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Railway Optimal Routing Using Spatial Multi Criteria Evaluation (SMCE), Shortest Path In GIS

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Abstract: *The costs paid solely for transport shows that investment in this section should be carefully reviewed, evaluated and selected. In this research, choosing best railway alternative has been investigated using a combination of Spatial Multiple Criteria Decision Making in GIS environment. Informational layers and influential ingredients, including slope, protected areas, main roads, streams, fault, privacy of village and town, geology and Land use. Tree model was developed. Layers were entered into tree model in two groups: limits and ingredient. Boolean standardization and fuzzy was applied on layers. Layers were weighted using weighting method or Analytic Hierarchy Process (AHP[1]). The results show more abilities for GIS in deciding the route by taking influential ingredients in comparison to traditional design method. The results proposed alternative A and B. By AHP path B selected as the ideal path.*

Keywords: Analytic Hierarchy Process (AHP), Boolean, Decision Making, Fuzzy, Modeling,

1. Introduction

Efficient transport network is one of the basic needs for sustainable development in the world. Railroad construction causes strengthening national economy and helps governments achieve the goals of sustainable development through saving energy and reducing devastating effects on environment. After the victory of the Islamic Revolution valuable experience in the industry has been achieved in more than 35 years (Management and Planning Organization, 2003). Establishing communication among human communities is important to provide service for different regions of the country and for the transport of food and fuel, labor force, etc; so, to reduce various financial and living losses during this transfer, optimization of transport routes is urgent. Also, usual and traditional routing methods are costly and time-consuming and are not accurate. They often don't provide desirable results (18]. Since traditional path designing depends heavily on the designer's experience, routing accuracy is overshadowed by this fact and this can impose irreparable cost on projects [1]. Spatial multi-criteria decision-making methods are commonly used with a set of alternatives that are evaluated based on conflicting and incompatible criteria [19]. Influential ingredient and criteria can be different due to features such as the purpose and method of doing work, region of study, and access to data and needed accuracy, etc. Researchers have proposed various ingredient to optimize road designs and railway in near-forest areas such as environmental agents [5] and [21], slope, land use, soil type [7] and the slope course or direct [15], rivers or areas of cultural heritage [20]. Other influential ingredient and criteria such as passenger demand and transferable population [Andersen and others, 2006) or socio-economic ingredient, or a combination of these is also used to design the ideal route [9]. Spatial Multi Criteria Evaluation (SMCE) is a process that combines geographic spatial data (main entrance) and provides decision (output) that can be the same as the ideal path railway offers. Researches in this field can be briefly summarized as follow:

The GIS-based methods have been used for highway design (22]. Wook KANG-Min, Buddha raja (2012), Rail route optimization has studied using geographic information systems. Choosing a high-speed railway along the Texas Urban Triangle have been performed using raster GIS2 and spatial decision support systems (SDSS)8 [10].

Because we cannot consider equal values for all influential ingredients in the model, we give the same value needed for relative importance of each criterion compared to the other, to provide value for each of the evaluation criteria using different ways. In fact, weigh is a relative value assigned to evaluation criterion. AHP1 is based on a simple theory that is based on three principles: decomposition, comparative judgment and synthesis or compound hierarchy of priority. Thomas Saaty is among pioneers in the introduction and operation of research known as (OR) 6 which seeks to provide a simple way to help ordinary people in the complex decisions making. It led to the introduction of analytical hierarchy process. This process depends on certain criteria that can be measured on a relative scale. Decision-makers should compare criteria in a pair wise manner so that standards are first qualitative and then will be quantitative using numbers 1 to 9. Since the binary comparisons must be consistent, inconsistency ratio should be such that it is smaller than 0.1. This shows an acceptable level of consistency with binary comparisons. In this paper, criteria for effective information layers in the model have been analyzed, prepared, weighted, standardized, and overlapped using Software ILWIS3.310. Finally, final layer zoning areas have become suitable for railway and route optimization (Fig. 3).

The aim of this study is the selection of ideal route to construct a railway and its adaptation and replacement by the railway under construction which is designed by traditional methods. The need of this study is using a new, low cost and comprehensive method using Geographic Information Systems.

