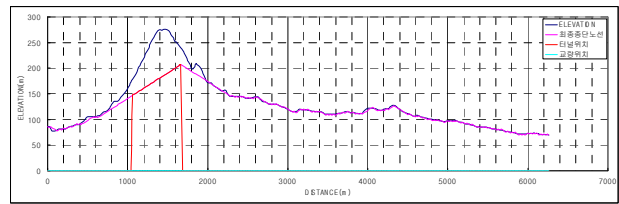


Figure 21(27). Result of vertical alignment(10% - Society)

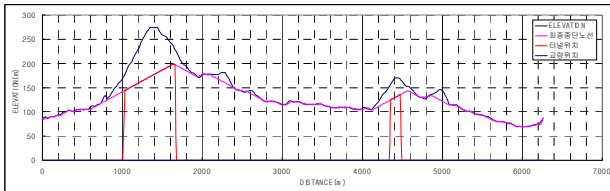


Figure 21(21). Result of vertical alignment(9% - Economy)

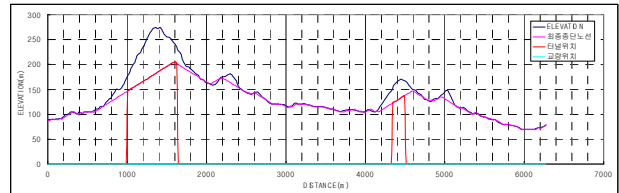


Figure 21(28). Result of vertical alignment(10% - Technique)

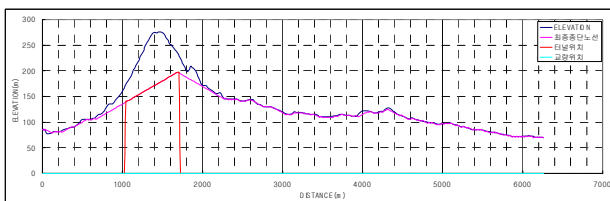


Figure 21(22). Result of vertical alignment(9% - Society)

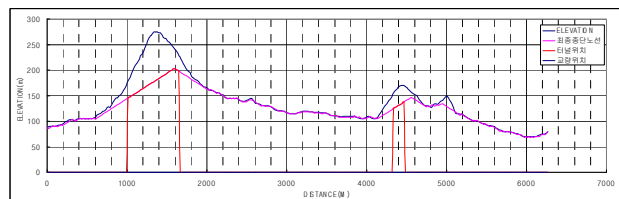


Figure 21(29). Result of vertical alignment(10% - Research)

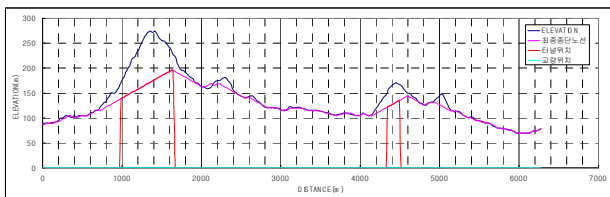


Figure 21(23). Result of vertical alignment(9% - Technique)

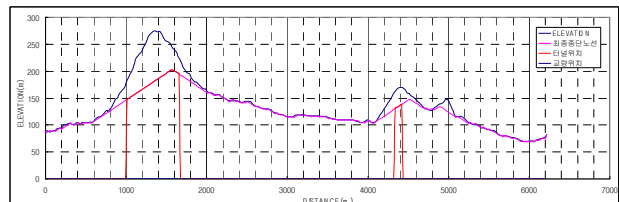


Figure 21(30). Result of vertical alignment(10% - Balance)

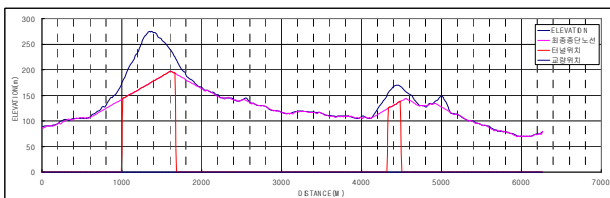


Figure 21(24). Result of vertical alignment(9% - Research)

