How to Apply the AHP method to a risk evaluation system in humid tropical region

Eisaku Hamasaki, Toyohiko Miyagi, Dinh Van Tien, and Ngo Doan Dung

Abstract AHP, which was established by Thomas L. Saaty in 1971, is decision-making method based on a pair comparison. Since its proposal by Saaty, the of evaluation standard the AHP method has been as an extremely technique in many evaluation method. In addition, AHP method in itself developed incrementally by adopting other theories (e.g. fuzzy theory). However, a lot of landslides and slope collapses are actualized the rapid development of countries such as Vietnam in humid tropical regions. As such, the progress of development countries slope disasters. In response, development of the AHP method expected in application to these slope risk evaluations. This paper utilizes case studies to illustrate the role of AHP method as a "teaching tool" in application to slope-risk evaluations. Further, the limited application of this method is also explained in this paper.

Keywords AHP, humid tropical region,risk evaluation, teaching tool

The AHP Method

Defining the AHP Method

In the process of decision-making we frequently encounter unavoidable critical situations. At an individual level such decisions may concern the purchase of a house or a car, while they may also influence the course of a person's life when involving decisions over marriage or a professional career. In society, the spheres of politics, business, industry, medicine or education involve a series of situations which require decisions on critical strategic objectives. As organisations become larger in scale, transparent decision processes are crucial for securing consensus among the organisation's members. However, a host of complex factors intervene in critical strategic decisions. In many cases, these factors exist in situations of competition and trade-off (e.g. choice between mutually exclusive alternatives such as that between benefits and costs); thus, in accordance with the location of our objectives the relevant significance of these factors will vary.

Addressing these complex problems, Thomas I. Saaty[1980]of the University of Pittsburgh proposed the Analytic Hierarchy Process (AHP). It is characterized as' a method which measures the relative influence among factors determining the evaluation standard.' The greatest benefit of this method is its ability to 'clearly quantify uncertain evaluation standards.'

Concretely, the system supports decision-making based on overall scores generated through the division of a task into three levels, i.e. 'goal' (level 1), 'criteria' (level 2), and 'alternative' (level 3).A factor's importance is determined through hierarchical structures allowing for comparisons of all factors present at each level, thus determining the relative weight of each factor at each level (see Figure 1, below).

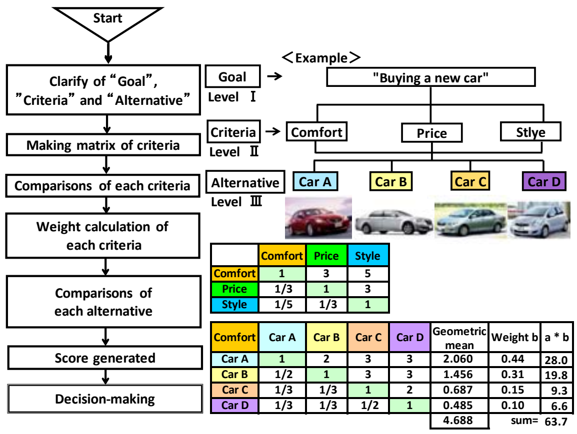


Fig. 1 AHP analysis flow and example “ Buying a new car ”models using AHP

In simple terms, this is a 'method for situations in which one has to select the most appropriate item out of a host of available options. As such, it facilitates rational decisions through paired comparison of these items while incorporating experience and intuition.' Thus, a key element of the AHP method is 'paired comparison'. AHP's paired comparison enables us to conduct a comparison of items which were previously incomparable, and thus represents an advantage which is lacking in other statistical methods.

The AHP Relative Measurement Method

The classical procedure of the AHP method is the AHP relative measurement method. This method first sets a 'goal' and determines necessary 'evaluation standards' which are incorporated into a hierarchical structure. A decision as to the most appropriate alternative is sought based upon the varying weight of evaluation standards with regard to multiple alternatives. In practice, first, a table of paired comparisons including all items comprising the evaluation standard is compiled; the weight of the evaluation standard is determined through the AHP quantification method. As shown in Table 1, tables with numerical input in the conduct of paired comparisons represent not only a shared premise of the AHP method, but are, indeed, a method peculiar to AHP.