2. Materials

Technical alternatives according to the criteria presented in this study, with the main track options designed by consulting engineers that portion of the rail track is being constructed to connect the two cities, Yazd and Shiraz in the Fars Province in Iran the second station in before the city of Yazd in the name of the Rakhsh station to Eqlid station, Overall, there were three variables that is located within the zone 40 UTM11projection, with the longitude 54 degrees 04 minutes 11 seconds to 54 degrees 51 minutes and 43 seconds on the Greenwich meridian and north latitude 30 degrees 53 minutes 16 seconds north latitude 31 degrees 44 minutes and 56 seconds with an average elevation of 1672 meters above the equator of the seas (Fig. 1).

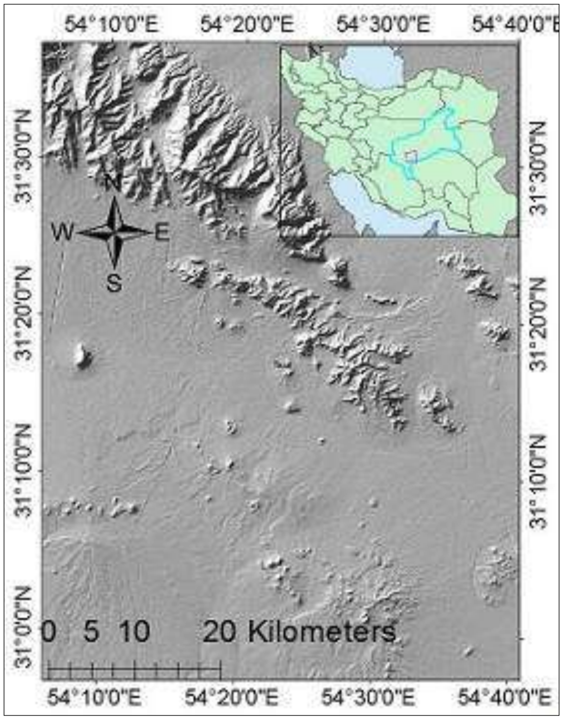


Fig. 1. The study area

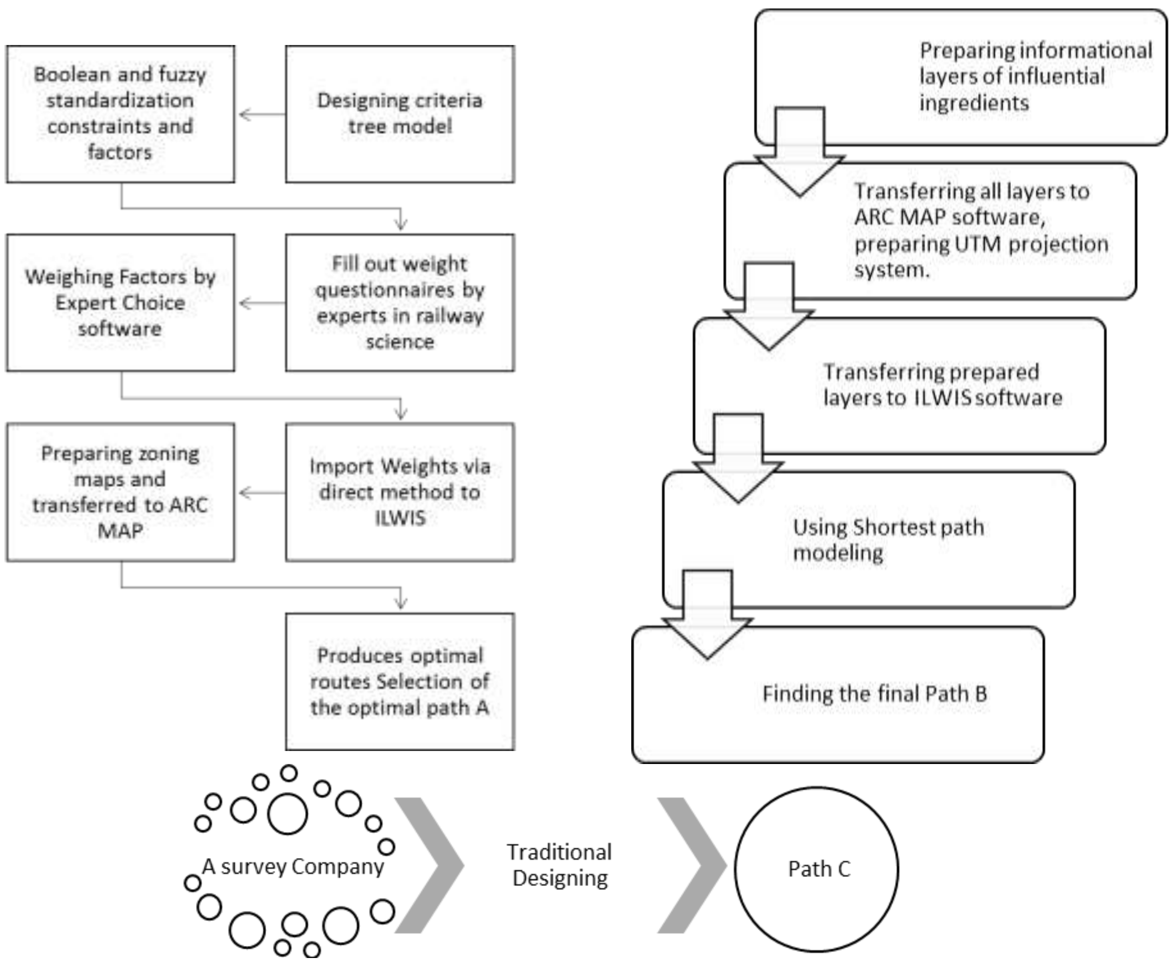
This study used a wide range of data that includes: Geological maps of the geology of the region Geological Survey of Iran to help knowledge Engineering Geology also solve problems preventing the Subsidence or landfall of earth, Better and more facilities to provide the road engineers to select the most economical route because of geological reasons and their role in the strength or breakdown of the route. Land use maps, prepared by the Department of Agriculture, which includes: use type such as groundwater, water or dry land agriculture and vegetation cover (Good Fair Poor) and rocky areas, urban forests, and lakes, etc. The slope the map created using DEM4 through ASTER7 sensor is available with good accuracy. These maps can be used to reviewed reasons such as stable and unstable slopes and to minimize excavation and earthwork, the importance of the criteria used in selecting the ideal route. Map of faults in the era to prevent landslides and building a safe route. Map environmentally protected areas: rail and road projects, because of the size and Type of projects that have a wide range of positive and negative effects on the economy, society and environment. Considering the environmental, economical and engineering boundaries (18] and topography [2] and Geology [15] and safety sustainable development projects to preserve national resources and prevent environmental and economical catastrophe.

