RESEARCHERID
THOMSON REUTERS

[Kuo* *et al.*, 5(9): September, 2018] ISSN 2349-0292
Impact Factor 3.802

GLOBAL JOURNAL OF ADVANCED ENGINEERING TECHNOLOGIES AND SCIENCES

SELECTING REVETMENT FOR RURAL RIVER USING AHP AND ANP MODELSIN TAIWAN– FROM VIEW OF CONSTRUABILITY

Kuo C P[*1] & Chao L C[2]
[*1,2]College of Engineering, National Kaohsiung University of Science and Technology, Kaohsiung 824, Taiwan

DOI: 10.5281/zenodo.1439197

ABSTRACT

Revetments are usually required to provide protections against erosion, to remain or improve hydraulic performance and to create recreation spaces along riverbanks. With an objective of developing a model for selecting the proper type of revetments, from views of construability, this study investigated three alternatives that are commonly used in Taiwan. By using of Analytical Hierarchy Process (AHP) model and Analytic Network Process (ANP) model, the final weights of alternatives are established. The results reveal that the final weights of the alternatives are 0.3714 (precast concrete block), 0.329 (rock riprap) and 0.2837 (gabion) when AHP model was applied, and 0.3676 (rock riprap), 0.3583 (precast concrete block) and 0.2741 (gabion) when ANP model was applied. This study illustrates an evaluation model for determining the priority of a rural river revetment construction.

KEYWORDS: AHP, ANP, Revetment.

INTRODUCTION

Revetments are generally constructed of stone or other materials that will provide sufficient armoring to protect a scarp, embankment, or other shoreline feature against erosion. The major components of a revetment include armor layer, filter and toe. The armor layer may be a random mass of stone or concrete rubble or a well-ordered array of structural elements that interlock to form a geometric pattern. The filter assures drainage and retention of the underlying soil. Toe protection is needed to provide stability against undermining at the bottom of the structure [1].

There are several types of revetment, including Rock Riprap, gabions, wire-enclosed rock, articulated block (Precast concrete), partially and fully grouted rock, concrete slope, biotechnical engineering. A brief description of commonly used revetments is given below [2].

- Rock riprap:
  Riprap revetments are a very effective and popular method to control riverbank erosion. It is a layer or facing of rock, stone, broken concrete blocks which is dumped or hand-placed onto an embankment to form a flexible revetment to prevent erosion, scour or sloughing of a structure or embankment. The type of stone used is usually determined by what is locally available. An illustration is shown in Figure 1.

Figure 1. Riprap (http://www.billdanceoutdoors.com)

- Gabion:
  Gabions are often used where riprap is not practical. They consist of rectangular, wire-mesh baskets filled with rock. A single gabion is formed by filling a pre-assembled wire basket with rock and is typically rectangular or trapezoidal in shape. Gabion revetments are formed by stacking the individual gabion blocks in a stepped fashion and are anchored to the channel bottom or bank. An illustration is shown in Figure2.

Figure 2. Gabions (http://www.gabionmattress.org)

- Precast Concrete Block (PCB):
  Precast concrete blocks or articulated concrete block systems provide a flexible alternative to riprap, gabions revetments. They are precast interlocking or cabled concrete grids designed for soil stabilization. They provide a more uniform surface for pedestrian or vehicular traffic. An illustration is shown in Figure3.

Figure 3. Precast Concrete Block (PCB) (http://incaconcrete.co.za/)

METHODS
AHP Model
As a comprehensive approach for solving various multi-criteria decision-making problems, AHP model is a theory of measurement that uses pairwise comparisons and relies on the expert judgements to derive the priority scales of attribute elements. In AHP model, a decision problem can be assumed and translated into a hierarchical structure. The top level of the hierarchy is usually the overall goal for the decision model, which can be de-composed to one or more levels of factors until a manageable level of sub-factors is met.

Based on the hierarchy, pairwise comparisons were used and factors weights were calculated. Each factor at Level 2 was compared pairwise with respect to the overall objective, each factor at Level 3 was compared pairwise with respect to the corresponding factor at Level 2, and each alternative was compared pairwise with respect to each factor at Level 3. The principle eigenvectors (P.E.-V.) indicating the relative scores.

The model has been applied to various decision-making problems for construction engineering, e.g. Skibniewski and Chao [4], Aminbakhsh et al. [5], Xu et al. [6], Vidal et al. [7], Hyun et al. [8], Kuo and Chao [9]. In this study, factors affect the selection of a revetment type were identified based on [4] and shown in a three-level hierarchy, see Figure 4. F1 refers the availability of materials for the respective alternative; F2 refers the complexity of on-site works for the respective alternative; F3 refers the equipment required for the respective alternative t; F4 refers the manpower needed for the respective alternative and F5 refers the estimated time for construction for the respective alternative.