Table 1 Degrees of the paired comparisons.

Intensity of importance	Explanation
1	Both of the items are important equally.
3	The item of the row is slightly more important than the item of the column(or conversely , 1/3).
5	The item of the row is more important than the item of the column(or conversely , 1/5).
7	The item of the row is considerably more important than the item of the column(or conversely , 1/7).
2,4,6	Intermediate values when compromise is needed.

The next step is for the weight of evaluation items relating to available alternatives to be determined through paired comparison. As a result, this mechanism allows for the generation of aggregated values for the weight of each alternative, based upon which the most appropriate alternative can be determined. This method becomes extremely complicated, however, if a large number of alternatives exist. Moreover, if evaluation standards and alternatives subjected to comparison increase after analysis has already begun, all the paired comparisons must be repeated from the beginning. Further, other shortcomings of this approach include the possibility of complete alternation of the order in the weighting of alternatives which has been created at the beginning of this process (see Figure 2, below).

The number of times compared in 4 alternatives were 6 times.(Example case is "comfort")
It's easy to compare each alternatives can the small matrix .

comfort	a	b	c	d	※score	order
a	1	3	5	5	2.94	1
b	1/3	1	7	5	1.85	2
c	1/5	1/7	1	3	0.54	3
d	1/5	1/5	1/3	1	0.34	4

※Geometric mean

However:
If the number of alternatives are increase (ex.10 items) ,the number of times compared are 45 times.
It isn't easy to compare each alternatives on large matrix.
And several order sometimes changes.

additional alternative

comfort	a	b	c	d	e	f	g	h	i	j	score	order
a	1	3	5	5	3	3	5	1	5	7	3.22	1
b	1/3	1	7	5	3	1	5	7	2	3	2.44	2
c	1/5	1/7	1	3	5	3	3	2	3	3	1.53	4 ※
d	1/5	1/5	1/3	1	2	3	7	5	7	7	1.64	3 ※
e	1/3	1/3	1/5	1/2	1	3	5	7	7	3	1.38	5
f	1/3	1	1/3	1/3	1/3	1	7	5	7	7	1.36	6
g	1/5	1/5	1/3	1/7	1/5	1/7	1	5	3	1	0.49	7
h	1	1/7	1/2	1/5	1/7	1/5	1/5	1	7	7	0.58	8
i	1/5	1/2	1/3	1/7	1/7	1/7	1/3	1/7	1	7	0.36	9
j	1/7	1/3	1/3	1/7	1/3	1/7	1	1/7	1/7	1	0.27	10

※Sometimes order changes

Fig. 2 Problems in the standard alternative the AHP relative measurement method and its shortcomings

The AHP Absolute Measurement Method

Thus the AHP absolute measurement method has been designed in an attempt to solve the above mentioned problems (see Figure 3, below). The AHP absolute measurement method uses the weights of the paired comparisons of evaluation standards as common measurement values. Basically, the weight aggregation through paired comparison of a value axis corresponds to the AHP relative measurement method. However, this method conducts no paired comparison for alternatives, but is employed for establishing a measure for judging the respective importance of each item along the evaluation axis.

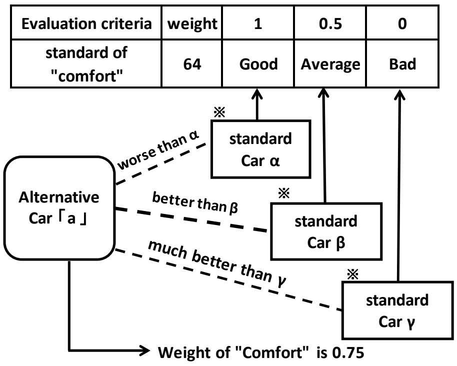


Fig. 3 An outline of the AHP absolute measurement method (※standard car criteria as "comfort")

Important here is the establishment of a series of 'indicators' which can represent paired comparisons along the evaluation axis (e.g. representative examples in the order ranging from cases of heavy weight towards cases of low weight)[Hamasaki,2013].

By applying concrete representative cases as 'indicators' we evade complicated paired comparisons that involve many alternatives. In this way, it becomes possible for us to generate almost equal weights between all items for all alternatives.

