

# Design and Application of Hydraulic Engineering Destroy Risk Avoidance Path System Based on ArcGIS Engine

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This paper took Visual Basic as the programming language, chose Windows XP system and ArcGIS 9.2 as the system platforms, and developed Hydraulic Engineering Destroy Risk Avoidance Path System (hereafter referred to as HEDRAPS) by ArcGIS Engine 9.2. The system has been applied to the practice of A hydraulic engineering destroy risk avoidance, aiming to verify its integrity and practicability of various functions. The application of HEDRAPS can both improve the theoretical research concerning the hydraulic engineering risk management and guide the practice process of hydraulic engineering risk emergency management.

## 1. Introduction

The flood is one of the main and frequent natural disasters in the world. The primary goal of hydraulic engineering is to prevent ecological damage and economic loss caused by the flood. Various countries have focused on the construction of hydraulic engineering. In the past half century, the major flood disasters are increasingly frequent around the world, therefore, result in severe damages. Therefore, the heavy loss caused by devastating flood shall not be neglected. The Arc Objects promoted by ESRI Company is integrated with most of GIS applications based on COM technology's component object library. Some scholars have conducted many beneficial researches on ArcGIS, which helped the research of this paper greatly. Olivera et al (2006) introduced the tool for water and soil evaluation based on ArcGIS in Texas. Boroushaki et al (2008) discussed the decision-making model integrated with AHP-OWA and ArcGIS. Kneissl et al (2011) applied ArcGIS software to design an independent map projection of volcanic eruption scale. Liu et al (2012) conducted quantitative evaluation on mineral resources based on the ArcGIS platform. Li and Luo (2013) took Visual Studio 2008 as the platform to develop the forest resource management system in Major Mountain Forest Farm and combing ArcGIS Engine secondary development kit.

From the perspective of the above mentioned research achievements, the scholars have conducted sufficient researches on the design and application of management systems based on ArcGIS. However, there are few researches on the prevention and control of destructive risk of hydraulic engineering. This paper constructed hydraulic engineering destroys risk avoidance path selection model based on the shortest path rule and Dijkstra algorithm by combing the fuzzy variable assessment method. The ArcGIS Engine 9.2 was adopted to develop HEDRAPS, so as to achieve the visual management at the time of destroy risk of hydraulic engineering.

## 2. Construction of Hydraulic Engineering Destroy Risk Avoidance Path Selection Model

### 2.1 Construct Road Network Database

The network applied by ArcGIS Network Analyst is stored in the form of the network database. We can build the network database by using the traffic roads within the risk impact region. The network database includes three network elements including border source, link point source and turn source. The line feature builds the database via border source. The point feature builds the database via link power. The turn features builds the database via turn source. The road network database is built in Geodatabase's work space, which can support road's multiple boundaries and focus sources so as to conduct multi-model network analysis.

## 2.2 Design Optimal Evacuation Road

The shortest path is the basic problem in applied mathematics. The design of the optimal evacuation path of hydraulic engineering destroy risk requires the analysis model of the shortest path for certain reference.

Assume  $G \leq V, E >$  is a non-empty simple finite graph;  $v$  is the set of node;  $E$  is the border set. For any of weight,  $P$  is the effective path between two points in  $G$ ; then it is the optimal path between two points in  $G$ .

Computer scientist Edsger W. Dijkstra (1956) have proposed the Dijkstra algorithm generates the shortest path according to the sequence of path length increment, which is applicable to the shortest path algorithms with all the arcs' weight as non-negative.

## 2.3 Shelter Selection

The shelter selection involves many complex and inconstant factors with certain range of fluctuation. According to this range, the variable fuzzy set can be determined to conduct fuzzy comprehensive evaluation. The characteristic value matrix of evaluation index of shelter selection scheme is as Eq (1).

$$X_{m \times n} = (x_{ij}) \quad (1)$$

The matrix row represents evaluation index  $i (i=1,2,\dots,m; m$  is the number of index); the matrix column represents index  $j (j=1,2,\dots,n; n$  is the number of alternatives), the standard interval  $[a, b]$  matrix  $I_{(a,b)}$  of scheme index  $i$  and grade  $h$ . References to the equations should be as Eq(2).

$$I_{AB} = AB_{m \times n} = [a, b]_{ih} \quad (2)$$

The solution procedure of variable fuzzy set engineering approach of shelter selection scheme is as follows:

Step 1, determine the variation interval  $[c, d]$  matrix of index  $i$  and grade  $h$  according to the interval  $[a, b]$ . References to equations should be as Eq (3).