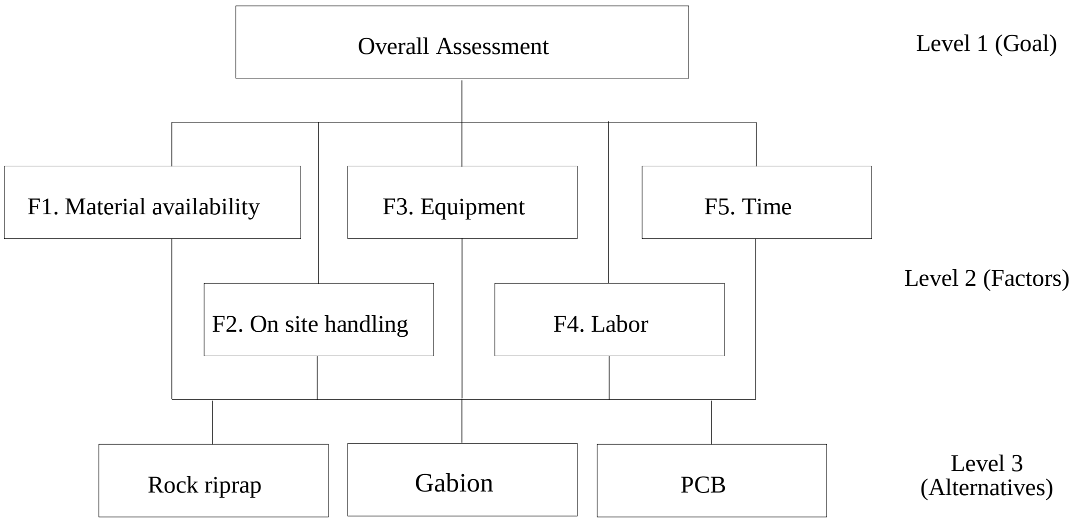

Figure 4. Hierarchical structure of factors for revetment selection

A scenario of a rural river revetment construction located in southern Taiwan was given to the design members who were chosen from three consultant firms (two members from each firm). Members were interviewed to provide weights of affecting factors based on the hierarchical structure and results of pairwise comparisons are given in Table 1-6. The initial super-matrix is given in Table 7 and the limit super-matrix is given in Table 8. The PCB receives the highest final weight of 0.3714, followed by rock riprap (0.3290) and gabion (0.2837). The suggested result indicates that PCP is the most appropriate alternative for design members when AHP model was applied.

Table 1. Comparison of factors in their influence on overall assessment.

Attributes	Material availability	On site handling	Equipment	Labor	Time	P.E.-V.
Material availability	1	1 1/3	2	1 1/2	1 1/3	0.2697
On site handling	3/4	1	1/2	1	1/2	0.174
Equipment	1/2	2	1	2	1	0.2304
Labor	2/3	1	1/2	1	2	0.1695
Time	3/4	2/3	1	2/3	1	0.1563

Table 2. Comparison of alternatives in their influence on material availability.

Attributes	Riprap	Gabion	PCB	P.E.-V.
Rock riprap	1	1/2	1/3	0.1593
Gabion	2	1	1/3	0.2519
PCB	3	3	11	0.5889

Table 3. Comparison of alternatives in their influence on site handling

Attributes	Riprap	Gabion	PCB	P.E.-V.
Rock riprap	1	2	2	0.4905
Gabion	1/2	1	1/2	0.1976
PCB	1/2	2	1	0.3119

Table 4. Comparison of alternatives in their influence on equipment

Attributes	Riprap	Gabion	PCB	P.E.-V.
Rock riprap	1	1/2	1/3	0.1722
Gabion	2	1	2	0.4778
PCB	3	1/2	1	0.35

Table 5. Comparison of alternatives in their influence on labor

Attributes	Riprap	Gabion	PCB	P.E.-V.
Rock riprap	1	2	3	0.5485
Gabion	1/2	1	1	0.2409
PCB	1/3	1	1	0.2106

Table 6. Comparison of alternatives in their influence on time

Attributes	Riprap	Gabion	PCB	P.E.-V.
Rock riprap	1	2	3	0.5374
Gabion	1/2	1	1	0.1946
PCB	1/3	1	1	0.268