Other AHP Methods

In addition, we witness new developments regarding AHP such as a network approach to the AHP method, or research on hybrid forms of AHP evaluation systems which apply approaches such as fuzzy inference. In particular, as the aggregation methods for calculating the weight determined through proportion measurement research has proposed approaches such as the arithmetical average method, the least squares method, the eigenvector method, or the geometric mean method have been proposed. Moreover, aggregation procedures that have implemented blank paired comparisons can be aggregated through mathematical methods. Yet, in conducting paired comparisons we cannot assume that human decisions are steady or consistent. The problem can be addressed by applying a consistency index (CI). Generally, if CI<0.1 we can conclude that there is consistency.

Applicability to AHP Slope Risk Evaluations

Established Slope Evaluation Systems

In the past, we have seen a number of approaches in the sphere of risk assessment development regarding slopes of an embankment. For example, based on a large-scale investigation of the damage of embankment residential areas at the Hanshin-Awaji earthquake Kamai et al have applied a neural network to create an earthquake risk assessment system for embankment foundations[Kamai,2004]. Moreover, as the physical properties of embankments are in comparison to natural ground relatively easy to simplify, research on risk predication methods for embankments has emerged which builds on the so called physical method employing Hamasaki et al.'s three dimensional instability analysis model RBSM (see Figure 4, below)[Hamasaki,2007].

However, with the exception of destruction, property values of slopes are difficult to assess in risk evaluations of natural ground landslides, which is why a versatile approach applying physical methods has not yet been achieved. Furthermore, statistical methods such as neural network and multivariate analysis statistical approaches, or the maximum likelihood method [Satou,2005] require supervised data.

Unfortunately, the amount of supervised data sufficient for model building is difficult to obtain.

As a result, landslide susceptibility maps prior to 2010 were limited to the scoring and the creation of evaluation models and were based upon experience points regarding topographical quantity and geology, or property values.

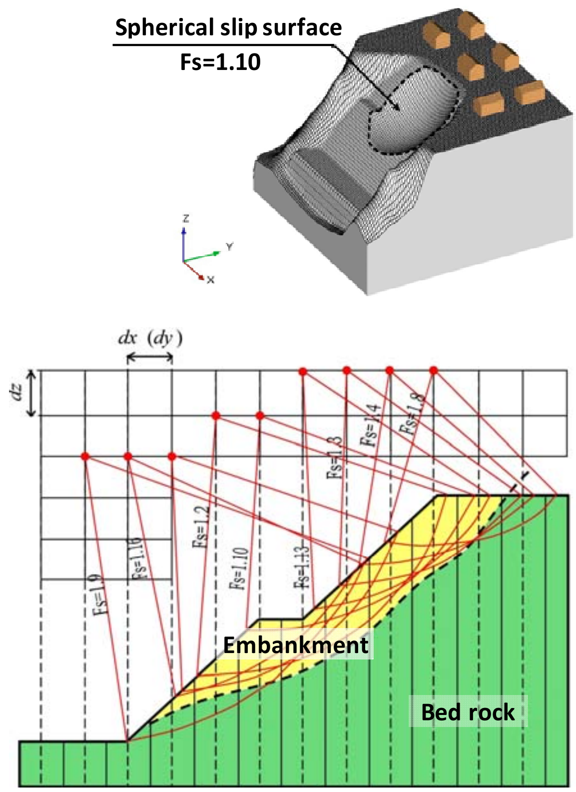


Fig. 4 An outline of the RBSM three dimensional instability analysis model (Fs : Value of slope stability)

AHP-Based Risk Assessment System Applying Aerial Photography Mapping

Japan's National Research Institute for Earth Science and Disaster Prevention (the former National Research Center for Disaster Prevention) has conducted large-scale aerial photography projects which have been published since 1982as topographic landslide maps with a scale of1:50000. In addition, the Tohoku research group of the Japan Landslide Society has developed a risk assessment system based on aerial photography maps [Hamasaki,2003 Miyagi,2004, Yagi,2009,].

