The Risk Analysis Model Design of the Emergency-Food Supply under Blizzard Conditions

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Abstract. This work aims to improve the risk analysis system of the preparation and the transportation of emergency food and to improve the safety, efficiency, and speed of the emergency-food supply in China. We combined the fuzzy analysis and the convolutional neural network to identify the main risk factors of the emergency-food supply. The identification of the risk factors by the fuzzy analysis improved the food-safety risk analysis system. On the other hand, the use of the convolutional neural network to determine the early-warning threshold and to optimize the transportation plan of emergency food effectively improved the safety, efficiency, and speed of the emergency-food supply.

1. Introduction
China's geographical and geological conditions are complex, the ecological environment foundation is relatively weak, and the major natural disasters are characterized by high intensity, large regional differences, wide distribution areas, and serious disaster consequences. After severe natural disasters, emergency food is often difficult to meet the efficient and fast supply demand, based on factors such as diversified food demand, lengthy and low efficiency of emergency food supply chain. Therefore, the methods to quickly and effectively provide food security for the people in disaster areas are an important research topic. Meiyi et al. [1] compared the mechanisms by which the United States, the European Union, and China provide food safety under emergency conditions, and suggested improvements for the China’s mechanisms, including the improvements on risk assessment capabilities and the intelligent mechanisms and plans to provide food safety under emergency conditions. Moreover, the authors suggested the establishment of a long-term evaluation mechanism. Dianhua et al. [2] used the fuzzy analytic hierarchy process (FAHP) method to evaluate the mechanisms by which Tianjin provides food safety under emergency conditions and suggested countermeasures for the weak links of the mechanisms. Zhao and Hongzhi [3] used the particle swarm optimization algorithm to simulate the distribution of emergency food and obtained a feasible and effective emergency-food distribution plan. Jie et al. [4] used interpretive structural modelling (ISM) to analyze the risk factors of the transportation of emergency food and proposed a risk assessment system of the transportation of emergency food.

In China, the research on the emergency-food supply under natural-disaster conditions started later than did similar research in other countries. In China, the research on the emergency-food supply under natural disasters started later than did similar research in other countries. The supply chain mainly focuses on the risk research of a single link such as the preparation and transportation of general food under conventional conditions. Prevention and control technologies mainly focus on the...
perspectives of the regulatory system, regulatory links, corporate integrity and consumer perception, and it is often difficult to achieve fast and effective supply results.

In this paper, the risk analysis of emergency-food supply under blizzard conditions is carried out by combining fuzzy analysis and convolutional neural network. The convolutional neural network is a type of deep feedforward neural network that contains convolution calculations and contains a deep structure. It is one of the representative algorithms of deep learning. [5-6]. Compared to traditional methods, the convolutional neural network automatically extracts target features and discovers samples’ concentrations. Therefore, the convolutional neural network is widely used in a variety of fields [7].

2. The Fuzzy-Theory-Based Risk Evaluation Model

2.1. The Risk Factors of the Emergency-food Supply under Blizzard Conditions

Major blizzard disasters usually cause housing collapse, roads, railways, civil aviation and other transportation areas are blocked on a large scale, further increasing the difficulty of emergency rescue, based on the heavy snowfall intensity, wide range, and long duration. Affected by the blizzard disaster, the early stage of emergency food dispatch mainly relied on local emergency food storage points. With the gradual increase in demand, insufficient material reserves will become the main influencing factor affecting the emergency food supply. Under Blizzard disaster conditions, emergency food supply chain management is the core content of emergency management. It will directly affect the efficiency of emergency food supply and the effectiveness of post-disaster rescue. Affected by a major snow disaster, power grid lines are damaged, and communications are interrupted. It is difficult to understand the local disaster situation and emergency food needs in the first time, which will greatly affect the emergency food allocation and transportation plan formulation. It is the key link of emergency food transportation, that is, to ensure that emergency food is delivered to the affected area in time and in sufficient quantities. Affected by the blizzard disaster, emergency food transportation may cause the emergency supply link to fail, which is affected by these factors: transportation distance, transportation time limit, transportation capacity, number of transport routes, road conditions, personnel management ability, number of people affected, communication information, weather conditions, etc. The main factors affecting the failure of emergency food supplies after the blizzard disaster are shown below.

![Figure 1. The risk factors of the emergency-food supply under blizzard conditions.](image-url)
Figure 1 presents the risk factors of the emergency-food supply under blizzard conditions, which encompass the risk factors of the preparation of emergency food and those of the transportation of emergency food.

2.2. The Analytic Hierarchy Process

The analytic hierarchy process (AHP) is a simple method that combines qualitative and quantitative analyses to make decisions for fuzzy or complex problems [8]. The AHP method involves 5 major procedures that are described as the following:
(1) The construction of a hierarchical model

A hierarchical model is constructed by classifying a problem into several levels according to the causal relationship of each factor of the problem. Generally, the first level of the problem is the target level, and the subsequent levels of the problem are the index levels.

(2) The construction of a judgment matrix

A judgment matrix is established by comparing the influence of factors B1, B2, ..., Bn on upper factor F in pairs.

(3) The consistency test of the judgement matrix

The consistency of the judgment matrix is evaluated by equations 1 and 2:

\[ CI = \frac{\lambda_{\text{max}} - n}{n - 1}, \]  

(1)  

\[ CR = \frac{CI}{RI}, \]  

(2)  

where (please describe the components of equations 1 and 2).

| n   | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  |
|-----|----|----|----|----|----|----|----|----|
| RI  | 0.00 | 0.00 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 |
| n   | 9  | 10  | 11  | 12  | 13  | 14  | 15  |
| RI  | 1.45 | 1.49 | 1.51 | 1.54 | 1.56 | 1.57 | 1.59 |

(4) The calculation of weight vectors

Weight vectors are calculated according to equation 3:

\[ \sum_{j=1}^{n} \omega_j = 1, \]  

(3)  

where \( \omega \) is the normalized vector.

