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Road Alignment Design Using GIS

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Abstract

In this study, several basic data for road design and GIS data were used for selecting the optimized road alignment database system. The cut and fill volumes were compared with existing manual road design method through the analysis and data application in this database system. We solved and estimated objective, economic, environmental and technical problems caused in road construction comparing existing manual method with the road alignment which was selected in GIS automatically. Also, we performed three dimensional simulation with the existing road design program and simulation of virtual reality through Virtual GIS. This study showed the method in selecting the optimized road alignment through the analysis and comparison of the selected road alignment. The goal of this study is comparison and analysis of definite cut and fill volume and environmental problem after the road construction through analyzing and comparing the social, economic, technical and environmental aspect in the road alignments with various statistic data.

Keywords : Road Desing GIS, 3D, Modelling

1. Introduction

The road construction is the basic and major industry of the nations. While constructing and improving the road, it is necessary to think over improvement by investigating the size of economy, the spending times, the necessity of construction and so on through the scientific method. For those, we should investigate the present state, the road traffic, road alignment, economy, environment, soil, construction site, compensation of land, price level and many other things. It can be processed with GIS.

Raper(1989) studied the rational method of road design which could predict the view scope distance, pleasantness and the visual stability with GIS model of topographic DTM. Hollingshead and Gerlt(1994) studied a traffic plan, a corridor position and computation of water supply inclusively. Watanatada(1987) studied for developing countries in United States and Europe. This was conducted in the focus of economical variable. And the relation between life cycle expenses of the road (construction, maintenance, user costs) and road design was used in policy decision. This model used simulation for the minimum cost alignment rather than computing optimized method.

Seo(1991) applied weight factors obtained by considering land utilization, land value and grade to a regular grid of the research area in deciding the optimized road alignment using GIS techniques. The decision of optimized road alignment using digital terrain model(Kim, 1992) showed the possibility of digital processing in planning the road alignment. The research of the earth quantity in applying GIS(Lee, 1994) was to decided an optimized alignment method by using factors that concern with earth works volume and executing method with automatic computer program. The basic design techniques of road using GIS (Park, Jeon, 1995) presented the possibility of utilization in deciding a comparative road alignment automatically in selecting the road alignment with SML, macro language algorithm in PC ARC/INFO. SQL application for selecting the position of road alignment(Lee, 1996) proposed the plan of visual analysis using a digital topographical map and applying SQL in deciding the position of road alignment. The application of GIS and Neural Network in deciding road alignment(Jo, 1998) presented the optimized road alignment considering economic, technical and environmental conditions in selecting road alignment by applying GIS and Neural Network.

This study presents the plan of selecting the optimized road alignment through the analysis and comparison of the selected road alignment by the existing manual method. The object of the study is comparison and analysis of defi-

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nite cut and fill volumes and environmental problem after completion in road construction. Other selected road alignments were conducted by a basic design using existing road design program and horizontal alignment, vertical alignment, slack, superelevation and view scope at 120 km/hr design speed was made. A bi-directional two-lane road was considered. We made a selection of the optimized road alignment through analyzing and comparing the social, economic, technical and environmental aspect in the road alignments proposed by various statistic data.

