TXT-tool 1.081-2.4 Risk Evaluation Using the Analytic Hierarchy Process (AHP)—Introduction to the Process Concept

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Abstract

In this paper, risk evaluation of Landslide using the Analytic Hierarchy Process (AHP) is introduced. 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. However, in order to make decision using by ordinary AHP, it needs paired comparison with not only criteria but also alternatives. Therefore, we propose that to apply the AHP of an absolute evaluation method to risk evaluation in this paper. Here, first of all, the basic AHP of a relative method is described using ordinary simple example. Next, the main characteristics of the relative and absolute methods are summarized. Then we describe how to adopt AHP method to risk evaluation system using the example data to estimate of people's ages. Moreover, Japanese inspection sheet for landslide risk evaluation system which use their aerial photography using absolute method of AHP is explained. Last we will consider a framework for converting implicit knowledge into explicit knowledge through these AHP algorithm.

Keywords

AHP · Risk evaluation · Absolute evaluation method
Micro-topography

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Contents

1 Basics of the Analytic Hierarchy Process

1.1 About the Analytic Hierarchy Process

When purchasing expensive items, such as cars or houses, we become very cautious and deeply indecisive about various creiteria. Given that there are multiple judgment criteria (for example, when buying a house: the price, distance from a train station, space, natural environment, convenience etc.) leading to a decision. It would be easier to make a decision if the buyer's criteria are simple and clear. If they are ambiguous, a buyer will become very indecisive, and later will often regret their decision When a decision is not personal, but rather an important matter that needs to be made by a company or group (for example, where to locate the company offices), an objective and rational judgment process (judgment basis) leading to a decision, is strongly required.

In order to resolve such problems, Dr. T.L. Saaty, University of Pittsburgh, proposed the Analytic Hierarchy Process (Saaty 1980). This method's greatest merit is that it "clearly quantifies ambiguous judgment criteria." Put another way, it "determines the relative influence among items of judgment criteria."

Specifically, this method ascertains the problem using a hierarchy for each element: Level 1, Goal; Level 2, Evaluation Criteria; and Level 3, Alternatives. A weight is assigned to each element by performing paired comparisons with other elements on the same level. The comprehensive score derived from this assists decision-making. In essence, when one must select the best choice from a number of candidates, this method enables one to make rational decisions using paired comparison, while taking intuition and hunches into account.

The main characteristics of this method are as follows: (1) Since each element is evaluated on subjective criteria, elements that express conflicting concepts or differing measurement scales can be compared; (2) use of paired comparison simplifies evaluation, enabling importance throughout to be ascertained cumulatively; (3) as it is a quantitative method, it can be quantitatively compared with other plans (4) it enables confirmation of the influence a given element exerts on the whole, and the consistency of the judgment.

The method is extremely simple, requiring only the key ideas of "paired comparisons" and their "weighting" (usually calculated by geometric mean). Using Excel, an experienced user can determine the best selection plan (called an "alternative" in the Analytic Hierarchy Process) in an hour.

There are many famous applications of Analytic Hierarchy Process. For example, in the 1996–1997 hostage crisis at the Japanese Ambassador's residence in Peru, Dr. Saaty used it to help Peruvian officials consider what action the government should take. In Japan in 1996, the Council for Relocation of the Diet and Other Organizations used the method to select the Tochigi/Fukushima and Gifu/Aichi regions from among 10 candidate regions.

1.2 Simple Example of the Analytic Hierarchy Process Method

The example we will use is "buying a new car." Our objective is to visualize this as a hierarchical chart (Fig. 1).

Here, we will examine the evaluation criteria of "comfort," "price," and "style."

There are four types of car: Car A, Car B, Car C, and Car D. The plans to be compared are generally called the "alternative plans," but they can also be called "comparison plans."

1.3 Instructions for the Most Commonly Used Analytic Hierarchy Process Method: Relative Comparison

In this example, we consider a buyer looking for a new car. The buyer values comfort, but is not very concerned with style.

1. First, make paired comparisons of the evaluation criteria, "comfort," "price," and "style."The paired comparisons are rearranged as a matrix, as shown in Table 1. Same items are written as "Same = 1."