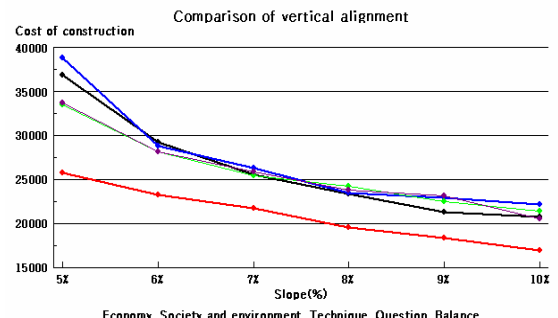


Figure 22. Comparison of vertical alignment classified cost of construction

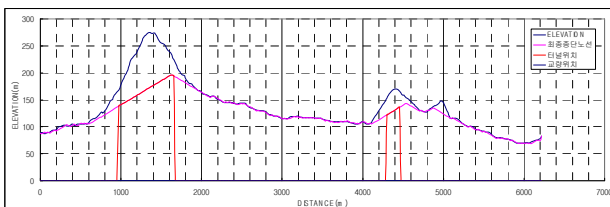


Figure 21(25). Result of vertical alignment(9% - Balance)

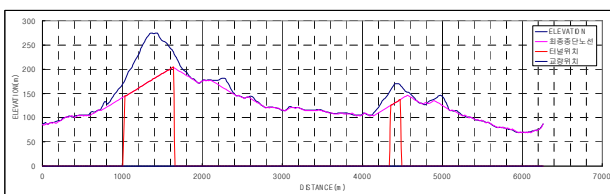


Figure 21(26). Result of vertical alignment(10% - Economy)

## 4.6 The Comparative Analysis of Alignments

### 4.6.1 The comparative analysis of the horizontal alignments

In order to verify the system constructed in this study, this study evaluates the already established road alignment which have practically been designed. This established road alignment is the four-lane highway with 20m width and 6.0km extension.

Figure 23 presents the results of overlapping the road alignments displaying the locations of the target areas of this research in the five horizontal plans obtained in the analytic hierarchy process with the already practically designed road alignments.

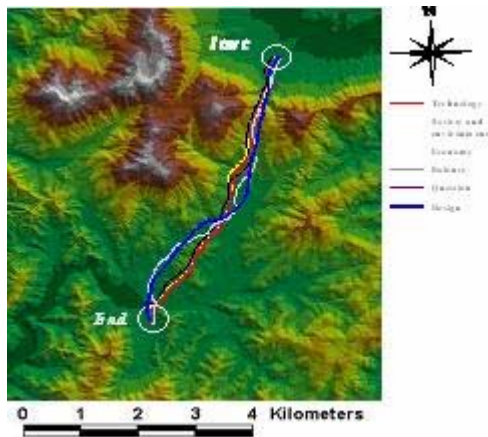


Figure 23. Overlay map of study area and horizontal map

The degree of importance is evaluated by comparing the area differences between the already established road alignments and the alignments selected by decision-making system. The estimation method is to estimate in terms of area the disparity volume between the standard road alignments and those to be compared. This method is illustrated in Figure 24. In order to quantitatively interpret the influence value of the side, the following conversion rate is applied. The importance of the horizontal alignment selected in each item is inversely proportional to the distanced area of the road alignments to be compared. Therefore, the rate can be converted into  $A : B : C = 1/A : 1/B : 1/C = A' : B' : C'$ . This rate of conversion value is selected as the influence value for each item. By converting this rate of  $A' : B' : C'$  into percentage, this study calculates the rate of influence value for each item. As the result of evaluating road alignments according to the area of target regions of this study, it is found that social and environmental aspects have been more considered than other aspects. Table 13 summarizes the compared values.

Therefore, using these methods, we can convert the evaluations of the already established road alignments and of those to be constructed into the quantitative values regarding the importance of each item.