2. GIS Application in Planning Road Alignment

2.1 Deciding the Optimized Road Alignment

While deciding an optimized road alignment, the candidate basic road alignment was selected with various data and objective analysis. Actually, while selecting a road alignment, it is heavily depends on the engineers's experiences, skill and intuitive decisions because of their lack of ability in analyzing spatial and various data. Road design is composed of several processing steps. First, the rough design step is conducted in road planning and road alignment using a topographical map on a scale of 1:25,000 or 1:50,000. Next step is a preliminary road design using a topographical map on a scale of 1:5,000. After that the execution design step is made with a topographical map on a scale of 1:1,000. The economic, technical and environmental aspect should be considered while deciding the road alignment. The technical aspect is divided into traffic for transacting vehicle traffic stream and the structure considering nature conditions. In traffic, it is considered that vehicle's safety, expediency, irrational alignment being vulnerable to traffic accident and the disaffection of the driver in traveling. And the technical part in structure evaluates the construction ability, safety, maintenance cost, and economical efficiency. A topographical map, contour map, geological map, and a road network map are required for these two parts. The propriety of the road planning is considered and estimated for the investment such as construction expenses, maintenance cost and economic facility from the economic analysis aspects. The construction cost is considered not only the location of the road alignments but also many others. And in case traffic volume is small and travelling cost and travelling time is large, the effect of investment goes down. In considering the environmental aspect, we should think over the violations of living rights, urban planning area, cultural assets, and the natural monument are legal or not.

An urban planning map, topographical map, and national territory utilization map are required for this. The above mentioned database is needed in deciding the road alignments. In addition to that, some parts of data in land value and slope can be constructed as latticed mesh data or cell data. The shortest travel and proposal of the road alignment is selected through considering the attributes data such as land value, contour, direction, grade, altitude, obstacle, and the basic attributes data which constructed in database. After classifying the surrounding area of the road alignment, the attributes data required in analyzing the road alignments is connected to mesh or cell. After cut and fill volumes are computed according to the road alignment, the road design is made through using a topographical map on a scale of 1:500 or 1:5,000, the cost is calculated and the road is simulated visually through the 3 dimensional simulation of the road design.

2.2 The Method of Raster GIS Application in Planning Road Alignment

The setting-up process of road design is divided into the following five steps; the investigation of present condition, analysis and estimate of traffic demands, deciding a road alignment and the design outline, making the preliminary design, and establishment of economic planning. Many works was performed by the existing manual method in road design so far. However, there are some problems such as the absence of standardized database, the inadequacy of considering geographical and spatial features of the research area, the difficulty of many analysis and expression and the impossibility of comprehensive management in planning the road economy in the existing manual method. GIS can solve a good many parts of above matters. We can analyze various database which are standardized in polygon and attributes data by using a database GIS function. Also, the optimized road alignment can be selected easily through the excellent functions of a spatial analysis and network analysis in deciding the road alignments. The analysis techniques for the comparative estimation of an optimized road alignment in this study are cell-based modeling technique, a weight application, euclidean distance, cost-path, cut and fill and so on. Cell processing of grid is an effective method of spatial storage in analyzing the geographical feature. Especially, it is a very efficient method for storage and expression of point, line, polygon, when spatial surface is a same form.

Modeling to solve the problem of position has a merit of cell centered storage method and analysis environment. Euclidean distance is the distance between center of the starting cell and center of all other cells. The distance is computed through the square root of height and the base line in triangle.

The cost surface was used in this study and was created by a model concerning various factors that influence construction cost in general.

The modeling of construction cost based on a slope, vegetation, soil, geological features, area of the slope, lake, river, and road was computed as the resistance values while the cell moving. For example, the cost model of the road construction is made up with factors such as a soil, slope, land value, ancient site, and the existence of a rare variety. An integer or real number is stored in the cell over the cost surfaces but the negative number should not be stored. Spline is an interpolation of the minimum curvature in 2D. It passes through the input point correctly and creates a smooth line. The basic minimum curvature technique is called that thin plate interpolation and we created lattice file by inputting the height values of contour for computing cut and fill volumes and extract a region which has real width of the road by using select mask command in grid. And the height values were extracted according to the centerline of the road alignment every 20 m and the 20 m section was computed without exceeding the limit of 6%. Each height value was input as the value of an attribute through buffering the real width of the road. A lattice file and tin file of surface model were created with the value of an coverage attributes.

The cut and fill volumes were estimated by using Cutfill command through a created lattice file using contour coverage and another created lattice file computing without exceeding the limit of 6% according to the centerline height of the road. We can verify cut and fill volumes in file included in coverage. The concept of Cutfill (Fig. 1) is below.