Map of main roads:

If the main roads interfere with the rail route, construction of underpass or overpass is needed, which increases the cost and duration of projects, and is considered a negative reason. The other hand can used of the main roads for traffic and local access and access the stations and logistics that have a positive effect, therefore, in this study the ideal distance of the railway track is considered. Considering the city limits map and rural areas, routes rail should not be close to city limit (to develop the city, traffic and urban settlements and industrial estates and urban facilities, etc.) and should not be because of the use of the station and rail transit it is too far and finally to an ideal distance to be determined. Stream map:

Areas that are likely to flood or flood there or swampy areas where they are needed to keep a safe and ideal distance from them. Maps of binding locations:

Points where railway track are needed crossing to track for them such as stations or towns or where that However, according to the directions of the employer it is necessary to cross the railway track. Preparation information layers of limits and ingredient of the organizations and institution, bases or available sensors with good quality, as well as consulting engineers designing the track. Preparing information layers such as file drawing, geological maps, land use and Digital Elevation Model to analyze the relevant software. Data analysis, weighting and standardization of data and finally produce the output file path by using the software ARC MAP, EXPERT CHOICE, ILWIS. Finally by using the method Spatial Multi Criteria Evaluation modeling, two outputs with different slopes produced that was compared with the original map designed and by using the Analytical Hierarchical Process method. The three alternatives were Paired Comparison with affected criteria and the ideal route is selected. Graphical workflow diagram is as shown in Fig [2].