$$I_{cd} = CD_{m \times c} = [c, d]_{ih}, \quad h=1, 2, \dots, c, \quad c \text{ is level} \quad (3)$$

Step 2, determine the matrix  $M$  of index  $i$  and grade  $h$  according to the analysis on index  $i$ . References to the equations should be as Eq(4).

$$M_{m \times c} = (m_{ih}) \quad (4)$$

Step 3, when the evaluation index  $x$  falls at the left side of matrix  $M$ , its relative difference should be as Eq(5).

$$\begin{cases} D_A = \left( \frac{x-a}{M-a} \right)^\beta, & x \in [a, m] \\ D_A = -\left( \frac{x-a}{c-a} \right)^\beta, & x \in [c, a] \end{cases} \quad (5)$$

When the evaluation index falls at the left side of matrix  $M$ , its relative difference should be as Eq(6).

$$\begin{cases} D_A = \left( \frac{x-b}{M-b} \right)^\beta, & x \in [M, b] \\ D_A = -\left( \frac{x-b}{d-b} \right)^\beta, & x \in [b, d] \end{cases} \quad (6)$$

Take the value as 1 with non-negative  $\beta$  in the formula. Namely, the relative difference function model is a linear function.

Step 4, calculate the synthetic relative membership matrix of sample  $j$  and index  $i$  to rank  $h$ . The equations should be as Eq(7).

$${}_j U_{m \times c} = ({}_j u_{ih}) \quad (7)$$

Step 5, determine the index weight vector. The equations should be as Eq(8).

$$\vec{w} = (w_1, w_2, \dots, w_m) = (w_i) \quad (8)$$

Step 6, calculate the grade feature value  $h$  of shelter selection scheme  $j$ . The equations should be as Eq(9).

$$U_{c \times n} = \vec{w}({}_j u_{ih}) = u_{hj} \quad (9)$$

Step 7, calculate the characteristic values of shelter selection scheme. The equations should be as Eq(10).

$$\vec{H} = (1, 2, \dots, c)(u_{ij}) = (H_1, H_2, \dots, H_n) \quad (10)$$

### 3. System Design and Development of HEDRAPS

#### 3.1 System Framework Design of HEDRAPS

The structure framework was showed in Figure 1.

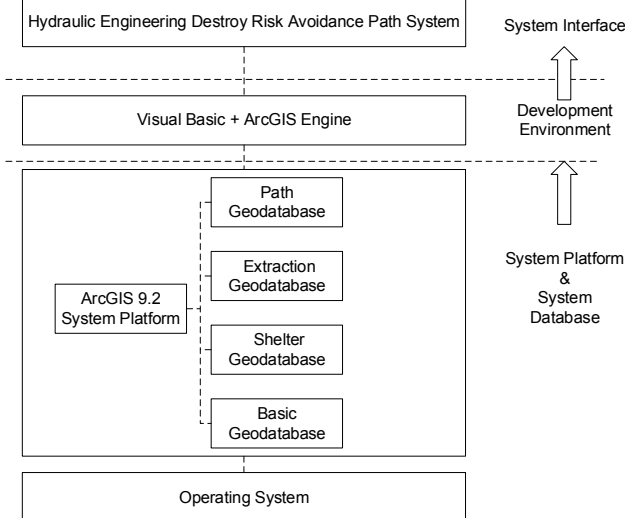


Figure 1: HEDRAPS's System Architecture Framework

It can be seen from Figure 1 that the system platform and system database layer are the substructure of system realization. The development environment is dominant by VB and ArcGIS Engine components.

#### 3.2 Construct Road Network Database

The system function design was shown in Figure 2.

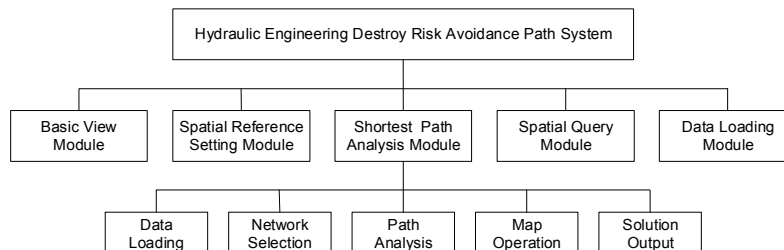


Figure 2: HEDRAPS's System Function Design

It can be seen from Figure 2 that the shortest path module is the core for the whole system function, which can be divided into five sub modules including data loading, network selection, shortest path analysis, man operation and solution output etc.

#### 3.3 Construct Road Network Database

The HEDRAPS took the Visual Basic as the programming language and Windows XP system and ArcGIS 9.2 as the system platforms to carry out the development by adopting ArcGIS Engine 9.2. The Visual Basic application can manage the database in various different provinces, which provides a reliable tool or GIS data analysis and processing.

