Risk Assessment of Urban Waterlogging Based on GIS

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Abstract. In this paper, based on ArcGIS spatial analysis technology, taking Tongshan County as an example, the risk index evaluation model of urban rainstorm waterlogging disaster is established. In the comprehensive risk assessment and regional research, the weight of each risk index is determined by analytic hierarchy process (AHP), and the fuzzy evaluation is applied to the raster data of GIS risk index, so as to realize the data management of risk index, the combination of spatial analysis and visual expression. The results of risk assessment classification and regionalization can provide technical support and decision support for urban waterlogging risk prevention and disaster reduction planning in Tongshan County.

1. Introduction
Urban waterlogging risk assessment is a non-engineering measure based on prevention and an important part of disaster management. The establishment of waterlogging disaster assessment system is helpful to improve the effective urban disaster management mechanism, enhance the risk awareness of urban residents to prevent disasters, and improve the level of urban waterlogging disaster risk management.

In this paper, Tongshan County is selected as the research object, based on GIS spatial analysis technology, the index analysis method and scenario simulation method are used to evaluate the risk of urban waterlogging, and some suggestions for regional control and control are put forward.

2. Analysis on the present situation of waterlogging
In recent years, the rainstorm is frequent and the rain peak is concentrated in Tongshan County. The maximum precipitation reached 247mm on July 4, 2010, resulting in 70 per cent of the river embankment and 80 per cent of the channels suffered varying degrees of damage, with a direct economic loss of 65.8 million yuan. Waterlogging occurs in many parts of the city (shown in Fig. 1). In Radio and Television Bureau, Nanshi Street, Waterfront Garden, Xinda Building Materials Market, Finance Bureau and so on, the waterlogging is particularly serious.

3. Determination of risk Assessment methods and Indexes for waterlogging

3.1. Identification of major risk factors
The risk of waterlogging disaster is composed of the risk of disaster factors, the exposure and vulnerability of disaster-bearing bodies. The risk influencing factors of waterlogging disaster mainly include risk influencing factors, exposure influencing factors and vulnerability influencing factors. The main risk factors are selected and six factors with great correlation with spatial distribution are selected, and the weight of each evaluation factor is determined, as shown in Table 1.
### Table 1. List of main risk assessment factors for waterlogging disasters.

| Type                      | Main risk factor         | Subfactor                        | Weight (%) |
|---------------------------|--------------------------|----------------------------------|------------|
| Risk influencing factor   | Ground elevation         | Terrain, ground elevation        | 25         |
|                           | Runoff coefficient       | Ground slope, ground permeability| 10         |
|                           | Freeness number          | Pump, drainage system            | 20         |
| Exposure influencing factors | Density of population   | Density of population            | 20         |
|                           | Pecuniary condition      | Pecuniary condition              | 15         |
| Vulnerability factors     | Pecuniary condition      | Emergency and disaster relief capability, disaster prevention and resistance capability, and medical rescue capacity. | 10         |
|                           | Total                    |                                  | 100        |

#### 3.2. Factor risk index determination

According to the magnitude of disaster risk that each risk factor may produce, the risk factor is divided into several risk sections, and the risk index of each factor is determined.

**3.2.1. Ground elevation.** According to the hydrological data of Tongshan County and the investigation of waterlogging disaster, several characteristic elevations in urban areas are as follows: constant water level of water system, water level of water body when waterlogging is serious, flood water level and elevation of construction land. According to these characteristic elevations, the urban land is divided into five risk sections, and the corresponding risk index is determined. The scope and area of each section are shown in Fig. 2 and Table 2.

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**3.2.2. Runoff coefficient.** Runoff coefficient is an important parameter to reflect the underlying surface, which is related to the degree of ground hardening, permeability, ground slope and so on. According to the attributes of the present plot, considering various factors and referring to the provisions of the Outdoor drainage Design Code (GB50014-2011), the runoff coefficient is divided into 5 sections and the corresponding risk index is determined. The scope and area of each section are shown in Fig. 3 and Table 2.

According to Fig. 3, the runoff coefficients of the present plot are 0.6 - 0.75 and 0.5 - 0.6. The high runoff coefficient and the low runoff coefficient are relatively small. Therefore, considering the ground slope and ground permeability, the risk distribution of the present plot is more uniform.

**3.2.3. Freeness number.** The urban water system and the drainage system are also one of the most important disaster factors in the urban water-logging disaster, and the coverage and drainage criteria are the key factors that directly determine the magnitude of the waterlogging disaster. There are some current drainage pipes in the old and old parts of the urban area of Tongshan County. In which, the old city is basically a drainage and drainage pipeline. The new urban area has a combined flow system and a split-flow system. The five risk sections shall be divided according to the standard of the drainage system meeting the different recurrence periods, and the corresponding risk index shall be determined. The scope and area of each section shall be shown in Fig. 4 and Table 2.