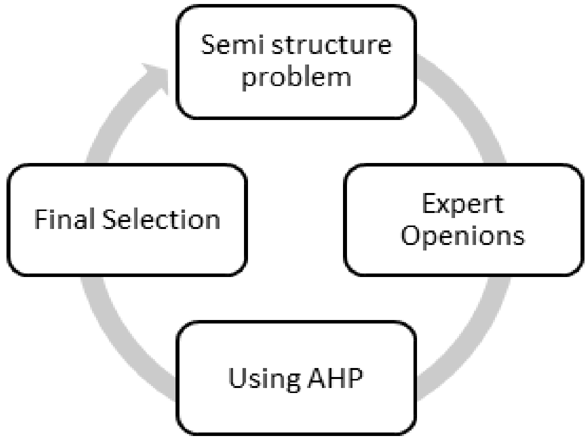


Fig. 2. Study flow chart

Data preparation:

Lack of access to spatial information and updated and usable in GIS, the absence or lack of descriptive information, and spatial terrains and dispersion information between different organizations is the main challenges in the application of GIS2 in problems solving in our country. [6].

To carry out the practical research model, informational layers needed after gathering from relevant organizations and institutions or their consulting engineers extracted, after fixing and converting the projection system into the needed projection system (here UTM40) were prepared for use in GIS2.

Implementing the details of work stages is fully described in the next chapter.

Practical implementation of the study:

The study was prepared informational layers and it were analyzed in the two shape, two output was prepared of the named option A and option B, Which together with alternative C, option is designed by the consulting engineers were paired comparisons (AHP[1]) and weighted and finally the ideal alternative is selected.

In this method, the aim of which is to fix suitable areas are crossing the railway was determined. Its limits that are include the maximum slope needs and ideal, was specified according to expert opinion by using questionaries. Effective Ingredient were identified and divided into two groups: The first group of technical perspective consists of the percent slope, land use, geology and the binding locations and environmental areas protected. The second group of economical vision includes asphalted roads and watercourse and faults and village and town boundaries.

As shown in Table [1] discovers the slope that is one of the most important causes in routing Railroads addition to technical causes have been identified as limit.

Here Alternative A, according to some experts, the slope ideal of natural land originally taken up to 30 percent and ideal produced path were analyzed. (Fig. 3)

At second alternative, after many studies and evaluation of the accuracy and various analyzes, the ideal slope of 2% for natural terrain is proposed. (Fig. 3)

Table 1. Criteria trees in ILWIS3.31

Row	Name of maps	Type of maps	Method of Standardized	Method of Rasterized	Weight	Method importing Weights	Type of Standardized
1	Slope	Constrain	boolean	attribute	-	direct	max=2,30
Group1	-	-	-	-	0.83	direct	-
1	Slope	Factor	fuzzy	attribute	0.28	direct	goal-0.2(cost)
2	Protected Area	Factor	fuzzy	distance	0.11	direct	benefit, max
3	Land Use	Factor	fuzzy	attribute	0.07	direct	attribute between 0 and 1
4	Mandatory Points	Factor	fuzzy	distance	0.5	direct	cost, max
5	Geology	Factor	fuzzy	attribute	0.04	direct	attribute between 0 and 1
Group2	-	-		-	0.17	direct	-
1	Floodway	Factor	fuzzy	distance	0.09	direct	benefit, max
2	Asphalt	Factor	fuzzy	distance	0.04	direct	combination
3	Fault	Factor	fuzzy	distance	0.05	direct	benefit, goal
4	Village	Factor	fuzzy	distance	0.39	direct	Pairwise linear
5	City Buffer	Factor	fuzzy	distance	0.43	direct	Pairwise linear