3. Research Example

3.1 Database Making

The research area is 6th section of Chungju-Sangju

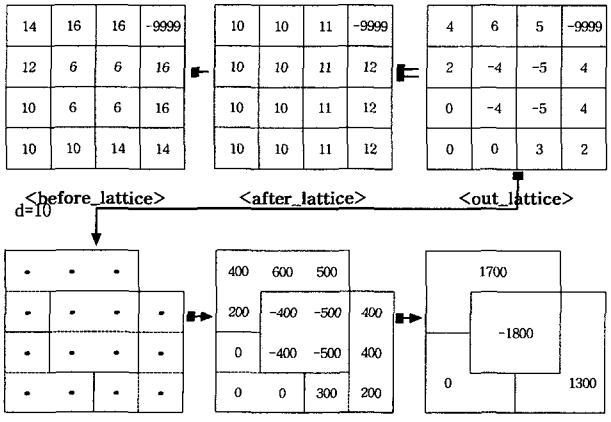

Fig. 1. Concept of Calculation of Cut and Fill Volume.

Fig. 2. GIS Data for Research Area.

expressway which is under construction.

1/5000 scale digital map and every classified thematic map are used to simplify research scope. We made a geological map, contour map, slope map, frequent heavy fog occurrence region, residential area, drainage network, government site like satellite control center database and Autocad, Arcview, Arcinfo software are used to extract, edit and CostGrid was made with weighted overlay and cost path function. We made optimized road alignment modeling with grid modeler and simulate it with erdas imagine and RD2000 programs.

3.2 Database Analysis

Costgrid model is made with Arc View modeler which can geo-spatial analyze and dynamic model. First we extracted contour with digital map and inputted landuse data, boundary lines, and heights attribute data. With this attribute data we calculated right-of-way cost which covered much portion of cost. In road design, analysis of economical efficiency is needed. The optimized path is sometime far from linear. So we should make euclidean distance analysis to assign distance of shortest path. euclidean distance is the distance between center of the starting cell and center of all neighbor cells. And buffer is not accessible in the region like dam, security area. And river data was extracted for raster GIS modeling. Basin sink was filled to decide flow direction of river. After flow-accumulation, we applied

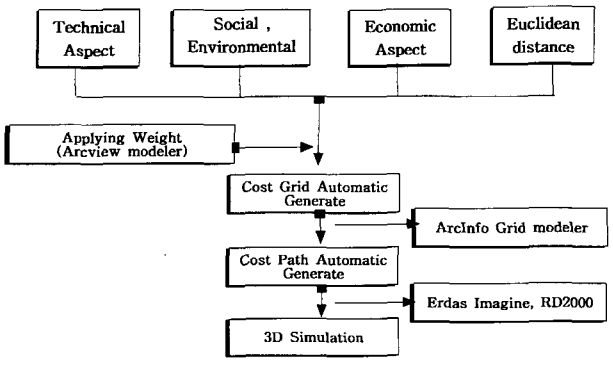

Fig. 3. Thematic Map Construction Flowchart.

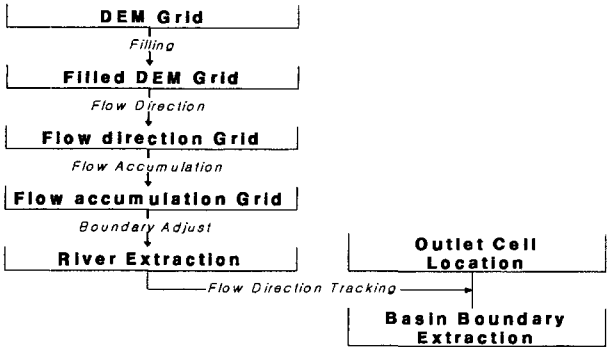

Fig. 4. River Basin Extraction Algorithm.