   (a) Looking at the table from the side, if "comfort" is 3 times more important than "price," it will be assigned a "3."
   (b) If we look at the items along the diagonal lines, and compare "price" with "comfort," we see that the numbers from (1) are reversed: 1/3.
   (c) As shown in Table 1, the degrees of comparison are 3, 5, and 7 (or conversely, 1/3, 1/5 and 1/7). Sometimes, these are even numbers (2, 4, 6), but generally odd numbers are used.
   (d) When all comparisons on the 3 × 3 matrix have been completed, the geometric mean* is calculated for each item. E.g., Comfort = (1 × 3 × 5) 1/3 = 2.466
   (e) After each geometric mean has been found, the total sum is recalculated to equal 100. This becomes the weight for the evaluation criteria. Here we will refer to it as "weight a."

2. Next we perform paired comparisons for each of the cars under consideration (alternatives) with respect to "comfort," "price," and "style." Finding "weight b" for each alternative within the conceptualization and evaluation items, is the same as in (1)–(5). However, in the overall evaluation, the true weight is weight a multiplied by weight b (a*b on Table 2).
3. When all weights have been found, the evaluation criteria weights for all cars (alternatives) are totaled.

As a result, evaluation scores (Analytic Hierarchy Process scores) are found for each alternative. Specifically, in the below list, since Car A has the highest evaluation score, it was selected. In general, the weights are adjusted so that they add up to 100 points when the evaluation scores are totaled.

Car A: Comfort (28.0) + Price (3.2) + Style (4.4) = 35.6

Table 1 Analytic hierarchy process method paired-comparison table

	Comfort	Price	Style	Geometric mean	Weight a
Comfort	1	3	5	2.466	64
Price	1/3	1	3	1.000	26
Style	1/5	1/3	1	0.405	10
				3.872	100

Geometric mean (Gm)

$$Gm = \left(\prod_{i=1}^{n} X_i\right)^{1/n}$$

Degrees of the paired comparisons:

1 Both of the items are equally important
3 The item in the row is slightly more important than the item in the column (or conversely, 1/3)
5 The item in the row is more important than the item in the column (or conversely, 1/5)
7 The item in the row is considerable more important than the item in the column (or conversely, 1/7).

Table 2 Values used in the relative car comparison example

Comfort	Car A	Car B	Car C	Car D	Geometric mean	Weight b	a*b
Car A	1	2	3	3	2.060	0.44	28.0
Car B	1/2	1	3	3	1.456	0.31	19.8
Car C	1/3	1/3	1	2	0.687	0.15	9.3
Car D	1/3	1/3	1/2	1	0.485	0.10	6.6
					4.688	Sum = 63.7	
Price	Car A	Car B	Car C	Car D	Geometric mean	Weight b	a*b
Car A	1	1	1/3	1/3	0.577	0.13	3.2
Car B	1	1	1/2	1/3	0.639	0.14	3.6
Car C	3	2	1	1/2	1.316	0.29	7.4
Car D	3	3	2	1	2.060	0.45	11.6
					4.592	sum = 25.8	
Style	Car A	Car B	Car C	Car D	Geometric mean	Weight b	a * b
Car A	1	1	3	7	2.141	0.42	4.4
Car B	1	1	3	5	1.968	0.39	4.0
Car C	1/3	1/3	1	1	0.577	0.11	1.2
Car D	1/7	1/5	1	1	0.411	0.08	0.8
					5.097	Sum = 10.5	
						Sum•(all) =100.0	

Car B: Comfort (19.8) + Price (3.6) + Style (4.0) = 27.4
Car C: Comfort (9.3) + Price (7.4) + Style (1.2) = 17.9 (18.0)
Car D: Comfort (6.6) + Price (11.6) + Style (0.8) = 19.0

2 Concept of the Absolute Evaluation Method in the Analytic Hierarchy Process

2.1 Problems with Relative Comparisons in the Analytic Hierarchy Process

The relative comparison method often used in the Analytic Hierarchy Process has the following three steps.

Step 1: Determine weights on evaluation axis by paired comparison of each element in it.

Step 2: Create a paired-comparison matrix of alternatives from which the final selection will be made, and determine a weight for each evaluation element.

Step 3: Estimate weights for each alternative on the evaluation axis, and find the best one in terms of the various alternatives' weights (evaluation scores).