(5) The overall consistency test of the judgment matrix

The overall consistency of the judgment matrix is calculated according to equation 4:

\[ CR^{(k)} = \frac{\sum_{j=1}^{n} a_{j} CI_{j}^{(k)}}{\sum_{j=1}^{n} a_{j} RI_{j}^{(k)}}, k = 3, 4, \ldots, s, \]  

(4)  

where (please describe the components of equation 4).
2.3. The Fuzzy Comprehensive Evaluation Method
By using the single-factor evaluation results that were related to the evaluation object, we constructed the corresponding evaluation matrix and used the weight factors that determined the importance of each factor for the fuzzy transformation to get the assessment results of the evaluation object, as shown below.

![Figure 2. The fuzzy comprehensive evaluation model of the emergency-food supply.](image)

3. The Risk Analysis Model of Emergency food supply

3.1. The Design Framework
The risk analysis model of the emergency-food provision involved the entry, analysis, and application (Figure 3). The entry described basic data such as the types and severity of disasters, the supply and demand of the needs, the basic information on emergency food, the information on the distribution of emergency-food storage points, and the transportation plan of emergency food. The basic data in the basic-data layer were analyzed in the data-analysis by methods such as the convolutional neural network, to conduct the early-warning threshold analysis and the risk classification to establish a dynamic–early-risk warning model that accommodated the changes in the basic data. The risk classification classified the risk elements of the emergency food supply into “low” risks, “general” risks, “greater” risks, or “major” risks.

According to the analysis results of the early warning threshold, remote dispatch was carried out in the data-application layer, and the emergency-food supply plan was optimized according to the early warning content to ensure efficient emergency-food supply.
3.2. The Determination of the Early-Warning Threshold

The CNN is one of the representative algorithms of feedforward neural network with deep structure including convolution calculation [9]. The CNN can divide the input information according to different hierarchical structures, and use translation invariance to characterize learning and classify input information. Therefore, the CNN is also referred to as the translation-invariant artificial neural network. The convolutional neural networks usually consist of three parts, namely the input layer, the hidden layer and the output layer.

The input layer can be used to process multi-dimensional data. Because of its better effect, it has been widely used in the field of computer vision. Therefore, three-dimensional input data including two-dimensional pixels and RGB channels on the plane are pre-assumed when performing calculations. The hidden layer is generally composed of three parts: a convolutional layer, a pooling layer, and a fully connected layer.

\[
Z_{i+1}(i, j) = [Z^l \otimes \omega^l_{i+1}](i, j) + b = \sum_{k=1}^{K} \sum_{x=1}^{f} \sum_{y=1}^{f} [Z^l_k(s_{i,j} + x, s_{0,j} + y)\omega^l_{i+1}(x, y)] + b
\]

\[
(x, j) \in \{0, 1, \ldots L_{i+1}\}
\]

\[
L_{i+1} = \frac{L_i + 2p - f}{s_0} + 1
\]

When the convolution kernel \(f = 1\), the step size \(s_0 = 1\).

\[
Z_{i+1} = \sum_{k=1}^{K} \sum_{i=1}^{L} \sum_{j=1}^{L} (Z^l_{i,j,k} \omega^l_{i+1}) + b = \omega^l_{i+1}Z_{i+1} + b
\]

\[
L_{i+1} = L
\]

The parameters of the convolutional layer include the convolution-kernel size, the step size, and the padding. The three parameters determine the size of the output feature map of the convolutional layer, which are the hyperparameters of the CNN. When the step size is 1, the convolution kernel scans each element of the feature map sequentially. When the step size is \(n (n > 1)\), the convolution kernel skips \(n-1\) pixel/s in the subsequent scan. The convolutional layer includes the activation function (equation 7) to express complex features:

\[
A^l_{i,j,k} = f(Z^l_{i,j,k})
\]

After the feature extraction (i.e., the extraction of input data) in the convolutional layer, the feature map is transferred to the pooling layer for feature selection and information filtering. The steps of selecting the pool area in the pool layer are the same as those of scanning the feature map with convolution kernel. The selection of the pooling area is controlled by the pooling size, the step size,
and the filling of the pooling layer. Lp pooling (equation 8) is a pooling model inspired by the hierarchical structure of visual cortex:

\[
A_p^i(j,k) = \left( \sum_{x=1}^{f} \sum_{y=1}^{f} A_p^i(s, j + x, s, j + y)^p \right)^{1/p}
\]

Mixed pooling and random pooling are the extension of the Lp pooling. The mixed pooling is expressed as a linear combination of mean pooling and maximum pooling (equation 9):

\[
A_m^i = \lambda L_m(A_m^i) + L_m(A_m^i), \lambda \in [0,1]
\]

3.3. The Optimization of the Transportation Plan

The analysis of the early-warning threshold and the determination of the crucial risk elements of the emergency-food supply were conducted by considering the supply and demand of emergency food in disaster areas, the distribution of emergency-food storage points, the transportation plan of emergency food, weather, transportation, and the shipping duration of emergency food by selected transportation methods. The real-time–early-warning determination of the risk elements that affect the emergency food provision assists the working teams of the emergency-food supply to optimize supply plans and to promptly conduct on-site remote harmonize to achieve the real-time management and control of the arrangement.

4. Conclusion

In this work, we used the fuzzy analysis to establish a risk assessment model of the emergency-food supply. Further, by using the CNN to determine the early-warning threshold and to optimize the conveyance plan of emergency food. The research results can provide technical support for risk prevention and control during the supply process of emergency food from deployment, transportation, and arrival to disaster-affected areas.

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