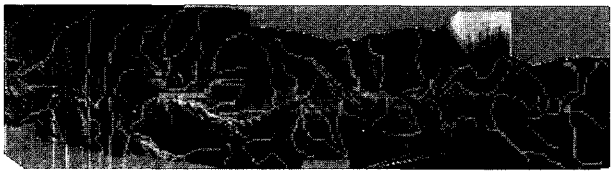

Fig. 5. Extract of River Boundary.

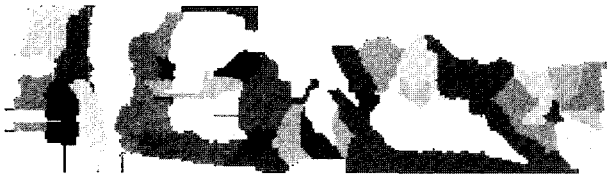

Fig. 6. Extract of River Basin.

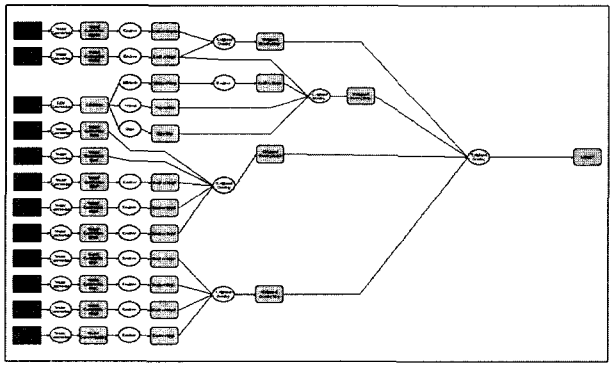

Fig. 7. CostGrid Modeling.

threshold number 100 and filtered out null data and exceed data.

The unit cost grid is made by Arc View modeler in cost-grid modeling. In this model it was easy to make change to new weighted costgrid.

Costpath model was made by arcinfo grid modeler. The step by step grid model was used during execution. Each step represents the grid expression made by expression builder.

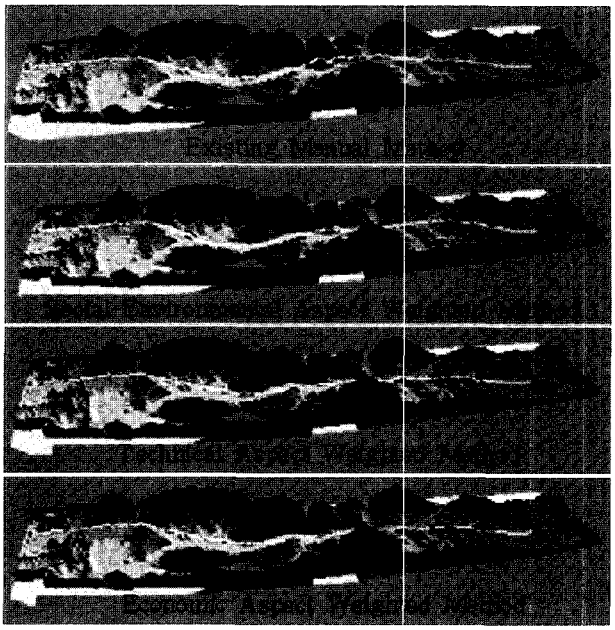

Fig. 8. Comparison of Different Weighted Model.

3.3 Road Alignment Decision with Raster GIS

To compare with previous method we made GIS based optimized road. The 1 m grids were generated for cut and fill soil volume. Raster GIS and road design program were used. Fig. 8 is the different weighted model comparison and Table 1 made a comparison of soil volume.

3D works are easily built with GIS application and road design program. We could simulate view scope and driving courses.