There are two drawbacks to this relative comparison method.

(1) There is no problem when the number of alternatives is small, but when it is large, this method is cumbersome.
(2) Once determined, if alternative items are added, all paired comparisons must be performed again; in rare cases, the initial ranking of the weights of alternatives may even reverse.

For example, suppose one has structured a system for looking for the best candidate among hundreds of apartments. Performing paired comparisons on each of the countless apartments is not the best system. However, if a system were designed so that the final judgment was not affected even if conditions under consideration in the paired comparisons were added or subtracted, this would be a more usable system.

To overcome this shortcoming, Saaty proposed an Analytic Hierarchy Process "absolute evaluation method." This model is effective when structuring diagnostic systems for judging many objects.

2.2 The Absolute Evaluation Method

In the absolute evaluation method, the weights found through paired comparisons of the evaluation criteria are implemented as common scale values. Essentially, the calculation of weights through paired comparisons on the evaluation axis in Step 1 is performed in a manner similar to the relative comparison method, but in Steps 2 and 3, paired comparisons of the alternatives are not performed. Instead, a scale is structured to judge the approximate rank of importance of each item on the evaluation axis.

Let us return to the problem of selecting a car from the previous section. The weights found through paired comparison on the evaluation axis are the same. That is, as evaluation axes, Comfort has a maximum score of 64 points, Price, a maximum of 26, and Style, a maximum of 10. When considering absolute evaluations of qualitative elements such as Comfort and Style, it is important to create specific standards for the evaluation axis, such as best (1) and worst (0), that are intuitive.

In other words, when evaluating Car A, it is necessary to consider weights while comparing the standard values on its evaluation axis. For example, in comparatively evaluating Car A, the buyer would have specific ideas, such as "Model 1 is the best (1.0), Model 2 the worst (0), while Model 3 is average (0.5)." So it would be impossible to infer that if Car A was better than Model 3, but worse than Model 1, it would score 0.75. Next, "Price" seems like something that can be expressed quantitatively. For example, the buyer can assign it an approximate weight by setting a score of 1.0 for cars less than one million yen, 0.5 for cars 3 million yen and over, and approaching 0 for cars over ten million yen.

The results of the absolute evaluation method applied to the car-purchasing problem are shown in Table 3.

The scale is such that positive factors such as high quality, inexpensiveness, etc. are scored as 1.0, while negative factors, such as poor quality, expensiveness etc. are rated as 0.0. The position that each evaluation should assume is compared to the criteria scale and assigned a numeric value from 0.0 to 1.0.

The results are consistent with those from the initial relative comparison method, with the order unaltered, and Car A is indicated as the best alternative. Thus, if the evaluation scale (standard) for absolute evaluation can be clarified, this method produces similar weights and evaluations to those obtained using the relative comparison method.

Table 3 Comparison of weights according to absolute comparison table and gross comparison

Evaluation criteria	Weight a	1	0.5	0	Car A		Car B		Car C		Car D	
Comfort	64	Good	Average	Bad	0.7	44.8	0.5	32.0	0.3	19.2	0.2	12.8
Price	26	In expensive	Average	Expensive	0.1	2.6	0.2	5.2	0.5	13.0	1.0	26.0
Style	10	Good	Average	Bad	1.0	10.0	0.8	8.0	0.5	5.0	0.3	3.0
		Absolute evaluation method			1	57.4	2	45.2	4	37.2	3	41.8
		Relative comparison method			1	35.6	2	27.4	4	17.9	3	19.0

2.3 Reasons for Applying the Absolute Evaluation Method to Landslide Risk Evaluation When Using Aerial Photographs

The main goal of applying the method in risk-evaluation system structures when using aerial photographs is to convert the implicit knowledge possessed by the landslide engineers into explicit knowledge In other words, by expressing judgments ("dangerous," "safe" etc.) that rely on experience and intuition as a numeric risk score, a common evaluation axis can be created. It will be accepted by more people since it will be objective. Also, if the resulting "explicit knowledge" is set down in a textbook, and if risk points and the order of risk weights are organized, it will create a cornerstone, enabling students just starting their study of landslide engineering to easily draw upon the knowledge of their predecessors.

This is not possible with methods other than Analytic Hierarchy Process. The method is deemed particularly well-suited for the following three reasons.

