Risk Identification and Assessment of the Accidents for Distance Water Transfer Project

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Abstract. For South to North Water Transfer Project (SNWTP) in China with a long open canal, the distance water transfer system is a complex river system communicating with rivers and lakes along the way. Water delivery safety is threatened by various potential accidents. In this paper, using check list method, the accident risk was identified and the accident types were distinguished. Then, using fuzzy opinion centralized decision method (FOCD) and analytic hierarchy process (AHP), the risk assessment system was established and the assessment model was developed. Finally, the accident risk and the influence degree of various types of accidents for SNWTP in Shandong Province were evaluated.

Introduction

SNWTP is a large infrastructure project to solve the serious shortage of water resources in northern China. There are three water diversion routes. The Grand Canal from Beijing to Hangzhou and its parallel rivers constitute the main and sub trunk of the Eastern Route Project delivering water from the lower reaches of Changjiang River to the north of China. Because of a variety of factors [1], there may be many accidents of water supply, for example, traffic accident, oil spills or other damage to the water quality, and so on. In order to deal with all kinds of unexpected accidents timely and effectively, it is necessary to identify and evaluate the sudden accidents along the line.

Many scholars usually divided the risk assessment method into three categories, such as, quantitative, qualitative and semi quantitative risk assessment [2]. Recently, scholars have done a lot of research on SNWTP. Xiong et al identified and analyzed the risk type for engineering buildings [3], Feng et al established a two dimensional risk portfolio model of composite event in the main canal [4]. Liu et al researched on the probability and characterization method of hazard consequences for water pollution accident caused by road transportation [5]. Zhu et al established the framework of flood risk calculation and put up a two dimensional risk calculation model of compound event [6]. He et al built the storm flood risk model based on Bayesian network theory [7]. Xiao et al studied on preventive measures for the occurrence of unexpected accidents during the operation period [8].

In this paper, ESNWTP in the section of Shandong Province (ESNWTP-SS) was taken as study object, for all potential sudden accidents, risk sources were identified, the assessment model was developed and influence degree of accidents on the project was evaluated.

Study Area

ESNWTP-SS consists of buried culvert, open canal and lakes etc. Almost all water routes are open and intersect the major transport corridors, there are many kinds of risk sources including diffuse dike, ice berg, embankment landslide, submerged pump station, surplus water, inrush, water pollution, and so on (Fig. 1).
Method

Risk Identification

ESNWTP-SS with long open canal, there would be likely to happen water pollution accidents by human poisoning, pollutant leakage resulting from traffic accidents. With the task of shipping coal and grain crops, the partial canal are easy involved risk caused by oil leakage and domestic sewage. Besides, some natural rivers being water trunk canal, the cross section shape is obviously changed, and regional precipitation is concentrated in summer. All the factors above may lead to geological landslide, earthquake, ice plug and other natural disasters. Authors identified and analyzed the potential risk factors listed in Table 1.

<table>
<thead>
<tr>
<th>Accidents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accident I</td>
<td>Water pollution accidents caused by pollutant leakage resulting from traffic accidents</td>
</tr>
<tr>
<td>Accident II</td>
<td>Water pollution accidents caused by oil leakage and domestic sewage resulting from shipping traffic incident</td>
</tr>
<tr>
<td>Accident III</td>
<td>Water pollution accidents by human poisoning</td>
</tr>
<tr>
<td>Accident IV</td>
<td>Engineering safety accident caused by geological landslide, earthquake, ice plug and other natural disasters</td>
</tr>
<tr>
<td>Accident V</td>
<td>Engineering safety accident caused by the pump stop, flooding, dam failure, etc.</td>
</tr>
<tr>
<td>Accident VI</td>
<td>Engineering safety accidents caused by explosive destruction or hostile terrorist attacks</td>
</tr>
</tbody>
</table>

Classification of Hazard Grade

Generally, it is reasonable to estimate the accident consequences from the aspects of economy, people's life safety, ecology \[9\], so economic losses, number of casualties, influence scope in society and impact on water ecology were taken as the indicators for analyzing possible consequence, the level of classification was determined as table 2.
Accident Risk Assessment

Accident risk assessment is to make a comprehensive evaluation on possibility and consequences and to determine the risk ranking of accident [10]. ESNWTP with a shorter running time, we evaluated the accident using expert investigation method, collected the opinions of many experts with FOCD [11], made a comprehensive evaluation using AHP [12, 13].