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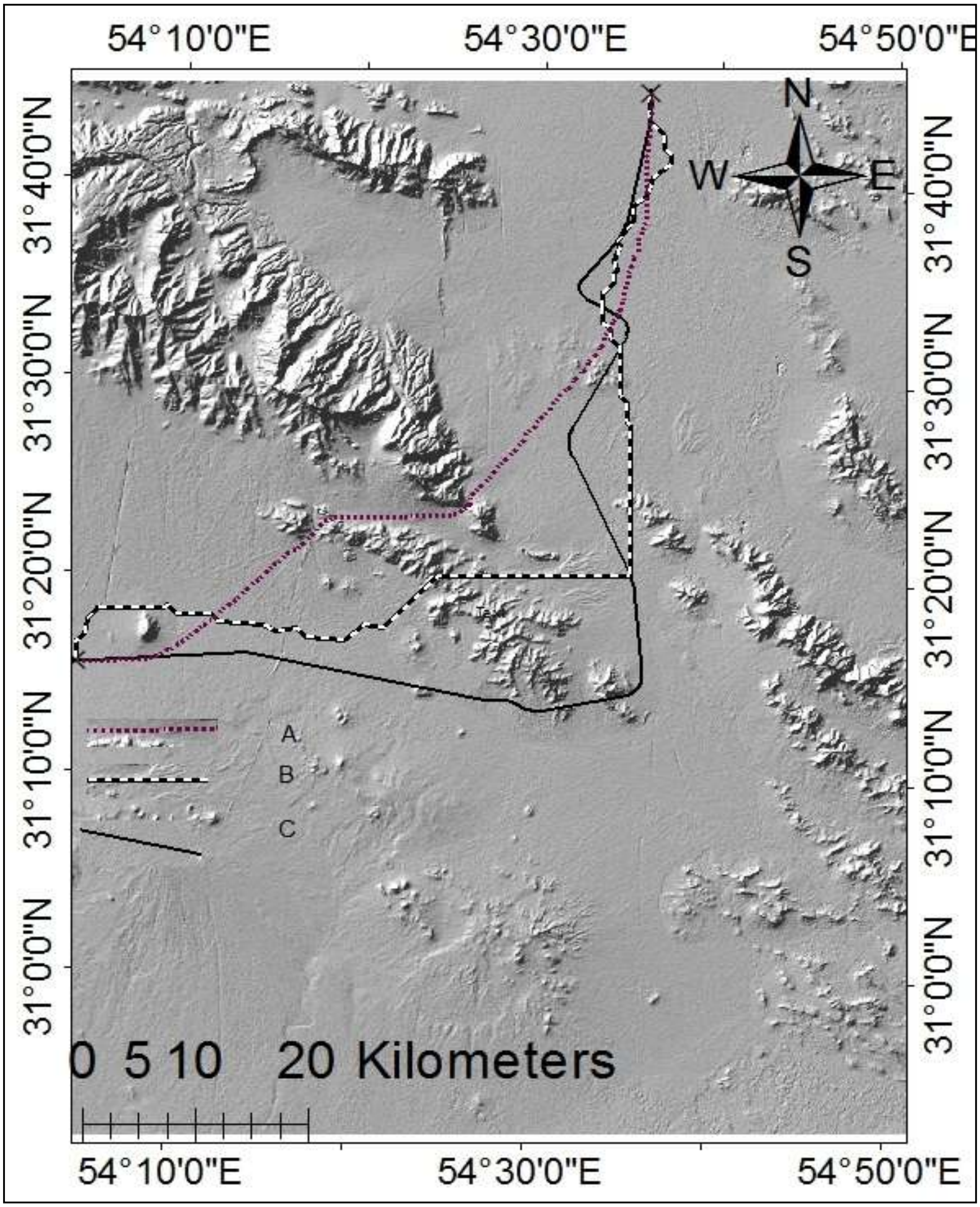

Fig. 3. Outputs resulted from A (by SMCE), B (by Shortest Path), C (by a company, traditional) methods.

In high steepness lands high trenches needed to be constructed to approach the slope allowed for railway. This could significantly raise executive costs of the project. As a consequence, in this method lands sloping more than 30 and 2 percent were completely eliminated in 1st and 2nd alternatives by Boolean method and they were considered as Zero. Slopes less than 30 and 2 percent were considered as maximum amount, that is, one.