Table 7. Initial super-matrix for the AHP

Attributes	Overall assessment	Material availability	On site handling	Equipment	Labor	Time	Rock riprap	Gabion	PCB
Overall assessment	0	0	0	0	0	0	0	0	0
Material availability	0.2697	0	0	0	0	0	0	0	0
On site handling	0.174	0	0	0	0	0	0	0	0
Equipment	0.2304	0	0	0	0	0	0	0	0
Labor	0.1695	0	0	0	0	0	0	0	0
Time	0.1563	0	0	0	0	0	0	0	0
Rock riprap	0	0.1593	0.4905	0.1722	0.5485	0.5374	1	0	0
Gabion	0	0.2519	0.1976	0.4778	0.2409	0.1946	0	1	0
PCB	0	0.5889	0.3119	0.35	0.2106	0.268	0	0	1

Table 8. Limit super-matrix for the AHP

Attributes	Overall assessment	Material availability	On site handling	Equipment	Labor	Time	Rock riprap	Gabion	PCB
Overall assessment	0	0	0	0	0	0	0	0	0
Material availability	0	0	0	0	0	0	0	0	0
On site handling	0	0	0	0	0	0	0	0	0
Equipment	0	0	0	0	0	0	0	0	0
Labor	0	0	0	0	0	0	0	0	0
Time	0	0	0	0	0	0	0	0	0
Rock riprap	0.3449	0.1593	0.4905	0.1722	0.5485	0.5374	0	0	0
Gabion	0.2837	0.2519	0.1976	0.4778	0.2409	0.1946	0	0	0
PCB	0.3714	0.5889	0.3119	0.35	0.2106	0.268	0	0	0

ANP Model

The ANP model is a generalization of the AHP model [10, 11]. AHP model achieves pairwise comparisons among factors or criteria in order to prioritize them at each level of the hierarchy using the eigenvalue calculation while ANP model is a general form that allows interdependencies, outer dependencies and feedbacks among decision elements in the hierarchical or non-hierarchical structures [12].The model has been applied to various decision-making problems for construction engineering, e.g., Chao and Cheng [13], Jia et al. [14], Bobylev [15].

Same group of design members attended the AHP model provided weights of affecting factors for ANP model. Results of general comparisons are given in Table 9-11. The initial super-matrix is given in Table 12 and the limit super-matrix is given in Table 13. The rock riprap receives the highest final weight of 0.3676, followed by PCB (0.3583) and gabion (0.2741). The suggested result indicates that rock riprap is the most appropriate alternative for design members when ANP model was applied.

Table 9. Comparison of factors in their influence with respect to rock riprap

Attributes	Material availability	On site handling	Equipment	Labor	Time	P.E.-V.
Material availability	1	3/4	1	1/2	1 1/2	0.1788
On site handling	1 1/3	1	1/2	1	1	0.1763
Equipment	1	2	1	2	1	0.2637
Labor	2	1	1/2	1	1/2	0.2152
Time	2/3	1	1	2/3	1	0.1661

Table 10. Comparison of factors in their influence with respect to gabion

Attributes	Material availability	On site handling	Equipment	Labor	Time	P.E.-V.
Material availability	1	1/2	1/2	2	1 1/2	0.1891
On site handling	2	1	2	1	1	0.2598
Equipment	2	1/2	1	2	1	0.2234
Labor	1/2	1	1/2	1	1	0.1512
Time	2/3	1	1	1	1	0.1766

Table 11. Comparison of factors in their influence with respect to PCB

Attributes	Material availability	On site handling	Equipment	Labor	Time	P.E.-V.
Material availability	1	2	2 1/2	2 1/2	1	0.3080
On site handling	1/2	1	2 1/2	2	1	0.2251
Equipment	2/5	2/5	1	1	1	0.1335
Labor	2/5	1/2	1	1	1/2	0.1154
Time	1	1	1	2	1	0.2179

Table 12. Initial super-matrix for the ANP

Attributes	Overall assessment	Material availability	On site handling	Equipment	Labor	Time	Rock riprap	Gabion	PCB
Overall assessment	0	0	0	0	0	0	0	0	0
Material availability	0.2697	0	0	0	0	0	0.1788	0.1891	0.3080
On site handling	0.174	0	0	0	0	0	0.1763	0.2598	0.2251
Equipment	0.2304	0	0	0	0	0	0.2637	0.2234	0.1335
Labor	0.1695	0	0	0	0	0	0.2152	0.1512	0.1154
Time	0.1563	0	0	0	0	0	0.1661	0.1766	0.2179
Rock riprap	0	0.1593	0.4905	0.1722	0.5485	0.5374	0	0	0
Gabion	0	0.2519	0.1976	0.4778	0.2409	0.1946	0	0	0
PCB	0	0.5889	0.3119	0.35	0.2106	0.268	0	0	0