### 4. Application of HEDRAPS

#### 4.1 Summary of A Engineering

An engineering is located in the "land of fish and rice" at the lower reaches of Yangtze River in China, where is the core region of Yangtze River Delta. An engineering will be easily invaded by large-scale flood during

Meiyu period with high probability for destroy risk. Based on this, this paper took the destroy risk confronted by A engineering as the research object to select proper avoidance place and path by applying HEDRAPs.

**4.2 Shelter Unit Division and Spatial Data Editing**

The specific steps are as follows:

- (1) Build Shapfiles, start ArcCatalog, select New/Shapfiles, input name and feature type.
- (2) Open the cell attribute table, select Opinions/Add Field, add the fields such as area and population size etc.
- (3) Open Field Calculator dialog box in the attribute table, check Advance options and input VBA code.

**4.3 A Engineering Destroy Risk Avoidance Shelter Selection**

(1) Initial Selection of Avoidance Shelter

In order to make a rapid choice, the initial screening must be done on the original scheme. Assume  $\Omega$  is the plane space within the range of risk influence,  $P_i=(i=1,2,\dots,n_1)$  was the evacuation point in the plane;  $B_j=(j=1,2,\dots,n_2)$  was the shelter point in the plane; the constraint condition of spatial space was  $|P_i - B_j| \leq d$ . This paper assumed  $d=9$  km; 16 shelter points were selected in the plane. The details are in Table 1.

Table 1: Refuge Point Primary Selection (Space distance constraints)

Symbol	Context	Symbol	Context	Symbol	Context	Symbol	Context
1	A	5	E	9	I	13	M
2	B	6	F	10	J	14	N
3	C	7	G	11	K	15	O
4	D	8	H	12	L	16	P

$S_i$  is the safety coefficient of various shelter points;  $s$  is the minimum safety coefficient; then  $S_i \geq s$ . Assumed  $s=2.5$ , the safety condition of various shelter points after the expert evaluation was showed in Table 2.

Table 2: Refuge Point Primary Selection (Security evacuation)

Refuge Point	Ground Elevation	Submerged(Y/N)	Security Index
A	17	Y	0
B	15	N	4.5
C	14	N	2.5
D	15	N	3
E	17	N	3
F	16	N	3.5
G	14	N	3
H	13	N	4
I	14	N	4.5
J	13	N	4.5
K	13	N	3.5
L	16	N	2
M	12	N	1.5
N	13	N	1.5
O	14	N	1.5
P	16	Y	0.5

It can be analysed from Table 2 that ten shelter points including B, C, D, E, F, G, H, I, J and K conform to  $S_i \geq s$  among 16 optional shelter points. Assume  $C_i$  is the capacity of shelter point;  $c$  is the population size of evacuation point, then  $C_i \geq c$ . This paper assumed  $c=150$  persons. The population capacity of various shelter points was shown in Table 3.

Table 3: Refuge Point Primary Selection (Victim capacity)

Point	Capacity	Point	Capacity	Point	Capacity	Point	Capacity
A	500	E	200	I	100	M	300
B	1500	F	200	J	300	N	150
C	130	G	100	K	1000	O	800
D	100	H	800	L	2000	P	900

It can be analysed from Table 4 that six shelter points including B, E, F, H, J and K conform to  $C_i \geq c$  among ten optional ones after safety evaluation. Assume  $G_i$  is the road grades around the shelter;  $g$  is the minimum road grade up to the requirement of evacuation access, then  $G_i \geq g$ . This paper assumed  $g=1$ . The road grades around the shelter points were shown in Table 4.

Table 4: Refuge Point Primary Selection (Road rank)

Point	Rank	Point	Rank	Point	Rank	Point	Rank
A	2	E	0.5	I	3	M	1
B	1	F	0.5	J	3	N	1
C	0.5	G	0	K	3	O	1
D	0	H	2	L	0	P	0

It can be analysed from Table 5 that four shelter points including B, H, J and K conform to the requirement  $G_i \geq g$  among six ones after safety evaluation and population capacity evaluation.

(2) Network Analysis

This paper took the evacuation point Z as the datum point to choose the shortest path among four evacuation points including B, H, J and K. The shortest path generation shall output the static shortest path and dynamic shortest path. The dataset definition attributes were shown in Table 5.