A large number of landslide experts participated in the building of this model. Based on the experience points of each expert, the AHP has been applied to stratify the conditions of the evaluated micro topography and its surrounding areas. Building on these procedures, evaluations of the weight of the decision standards have been discussed. In principle, this approach applies the AHP absolute measurement method: scored decision standards are integrated into a data sheet while a risk assessment is conducted through the inclusion of level checks for each decision element. That is, established standards for each evaluation item are stratified with declining scores from left to right. As such, this system allows for decisions through 'paired comparisons' thus avoiding deviation in decision on each item of a respective slope ground. After the completion of this AHP risk assessment model, our model region investigated has witnessed several cases of landslide through earthquakes and thaw, as well as rainfall. Most of these landslides occurred in areas considered to be high risk under the AHP assessment system, thus proving the model's validity [Yagi,2012].

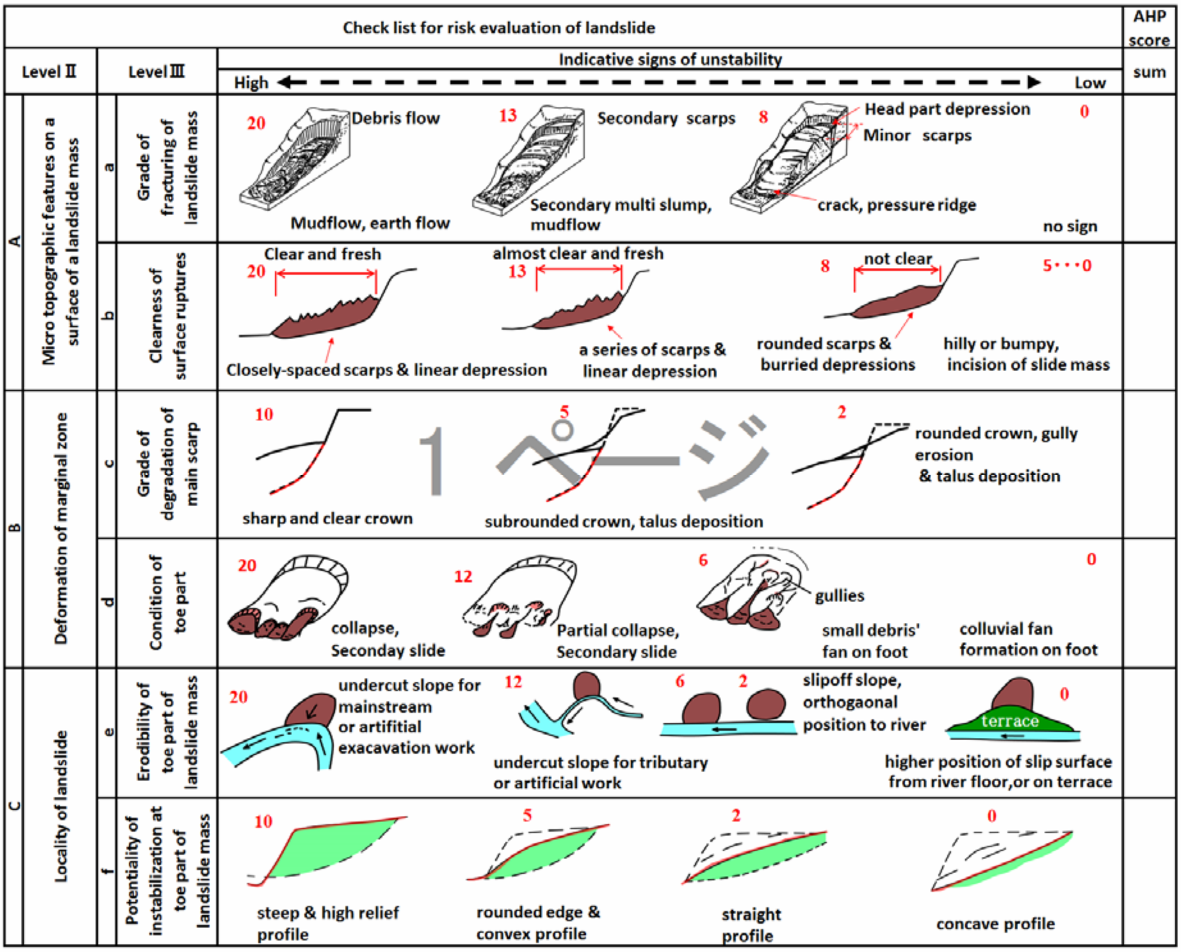


Fig. 5 Example of a data sheet through AHP aerial photography

Problems in Applying AHP to Slope Risk Assessment

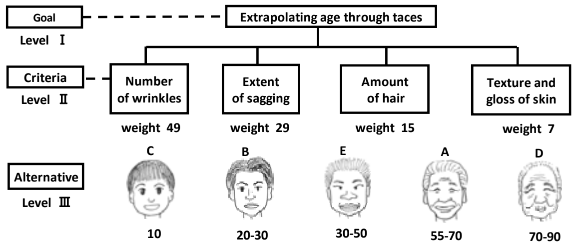
In the building of evaluation systems, the AHP approach allows us to compensate for insufficient supervised data through experience points. However, caution is required if engineers with insufficient experience freely participate in the system construction; this may result in deviation from the approach's initial purpose. Therefore, it is necessary that experts with a high degree of experience will be summoned for this process to be effective. Furthermore, in order to determine the evaluation standard of slope risk assessments in a given region, it is necessary that research groups conduct on-site surveys and brainstorming in order to enhance specific knowledge of a given area. Of course, in addition to these procedures it is necessary to investigate the relations between the topology and geology of an area and slope stability using GIS. Building on these findings, evaluation standard determinations, hierarchies, and point allocations should be constantly improved.

