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RESEARCH PAPER

Evaluation of the Design Alternatives of Emergency Bridge by Applying Analytic Network Process (ANP)

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Abstract: The article introduces the basic process that uses analytic network process (ANP) to design alternative evaluation of emergency bridge. ANP is a better evaluation method for bridge designs and is now widely used in decision making with dependence and feedback. ANP considers all factors, estimates the relative influence from the factors, values factors with ratio scales from 1 to 9, makes pairwise comparisons on factors, and synthesizes to obtain overall results. An ANP case is conveniently computed by super decisions ANP software. The computed results show that the ANP is suitable for evaluating the design alternatives for emergency bridges.

Key Words: analytic network process (ANP); decision science; emergency bridge; alternatives evaluation

1 Introduction

Due to the considerable development of traffic projects, more and more bridges are built in China, and the length of those bridges is becoming increasingly more. To ensure rapidness in bridge building and to ensure the quality of bridges, before a bridge is built, the most important task is to erect a temporary bridge (or emergency bridge) before construction. For example, Figure 1 shows the temporary bridge for constructing Hangzhou Bay Bridge. To ensure the safety of the temporary bridge during construction and to reduce the cost of input, the bridge proprietor often considers the emergency bridge as the construction convenience bridge and organizes the bridge experts to make a comprehensive evaluation of the alternative bridge designs of the emergency bridge[1−2]. The overall performance of the emergency bridge depends on a multiobjective and semistructured problem. There is relative dependence between the property index such as safety and economy. If the economy is higher, then the safety is reduced. If the safety is higher, then the cost effectiveness is reduced. For these reasons, this article considers the analytic network process (ANP)[3−4] that is based on dependence and feedback to evaluate the alternative bridge designs of the emergency bridge. American Professor Thomas L. Saaty developed a decision science method—analytic network process, which can suit the comprehensive structure. Specifically, this method considers the relative influence and the feedback from the factors, values the factors with ratio scales from 1 to 9, makes pairwise comparisons on factors, and synthesizes to obtain overall results.

2 Bridge design alternatives

Construction periods, the total length of the bridge, the load-carrying capacity, the width of roadway, the central separated zone of roadway, and the navigational headroom below the bridge, are given. These factors need to be compared as shown below:

1. Safety. As with a new construction project, safety is of primary importance, that is to say, safety has the highest priority. Safety includes structure strength (S_1), stiffness (S_2), and stability (S_3) A high-strength temporary bridge must have high stiffness but not necessarily high stability. A

Figure 1. Temporary bridge for constructing Hangzhou bay bridge

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highly stable bridge must have high strength and high stiffness. A high stiffness can guarantee high strength and high stability to a temporary bridge.

2. Economy. Economy is related to costs of materials (E_1), production (E_2), installation (E_3), and maintenance (E_4) in the field. It is incompatible between economy and safety. The higher the economy, the lower is the safety. The higher the safety, the lower is the economy. If finer bridge material is used, that is to say, high material cost, maintenance cost can be reduced.

3. Durability. Durability is the service life expectancy (D_1) of bridges. Durability, which is associated with the primary materials of bridges, is a very important factor. For example, steel material has durability and bridges made of steel are rapidly erected. The durability of emergency bridge must be relative to construction periods. There is interdependence among durability, economy, and safety. If the durability of the bridge is above construction periods, safety is ensured, but it is not economical. If the durability of bridge is below construction periods, safety cannot be guaranteed, but it is economical.

4. Manufacturability. It includes manufacture technology (M_1) in the factory and construction speed (M_2) in the field. Good constructability shows good manufacture technology and facilitates construction. Dowel or bolt connection is used in local fixing to guarantee the whole quality of bridge, and welding should be avoided. Because local welding quality is considerably influenced by external factors, the number of local welding should be reduced.

To summarize, economy and safety are interdependent. For example, the construction period is three years, but the safety needs to be guaranteed for six years, which means higher material cost, higher constructability request, and poor commercial viability. If safety needs to be guaranteed for three years, the material cost and constructability request will be lower, but the safety is reduced.

Durability and safety are interdependent, but they are inversely related with economy. Durability is good, so is safety, but economy is reduced. Safety is good, so is durability.

3 Steps in applying ANP for evaluating bridge design alternatives

3.1 Building ANP decision bridge model

Since a long time when the design alternatives of a emergency bridge were evaluated, most of the designs paid more attention on the cost of the structure material, but not on the construction period. From the view of economic analysis, time means money and profit because reducing bridge-construction period can assure that the bridge will be completed ahead of schedule. When the bridge is completed, it will bring about economic benefits and social benefits. From the analyses of the relationships among the factors of the design alternatives of the emergency bridge, an ANP decision model with inner dependence is built, in which the cluster is linked to itself and a loop link appears as shown in Figure 2.

3.2 Computing weight

Generally, the construction company will provide one to three design alternatives of the emergency bridge for the owner and the supervisor to make a decision. If there is only one alternative, ANP is not needed because it only needs the leaders or experts to vote for an answer of "Yes" or "No" If there are two alternatives, either voting or AHP method can solve the problem[5−6]. While there are three alternatives, the problem is very complicated because the factors have the complex dependence and the feedback relations that AHP cannot solve the problem well. In this article, therefore, we consider the ANP to evaluate three design alternatives of the

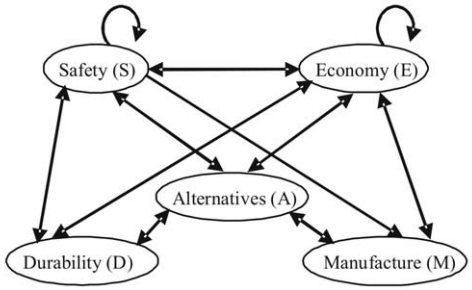

Figure 2. Dependence of design alternatives for the bridge model

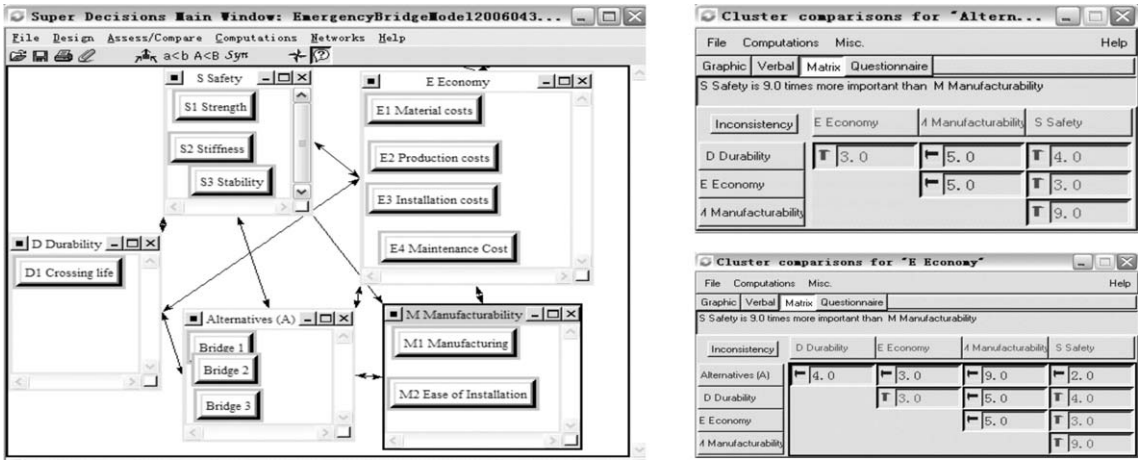

Figure 3. Interfaces of super decisions