Table 5: Network Dataset Attribute Definition

Symbol	Context	Symbol	Context	Symbol	Context	Symbol	Context
NAME	Name	USE	Usage	UNITS	Units	DATAT	Datatype
LEN	Length	MCOST	Money	MET	Meters	DOUBLE	Precision
MINT	Mint	TCOST	Timing	MIN	Minutes	DOUBLE	Precision

(3) Fuzzy Variable Assessment Analysis

Assume the evaluation index is the shortest spatial distance;  $X_1$  is the shortest evacuation time;  $X_2$  is the safety condition of shelter points;  $X_3$  is the population capacity of shelter points;  $X_4$  the index value of various shelter points is shown in Table 6.

Table 6: Value Index of Refuge Point

Refuge Point	$X_1$	$X_2$	$X_3$	$X_4$
B	6.278	9.7	4.5	1500
H	8.467	16.1	4	800
J	10.167	21.6	4.5	300
K	10.053	16.4	3.5	1000

The evaluation standard interval of shelter selection is shown in Table 7 by combing the practical condition and experience evaluation.

Table 7: Value Index of Refuge Point

Index	I	II	III	IV	V
$X_1$	1-7	7-12	12-18	18-24	24-30
$X_2$	1-10	10-120	20-30	30-45	45-80
$X_3$	5-4	4-3	3-2	2-1	1-0
$X_4$	6,000-1,000	1,000-500	500-300	300-150	150-50

To calculate the grade standard difference function  $v_A(\mu)_{in}$  by judging whether the evaluation index  $x$  was at the left side or right side of  $M$  according to matrix  $I_{ab}$ ,  $I_{cd}$  and  $M$ . If  $x$  was at the left side of  $M$ , then choose the Eq (5); if  $x$  was at the right side of  $M$ , choose the Eq (6).

Relative Membership Matrix of Shelter Point B, H, J, K

$$\mu_1 = \begin{bmatrix} 0.56 & 0.44 & 0 & 0 & 0 \\ 0.52 & 0.48 & 0 & 0 & 0 \\ 0.5 & 0.5 & 0 & 0 & 0 \\ 0.2 & 0.7 & 0.3 & 0 & 0 \end{bmatrix} \quad \mu_2 = \begin{bmatrix} 0.35 & 1.07 & 0.15 & 0 & 0 \\ 0.2 & 1.01 & 0.31 & 0 & 0 \\ 0.75 & 0.25 & 0 & 0 & 0 \\ 0 & 0 & 0.5 & 0.5 & 0 \end{bmatrix}$$

$$\mu_3 = \begin{bmatrix} 0.18 & 1.07 & 0.32 & 0 & 0 \\ 0 & 0.42 & 0.66 & 0.08 & 0 \\ 0 & 0.5 & 0.5 & 0 & 0 \\ 0.5 & 0.5 & 0 & 0 & 0 \end{bmatrix} \quad \mu_4 = \begin{bmatrix} 0.19 & 1.07 & 0.31 & 0 & 0 \\ 0.18 & 1.02 & 0.32 & 0 & 0 \\ 0.25 & 0.75 & 0.25 & 0 & 0 \\ 0.9 & 0.1 & 0 & 0 & 0 \end{bmatrix}$$

According to the variable evaluation model, as Eq(11).

$$v_A(\mu)_h = \frac{1}{1 + \left\{ \frac{\sum_{i=1}^m [w_i(1 - \mu_A u_{ih})]^p}{\sum_{i=1}^m (w_i \mu_A u_{ih})} \right\}^{\frac{\alpha}{p}}}$$

The modelling standard parameter  $\alpha=1$  with hamming distance  $p=1$ . The characteristic values of different weight grades of various schemes were obtained by taking all the above parameter vectors into weight evaluation model, the comprehensive evaluation is shown in Table 8.

Table 8: Comprehensive Evaluation of Refuge Point

Refuge Point	Characteristic value of unequal weight grades	Standard interval of shelter
B	1.579	II
H	1.963	II
J	2.317	III
K	1.955	II

According to the principle in Table 8, the smaller of unequal weights, and the better. The shelter point B shall be selected as the evacuation point Z's shelter point with the shortest avoidance path.

## 5. Conclusions

The following conclusions can be reached through the research of this paper.

- (1) HEDRAPs took Visual Basic as the programming language and Windows XP system and ArcGIS 9.2 as the system platforms and adopted ArcGIS Engine 9.2 for development, which is applicable to non-professional personnel operation with improved human-computer interaction.
- (2) The GIS spatial analysis function and network analysis function were fully applied to drive HEDRAPs to become a system with complete structure.
- (3) HEDRAPs adopted fuzzy variable assessment method to evaluate the initial scheme of shelter selection, which improves the accuracy and reliability of HEDRAPs on calculating the shortest path of shelters.

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