In order to confirm the validity of the AHP model, it is also necessary to build a model for the investigation of the potential reoccurrence of slope destructions (landslide, collapse). For example, a more appropriate model may be achieved through the combined application of likelihood rate decisions and fuzzy theory which incorporate a probability density function.

Perspectives and Empirical Cases of the Method as Teaching Tools

We have elaborated above the benefits and problems of AHP. The basis of the AHP approach is that it serves as a tool to transform the vast amount of individual tacit knowledge into explicit knowledge, thus representing an outstandingly effective method for the use as an instrument in education to communicate technology.

We have prepared and contributed PowerPoint slides describing the AHP method and the possibility for its application in risk assessment. While these elaborate on the basic method, the slide entitled 'From tacit to explicit knowledge' elaborates on the role of AHP in explaining the principle of transforming 'tacit' into 'explicit knowledge' as a process which allots to a 'persons face and age'. That is, we explain how in response to the final goal of 'guessing a person's age' through intuition we employ a number of indicators such 'the number of wrinkles', 'the extent of a skin sagging', 'the amount of hair', or 'the texture and gloss of the skin' in order to conduct a weight assessment using the AHP method results in the establishment of a 'model program for guessing a person's age' (see Figure 6, below).



	Weight	Evaluation axis			A		B		C		D		E	
		1	0.5	0	a	a•w	b	b•w	c	c•w	d	d•w	e	e•w
number of wrinkles	49	Many	Average	None	0.8	39.6	0.3	14.8	0.1	4.9	1.0	49.5	0.5	24.7
extent of sagging	29	Much	Average	None	0.7	20.3	0.4	11.6	0.1	2.9	1.0	29.1	0.6	17.4
amount of hair	15	None	Average	Thick	0.5	7.4	0.3	4.4	0.1	1.5	0.7	10.3	0.3	4.4
texure & gloss of skin	7	Rough	Average	Smooth	0.2	1.3	0.6	4.0	0.2	1.3	0.3	2.0	0.5	3.4
	Evalution on absolute scale				Sum=	67	Sum=	31	Sum=	11	Sum=	89	Sum=	47

Fig. 6 Model of guessing a person's age through an analysis of his/her face applying the AHP method

Yet, while this may apply to same ethnicities, we explain that if ethnicities vary our accuracy of guessing a person's age declines. We have shown how this intuitively relates the AHP method's 'aerial photography landslide risk assessment system'.