ISSN 2349-0292
Impact Factor 3.802

Table 13. Limit super-matrix for the ANP

Attributes	Overall assessment	Material availability	On site handling	Equipment	Labor	Time	Rock riprap	Gabion	PCB
Overall assessment	0	0	0	0	0	0	0	0	0
Material availability	0	0.2279	0.2279	0.2279	0.2279	0.2279	0	0	0
On site handling	0	0.2167	0.2167	0.2167	0.2167	0.2167	0	0	0
Equipment	0	0.206	0.206	0.206	0.206	0.206	0	0	0
Labor	0	0.1619	0.1619	0.1619	0.1619	0.1619	0	0	0
Time	0	0.1875	0.1875	0.1875	0.1875	0.1875	0	0	0
Rock riprap	0.3676	0	0	0	0	0	0.3676	0.3676	0.3676
Gabion	0.2741	0	0	0	0	0	0.2741	0.2741	0.2741
PCB	0.3583	0	0	0	0	0	0.3583	0.3583	0.3583

CONCLUSION

This study proposes an AHP and ANP based models for revetment type selection. The rankings of the alternatives obtained are 0.3714 (PCB), 0.329 (rock riprap) and 0.2837 (gabion) when AHP was applied. In addition, the rankings of the alternatives obtained are 0.3676 (rock riprap), 0.3583 (PCB) and 0.2741 (gabion) when ANP was applied. The ranking of the alternatives proposed by AHP and ANP differ from each other. However, it is suggested that the result obtained from ANP shall be adopted since the model considers not only a hierarchy, furthermore a network.

REFERENCES

[1] Design of Coastal Revetments, Seawalls, and Bulkheads, Engineering and Design, US Army Corps of Engineers, US Army Corps of Engineers, 1995.
[2] Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance, Vol 2 Third Edition, Federal Highway Administration, 2009.
[3] T. L. Satty, “Decision making with the analytic hierarchy process”, Internal Journal of Services Sciences, 2008, Vol.1, Issue 1, pp.83-98.
[4] M. J. Skibniewski and L. C. Chao, “Evaluation of advanced construction technology with AHP method”, Journal of Construction Engineering Management, 1992, Vol. 118, Issue 3, pp. 577-593.
[5] S. Aminbakhsh, M. Gunduz and R. Sonmez, “Safety risk assessment using analytic hierarchy process (AHP) during planning and budgeting of construction projects“, Journal of Safety Research, 2013, Vol. 46, pp. 99-105.
[6] K. Xu, C. F. Kong, J. F. Li, L. Q. Zhang and C. K. Wu, “Suitability evaluation of urban construction land based on geo-environmental factors of Hangzhou”, 2011, Computers & Geosciences, Vol. 37, pp. 992-1002
[7] L. A. Vidal, F. Marle and J. C. Bocquet, “Using a Delphi process and the Analytic Hierarchy Process (AHP) to evaluate the complexity of projects”, 2011, Expert Systems with Applications, Vol. 38, pp. 5388-5405.
[8] K. C. Hyun, S. Min, H. Choi, J. Park and I. M. Lee, “Risk analysis using fault-tree analysis (FTA) and analytic hierarchy process (AHP) applicable to shield TBM tunnels”, 2015, Tunnelling and Underground Space Technology, Vol. 49, pp.121-129.
[9] C. P. Kuo and L. C. Chao, “AHP Model for Evaluation of Pile Installation Methods”, 2016, Applied Mechanics and Materials, Vol. 858, pp 67-72.
[10] T. L. Saaty, Decision Making with Dependence and Feedback: The Analytic Network Process, Pittsburgh: RWS Publications, 1996.
[11] T. L. Saaty, Theory and Applications of the Analytic Network Process: Decision Making with Benefits, Opportunities, Costs and Risks (Pittsburgh: RWS Publications), 2005.
[12] A. Görener, “Comparing AHP and ANP: An Application of Strategic Decisions Making in a Manufacturing Company”, 2012, International journal of business, social and scientific research, Vol 3, Issue 11, pp.194-208.
[13] L. C. Chao and L. C. Cheng, “ANP model for evaluation of false-work systems for cast-in-place cantilever bridges”, 2014, Procedia Engineering, Vol. 85, pp. 104-112.

[14] G. Jia, X. Ni, Z. Chen, B. Hong, Y. Chen, F. Yang and C. Lin, "Measuring the maturity of risk management in large-scale construction projects", 2013, Automation in Construction, Vol. 34, pp.56-66.
[15] N. Bobylev, "Comparative analysis of environmental impacts of selected underground construction technologies using the analytic network process", 2011, Automation in Construction, Vol. 20, pp.1030-1040.