FOCD Method

Assume $U = \{u_1, u_2, \cdots, u_m\}$ be a finite set, sort the elements in $U$, panel $|V| = n$, $m$ opinions from $m$ persons can be denoted as, $V = \{v_1, v_2, \cdots, v_n\}$, where $v_i$ is the $i$th opinion sequence, $B_i(u)$ be the number of elements following behind $u$ in $i$th opinion sequence $v_i$, with $\leq \in U$. If $u$ is No. 1 ranking, $B_1(u) = n - 1$; If $u$ is No. 2 ranking, $B_2(u) = n - 2$; If $u$ is No. $k$ ranking, $B_k(u) = n - k$. For any criterion, $B(u)$ is expressed as $B(u) = \sum_{i=1}^{m} B_i(u)$.

Accident Possibility Ranking for ESNWTP

According to the risk identification, there are six types of accidents $u_1, u_2, \cdots, u_6$ likely occurring in ESNWTP. We selected six relevant professional experts as the panel and obtained six opinions. That is $U = \{u_1, u_2, \cdots, u_6\}$, $|V| = 6$, $V_p = \{v_{1p}, v_{2p}, \cdots, v_{6p}\}$.

According to the border count, sorting all elements in $U$, the opinion matrix can be obtained as $V_p$. According to the ranking in $V$, calculate the border counts of possibility for six kinds of accidents, respectively. The results are as $B(u_1) = 30$, $B(u_2) = 22$, $B(u_3) = 16$, $B(u_4) = 13$, $B(u_5) = 9$, $B(u_6) = 0$. Sorting all elements in $U$, one can obtain the sort as $u_1, u_2, u_3, u_4, u_5, u_6$.

Accident Consequences Ranking for ESNWTP

In the same way, the consequences matrix of opinion can be obtained as $VC$, $B(u_1) = 25$, $B(u_2) = 15$, $B(u_3) = 3$, $B(u_4) = 20$, $B(u_5) = 3$, $B(u_6) = 24$, the sort as $u_1, u_2, u_3, u_4, u_5, u_6$.
Risk Hierarchy Model Construction

Establish the structure drawing of AHP for ESNWTP as Figure 2.

![Figure 2. The structure drawing of AHP for ESNWTP.](image)

Construction of Comparison Matrix and Consistency Check

Firstly, calculate the important degree of the second layer factors relative to the first layer factor. The important degree is calculated by weighted average method. The comparison matrix B-A can be expressed as in Table 3. The border counts normalized of possibility and consequences for six kinds of accidents were listed in Table 4.

<table>
<thead>
<tr>
<th>Accidents</th>
<th>border counts of possibility</th>
<th>border counts of consequences</th>
<th>normalization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>

The comparison matrix of B1- C and B2- C of the third layer factors relative to the second layer factors can be constructed and the consistency can be judged as Table 5.

Hierarchical Total Ranking

The weight value of the total ranking is the product of hierarchical ranking weights (HRW) of B layer factors and HRW of C layer factors. The result is shown in Table 6.
Table 6. Comprehensive weight.

<table>
<thead>
<tr>
<th>Layer C</th>
<th>Layer B</th>
<th>Total ranking weight of Layer C</th>
<th>Consistency check</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$CI=0.055$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$CI/RI=0.043$</td>
</tr>
<tr>
<td>$C_1$</td>
<td>0.438</td>
<td>0.305</td>
<td>0.405</td>
</tr>
<tr>
<td>$C_2$</td>
<td>0.221</td>
<td>0.122</td>
<td>0.196</td>
</tr>
<tr>
<td>$C_3$</td>
<td>0.145</td>
<td>0.042</td>
<td>0.119</td>
</tr>
<tr>
<td>$C_4$</td>
<td>0.105</td>
<td>0.183</td>
<td>0.124</td>
</tr>
<tr>
<td>$C_5$</td>
<td>0.061</td>
<td>0.043</td>
<td>0.056</td>
</tr>
<tr>
<td>$C_6$</td>
<td>0.031</td>
<td>0.305</td>
<td>0.099</td>
</tr>
</tbody>
</table>

From table 6, the weight values of the final ranking of the accident risk for ESNWT are: 
\[ \omega = (0.405, 0.196, 0.119, 0.124, 0.056, 0.099) \].

**Conclusion**

In this paper, we investigated risk identification and assessment of the accidents possibly occurring in ESNWTP-SS. Firstly, six kinds of potential accidents that may occur along the route have been recognized and classified 6 grades. Using combined method, risk assessment system and model were established to evaluate the accident risk. As shown in the results above, the main risks of ESNWTP-SS including traffic accidents caused by transportation and shipping, the secondary risk mainly includes human poisoning, natural disasters and other accidents resulting from machine failure and so on.

Using FOCDM method and AHP method, a new comprehensive evaluation method was put up. The new method can effectively avoid the shortcomings of the traditional arithmetic average method which may conceal some of the more prominent points, as well as, improve the accuracy of risk assessment.

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**References**