Under expert supervisions other influential ingredient were turned into distance map and raster. Causes included distance from fault, binding points, road, ecological and geological regions as well as streams. It needs mentioning that all files were sliced in ARC MAP and they were zoned 40 after determining and turning visual system to UTM[5]. After preparation in ILWIS3.31 they are imported for SMCE3 modeling. Generally, executive steps for preparing ideal path include:

Preparing informational layers and influential ingredient from DWG[9] files of consultant engineers, geology organizations, surveying and agricultural Jihad department. Extracting required informational layers from existing files. Entering all informational layers in ARC MAP software, to slice and prepare projection system.

Transferring all informational layers to ILWIS3.31 software. Determining and reapplying projection system (UTM, WGS84, Zone40N)[5] and determining Spheroids and Datum's. Changing all influential ingredient and limit to Raster files.

Constructing tree model or criteria tree. Mapping influential criteria including slope map by the use of contour line and creating distance maps from other ingredient. Standardizing all ingredient and limits. Weighting to ingredient and groups using AHP1 method and EXPERT CHOICE software. Overlapping layers and producing the final layer of suitable zoning for railway passing. Transferring final map zoning to ARCMAP and produce final layer path. Three produced alternatives A, B, C are finally analyzed and compared be expert view and AHP1 method about every single criterion. At last, the ideal alternative is chosen.

5. Results and discussion

in designing routes, other researchers introduced just some influential ingredients such as culture, land use, natural resources [7] or mineral resources, population density, economic and environmental factors [5] and [12] as influential.

Using statistical tools and topography as well as preparing appropriate algorithms [11] and [14] and the informational layers of main roads and subsidiary roads, forbidden areas, faults and erosion and (Darvishsefat et al., 2007) and (Heydari et al., 2008) and (Negahdari et al., 2012) have been introduced and investigated as influential ingredients.

The results of previous studies were related to informational layers and influential ingredients and any lack in them could affect final result. It is essential to use a route designed in such a way that all economic aspects (shortest path) as well as environmental and technical ones are considered in railway routing. On the other hand, after preparing final route it is necessary to assess the accuracy and control the route using technical requirements (railway geometrical plan by-law, 2004). This point has not been investigated in previous studies. No optimal slope of natural lands was suggested for route designing in previous studies. Furthermore, the proposed slopes could not provide the longitudinal slope required for railway. Expert reviews have considered slope as the most influential ingredients in route designing. Thus in the present study, route slope has been examined in two states. Figure [3] shows the main output of the first and second methods as well as the existing route. As they show, option A is the shortest path but it passes more steep and mountainous areas and it has obtained lowest expert ranking in comparison to other options.

6. Conclusion

Option A, which is the route designed by SMCE[3] modeling, has been designed by the expert supervision considering the restriction of natural land slope of 30%. It provides influential ingredients according to standards required for them. It is the shortest route but it passes very steep areas in such a way that in some places the longitudinal slope suitable for railway has been violated (Fig. 3).

Route B has been designed by SMCE[3] modeling and it has modified natural land slope to 2%. After controlling longitudinal slope, it passed areas with more suitable longitudinal slope. It provided the suitable slope. Also, influential ingredients as well as limitations were regarded according to required standards (Fig. 3).

Route C, which was designed by traditional route engineers, is the longest route and thus the most costly route to build (because of length). It mainly passes less slanted areas (Fig. 3).

In this study, the relative importance of every single option is considered in comparison to other options and to influential ingredients. Also, expert views were considered and used in final conclusion. Using AHP, option B has been chosen.

Finally, the most important capability of SMCE models, which is the ability to consider wholly and comprehensively all ingredients and limitations and to analyze overlap and produce output, has been proved.

The capability to examine the studied area in different states and conditions regarding different inputs is one of the advantages of GIS[2].

Notes:

1-Analitical Hierarchical Process (AHP)
2-Geographical Information System (GIS)
3-Spatial Multi Criteria Evaluation (SMCE)
4-Digital Elevation Model (DEM)
5-Universal Transverse Mercator (UTM)
6-Operation Research (OR)
7-Advanced Space borne Thermal Emission and Reflectance Radiometer (ASTRE)
8-Spatial Decision Support System (SDSS)
9-Drawing (DWG)
10-Integrated Land and Water Information System (ILWIS)
11-Remote sensing (RS)

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