According to Fig.4, in the north and west of the urban area, because the development and construction are not perfect, the drainage pipeline is lacking, only the channel naturally formed by the current road surface is drained to the river channel, and the river channel of the water receiving area is not treated, and the drainage capacity is low and is in the high-risk area. The old city and the new urban area have a large section of the pipe canal, which can meet the design requirements, and even meet the drainage standard with the recurrence period higher than 5 years. In the figure, the pipelines in the yellow and green filling areas meet the standards, and the current pipelines in other areas need to be re-calculated and modified.
3.2.4. Density of population. The direct consequence of urban waterlogging disaster is to threaten and destroy the life, production, and even life and property of urban residents. The residential density of the urban population is also related to the degree of loss that may be caused by disasters. Five risk sections are divided according to the population density standard, and the corresponding risk indices are determined. The scope and area of each section are shown in Fig. 5 and Table 2.

As shown in Fig. 5, the population density of the old urban area is large, and the population density of Fengchi community is the largest (red filled area), which is the highest risk level of more than 30,000 people / km². The Macaoqiao community and the Nanmenqiao community on the south bank of Tongyang River in the old urban area are the second (blue filled area). Then there are Xincheng community and Shuangquan community (purple filled area), the population density is moderate. Guta community (orange filled area) population density is small, the risk level is low. The other green filled areas are the present plots that have not formed the area, and their population density is the lowest, and the corresponding risk grade in the population density risk assessment is also the lowest.

3.2.5. Pecuniary condition. The direct consequence of urban waterlogging disaster is to cause damage and loss to property. The degree of property loss is related to the nature of land use. According to the different land nature of the present plot, considering the relative size of the disaster loss at the time of waterlogging, according to the commercial, industrial, residential, office, green space and so on, it is roughly divided into five risk sections, and the corresponding risk index is determined. the scope and area of each section are shown in Fig. 6 and Table 2.

As shown in Fig. 6, the area of each risk area is the most residential area (purple fill area). For the high-risk area of commercial land, it is necessary to take full consideration of the actual situation in the measures such as the subsequent arrangement of the pipe network, the regulation of the river course, the vertical adjustment and so on.

3.2.6. Disaster prevention and resistance. The ability of urban disaster prevention and resistance is also one of the main factors that determine the degree of disaster. In the urban area, the residents’ awareness of disaster prevention, the government’s emergency relief ability and the ability to prevent and resist disasters can be regarded as basically the same, and there is little change in space. The planning represents the ability of urban disaster prevention and resilience only by medical rescue ability, divides four risk sections, and determines the corresponding risk index. The scope and area of each section are shown in Fig. 7 and table 2.

As shown in Fig. 7, there are larger hospitals in the old and new urban areas, with perfect medical facilities and better medical conditions. The construction in the north is scattered, far away from the hospital, considering the inconvenience of transportation, its medical conditions are poor.

The specific criteria for the classification of the six risk factors mentioned above are detailed in Table 2.

| Risk factor                  | Risk classification   | Area (ha) | Index number |
|------------------------------|-----------------------|-----------|--------------|
| Ground elevation (m)         | Classify              | ≤Constant Water Level | Constant Water Level | Elevation of Construction Land | Waterlogging Water Level | >Flood Control Level |
|                              | 55                    | 57        | 500          | 92             | 60               |
| Runoff coefficient           | Classify              | >0.75     | 0.60 < n≤0.75 | 0.50 < n≤0.60 | 0.35 < n≤0.50 | ≤0.35             |
|                              | 0                     | 839       | 420          | 5              | 10               |
| Drainage system (return)     | Classify              | p≤1       | 1 < p≤2      | 2 < p≤3       | 3 < p≤5         | p>5               |
|                              | 474                   | 156       | 130          | 136           | 378              |

Table 2. Risk index of waterlogging risk factors.
4. Risk Assessment and Regionalization of Waterlogging

The risk assessment scope is divided into a plurality of cells. The comprehensive risk index of each cell is obtained according to the above determination risk factors, the risk index and the weight of each risk factor. Conduct the risk zoning according to the comprehensive index. See Fig. 8 and Table 3 for the results of risk assessment and zoning for waterlogging.

Table 3. Waterlogging risk assessment table.

| Risk assessment level | High-risk | Medium-risk | Low-risk |
|-----------------------|-----------|-------------|----------|
| Comprehensive risk index | >7.5 | 5.0 ≤ n≤7.5 | ≤5.0 |
| Area (ha) | 105 | 525 | 644 |

According to Fig. 8, the high risk areas are mainly distributed on both sides of the Tongyang River. Considering comprehensively, the main factors of high risk area are high population density, low terrain, poor drainage capacity of drainage pipeline, low outlet position and so on.

For the high risk area, the first problem to be solved is to improve the pipe network and improve its drainage capacity through the new pipeline or the reconstruction pipeline. For the lower position of the drainage port, it is considered to regulate the river channel, lower the water level, or set up a drainage pumping station to solve the problem, and for the areas with low terrain, we should consider filling up the high plot during reconstruction or new development and construction.

Most of the areas in the low risk area are not perfect in development and construction, the runoff coefficient is small, and the population is small. In order to avoid the future development of the high risk area, it is necessary to fully consider the low impact development of the subsequent construction, build a perfect drainage system, popularize medical facilities and so on.
Figure 3. Runoff coefficient section division.

Figure 4. Division of drainage standard section.

Figure 5. Population density section division.

Figure 6. Land use section division.

Figure 7. Division of disaster prevention capacity.

Figure 8. Waterlogging risk assessment chart.
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