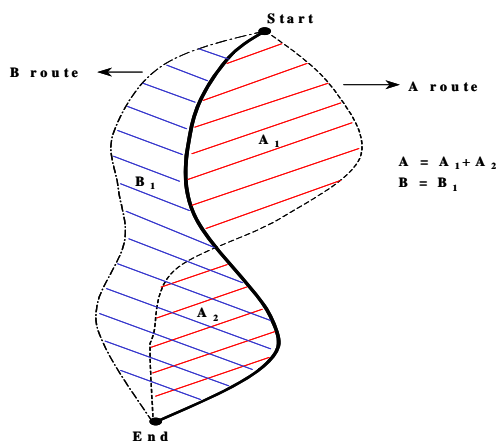


Figure 24. Method of comparison by area

Classification	Area (m <sup>2</sup> )	Evaluation
Technique	954,238.832	16.8%
Society and environment	552,842.604	29.0%
Economy	978,139.049	16.4%
Balance	838,360.637	19.1%
Question	856,309.764	18.7%

Table 13. Result of evaluation by aeca

#### 4.6.2 The Comparative Analysis of the Vertical Alignments

As the result of comparing the vertical alignments of the practicably designed road networks with the vertical alignments constructed in this system by using algorithm, it is found that the inclination of the already established vertical alignments are designed to the maximum 6%. Accordingly, this study designed the vertical inclination at 6% and comparatively analyzed it. Figure 25 describes the practicably designed vertical alignments of topographical features, and Figure 26 depicts the vertical alignments designed at the 6% vertical inclination by the system constructed in this study. Table 14 provides the analyzed values.

When we compare the already designed vertical alignments with those drawn from the comparative analyses in this study, we find that the volumes of earthwork are somewhat different from each other. It may be because the mass curve was not considered in the system of this study and because the planned vertical height was set up. Hereafter, if this weak point is complemented, it will be judged practicable to apply the method of selecting road alignments according to the decision making system to the basic design.

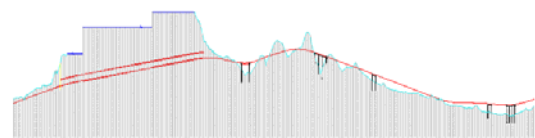


Figure 25. Design of vertical alignment in study area

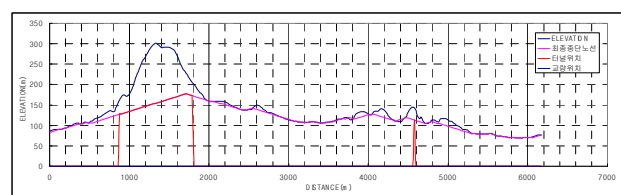


Figure 26. Result of design and result in study area(6%)

Classification	Design of vertical alignment	Plan of vertical alignment
Volume of banking	412,214.50 m <sup>3</sup>	143,447 m <sup>3</sup>
Volume of cutting	395,464.54 m <sup>3</sup>	328,897 m <sup>3</sup>
length of bridge (EA)	370m (5EA)	0m
length of tunnel (EA)	1,805m (1EA)	954m (2EA)

Table 14. Comparison of design and result vertical alignment

## 5. CONCLUSION

The following results have been drawn from the construction of the decision making system for the reasonable selection of road alignments on the basis of GIS and, at the same time, from the exploration of the method to evaluate it.

First, this study could quantitatively evaluate the appropriateness of the established road alignments by applying the analytic hierarchy process based on GIS. If this is applied to the road alignments to be constructed, objective and reliable road alignments can be selected at the moment of road planning and basic design.

Second, this study improved the technique to select road alignments by applying the decision making system based on three-dimensional information, which considers not only the decision making system based on the existing two-dimensional information but also the vertical planning. A road network can be designed scientifically and reasonably because various information can be considered independent variables, such as the vertical inclination, the volume of earthwork, the size of structure, and the construction cost, etc.

Third, it is concluded that this study can contribute to the utilization of GIS skills and to the development of road design skills because it automates the selection of road alignment by using the quantitative evaluation system constructed here and because it can also draw many comparisons in a short time.

Henceforth, road alignments will be selected in a much more developed way, if detailed items are added considering more reasonably and generally quantitative data and regional features at the time of selection the road alignment in connection with the analytic hierarchy process.

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