Conclusions

Here, we have explained on the conventional methods in the form of the 'AHP relative measurement method' and the 'AHP absolute measurement method' and elaborated on the possibility of applying the approach to a slope assessment system, as well as on the necessary conditions of using the AHP method. Furthermore, as a teaching tool we have elaborated on the process of transforming 'tacit knowledge' into 'explicit knowledge'. Here, we applied the example of guessing 'a person's face and age' to illustrate the utility of the AHP method. In conclusion, the AHP method has achieved tutorial application.

Acknowledgments

First of all, I would like to express Vietnam project Leader and our supervisor, Prof. Kyoji Sassa, who give us some chances to study Vietnam Area, many research experiences. And, I would like to thank the other members of WG2 of Vietnam project, Dr. Hiroyuki Yoshimatsu, and Dr. Shinro Abe, Dr. Hiromu Daimaru, Mr. Takeshi Kato, Mr. Tatsuya Shibasaki, and Ms. Akemi Yoda. They provided at all levels of the research project. Finally, I would like to thank Ms. Haruna Ishikawa from Advantechnology co,.ltd for the support to writing this article.

References

HAMASAKI Eisaku, HIRAI Takesa, MIYAGI Toyohiko, (2003)Evalution of the Probability of Landslide Occurrence by AHP based on the Results of Aerial-photo Interpretation. Conference Proceedings of the 42nd Annual Meeting of Japan Landslide Society, 19-22 August 2003., Japan. pp. 227-230

HAMASAKI Eisaku, MIYAGI Toyohiko, Takeuchi Norio, Ohnishi Yuzo, (2007)Risk Evaluation of the Earthquake Triggered Landslide on the Land Reclamation Slope by Three Dimensional Instability Analysis of Simplified RBSM. Journal of the Japan Landslide Society. Vol.43, No.5: 251-258

HAMASAKI Eisaku, (2013)Structure of the AHP method, and Landslide Risk Evaluation System based on it, Daichi ga ugoku. Touhoku branch of Japan Association for Slope Disaster Management. Japan. 20-48p

KAMAI Toshitaka, SHUZUI Haruo, KASAHARAA Ryouichi, KOBAYASHI Yoshiyuki, (2004)Earthquake risk assessments of large residential fill-slopes in urban areas. Journal of the Japan Landslide Society. Vol.40, No.5: 29-39

SAATY Thomas L., (1980)The Analytic Hierarchy Process. McGraw-Hill Book Company, NewYork. 265p.

SATO Hiroshi, SEKIGUCHI Tatsuo, KAMIYA Izumi, HONMA Shinichi, (2005) Comparative study on landslide susceptibility mapping between artificial neural network and maximum likelihood method. Journal of the Japan Landslide Society. Vol.42, No.4: 13-22

MIYAGI Toyohiko, PRASADA Gyawali B, TANAVUD Charlchai,POTICHAN Aniruth, HAMASAKI Eisaku, (2004)Landslide Risk Evaluation and Mapping - Manual of Landslide Topograhy and Risk Management -, Report of the National Reserch Institute for Earth Science and Disaster Prevention No.66. Report of the National Reserch Institute for Earth Science and Disaster Prevention. Japan. 75-137p

YAGI Hiroshi, HIGAKI Daisuke,(2009)Methodological study on landslide hazard assessment by interpretation of aerial photographs combined with AHP in the middle course area of Agano River, Central Japan. Journal of the Japan Landslide Society. Vol.45, No.5:356-366

YAGI Hiroshi, HAMASAKI Eisaku, MIYAGI Toyohiko, SASAKI Akihiko, (2012)Risk evaluation method of quake-induced landslides using AHP, Earthquake-induced Landslides.Journal of the Japan Landslide Society. Japan.182-183p

Eisaku Hamasaki (✉)
Advantechnology co.,ltd. Department of Technology, Sendai 980-0013, Japan
e-mail: hamasaki@advantechnology.co.jp
Toyohiko Miyagi
Tohoku Gakuin University, Department of Regional Design,Sendai 981-3193, Japan
e-mail: miyagi@izcc.tohoku-gakuin.ac.jp
Dinh Van Tien
Institute of Transport Science and Technology, Hanoi 84, Vietnam
e-mail: dvtien.gbn@gmail.com
Ngo Doan Dung
Institute of Transport Science and Technology, Hanoi 84, Vietnam
e-mail: ngodoandung@gmail.com