We compared existing manual method with GIS based road alignment for Chungju-Sangju highway, Kyungsang-buk-do. The existing manual road design methods are lack of geo-spatial analysis so it is heavily relying on expert's experience and ability. But, with this GIS analysis we

Table 1. Comparision of Cut & Fill Volume for Each Alignment (m^3)

Alignment \ Method	GIS Method			Road Design Program		
	Cut Volume	Fill Volume	Net Volume	Cut Volume	Fill Volume	Net Volume
Manual Method	2,010,000	4,001,000	1,991,000	3,090,000	3,740,000	650,000
Social Environmental Weighted Method	2,550,000	3,800,000	1,250,000	3,150,000	3,960,000	810,000
Technical Weighted Method	2,305,000	4,060,000	1,755,000	3,050,000	3,520,000	470,000
Economic Weighted Method	2,800,000	3,680,000	880,000	3,490,000	3,665,000	175,000

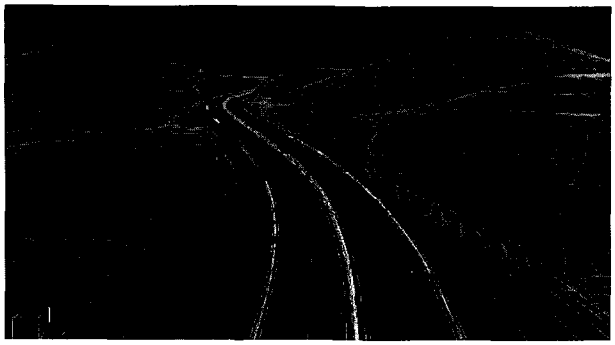

Fig. 9. Virtual Drive Simulation.

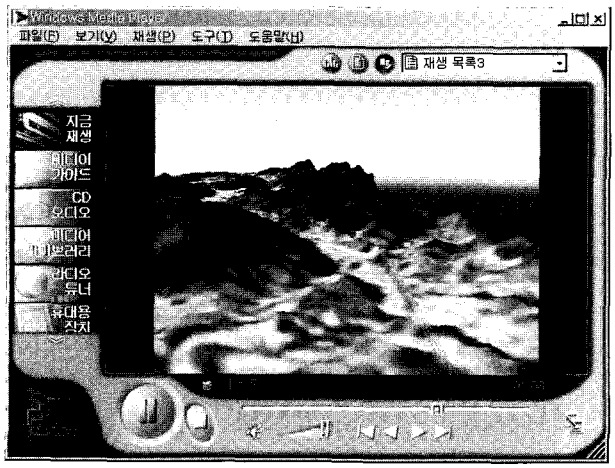

Fig. 10. Virtual Flight Simulation.

could handle data synthetically and objectively so that we might deal with public discontent quickly by changing modeling.

Economic, technical, social, environmental weight factor were computed, and it was easily changed for public discontent. 3D virtual GIS simulate view scope and environmental effect. It would be more effective when more detail factors are put into consideration.

4. Conclusions

In this study, we analyzed and compared the optimized road alignment by the existing manual design method with the road alignment automatically selected by GIS to select the optimized road alignment which is the basis of road planning. Also we studied on the measures to select reasonable road alignment and decision making through automation and development of system unlike the existing optimized road design.

We considered the social, economic, technical and environmental aspects for comparing the road alignment using the existing manual method with the automatically selected alignment by using GIS technique and reached a conclusion as belows.

While comparing an existing manual road alignment method with a GIS method, the selected optimized road alignment in GIS could minimize economy and time losses. Raster GIS technique could make automatic production of an optimized road alignment and comparison of cut and fill volumes. An optimized road alignment by the manual method was difficult in visual and three-dimensional analysis with the existing 2D topographical map. Therefore, we simulated it through the 3D Virtual GIS and it was possible to simulate view scope and scenery. The optimized road alignments could be more objective and systematic by using structures such as the bridges and tunnels which are important in designing the road alignments.

There was an economical efficiency in verifying the part of the result comparing the existing design method with GIS method in designing the road alignment. The detailed modeling using more data makes possible the better road design and it could be more objective and systematic system for supporting the decision maker in a policy making and planning. And it could be used in the actual work of deciding the road alignments and road management system.

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