1. In constructing the landslide risk evaluation method, it is difficult to obtain with standable load and uniform analysis data. In other words, in the field where landslides have actually occurred, it is very rare to obtain all of the items—quantity, topography, and geology—of the elements used in making judgments.
2. Even if a number of experienced landslide engineers are brought together, each has a different level of experience, making normal statistical methods (such as surveys) difficult. Each engineer's field or area of landslide expertise will be slightly different, making it hard to decide on an evaluation axis using normal methods.
3. Brainstorming among experienced engineers is critical to determining evaluation items and evaluation axes. For this, "quality control," at which the Analytic Hierarchy Process method excels, is better than "regular statistical analysis."

2.4 Converting Implicit Knowledge into Explicit Knowledge

Here we will consider a framework for converting implicit knowledge into explicit knowledge. Consider the relationship between a person's face and their age. Generally, people can intuitively judge the ages of others within their population group—for instance whether they are in their 30s–40s, or around 20.

Moreover, as shown in Fig. 2, people can, mostly correctly, arrange many people in order of age by comparing their faces and sorting them. In particular, in cases where there are only subtle differences between the people, careful guesses must be made, while doing paired comparisons of the faces.

This is precisely the essence of Analytic Hierarchy Process. That is, if the intuitive judgment criteria we use to determine a person's age can be clarified, hierarchized, and a weighted evaluation A trial evaluation of the five people in Fig. 1 based

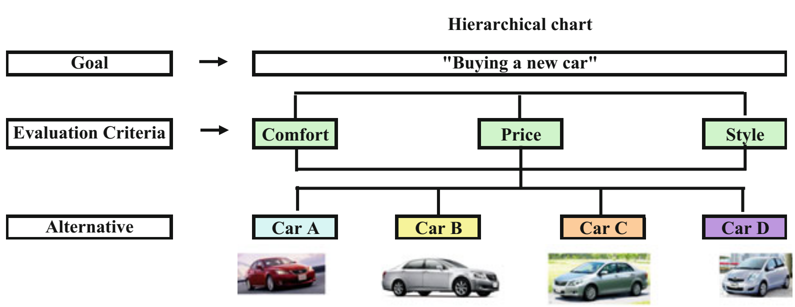

Fig. 1 A hierarchy chart for a new car purchase

Table 4 Analytic hierarchy process relative comparison method for evaluating criteria for judging age from faces between five people, A–D

Apparent age	Number of wrinkles	Extent of sagging	Amount of hair	Texture and gloss of skin	Geometric mean	Weight
Number of wrinkles	1	2	3	7	2.55	49
Extent of sagging	1/2	1	2	5	1.50	29
Amount of hair	1/3	1/2	1	2	0.76	15
Texture and gloss of skin	1/7	1/5	1/2	1	0.35	7
					5.15	100

Table 5 AHP evaluation performed by absolute comparisons between five people, A–D

	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
Texture and 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
Evaluation on absolute scale					Sum	67	Sum	31	Sum	11	Sum	89	Sum	47

on these criteria was performed. The results, shown in Table 4, generally indicate the appropriate ages. This is the essence of the Analytic Hierarchy Process method made, this evaluation method will lead to "explicit knowledge."

In Table 5, paired comparisons using Analytic Hierarchy Process were made along the evaluation axes of "Number of wrinkles," "Extent of sagging," "Amount of hair," and "Texture and Gloss of skin." To the right of the table, weights derived from the table are shown. A standard is prepared for each.

3 Creating Evaluation Criteria

3.1 General Categories

Persons experienced in landslides in Japan (Tohoku) compiled their previous experience with landslides in the Tohoku region, then created a hierarchy of evaluation criteria for interpretation based on this experience. As a result of brainstorming the engineers judged that three general classifications are important, as shown in Figs. 3 and 4: "(α) landslide body micro-topography," "(β) landslide body boundary," and "(γ) topography surrounding the landslide body".

α. Landslide body micro-topography (index related to movement characteristics) Various kinds of micro-topography, mainly distributed within the region of the landslide body, suggesting movement characteristics, and their spatial placement.

β. Landslide body boundary (index related to time elapsed) Extent of dissection, due to subsequent non-landslide processes, i.e. constant topographical fluctuations, of

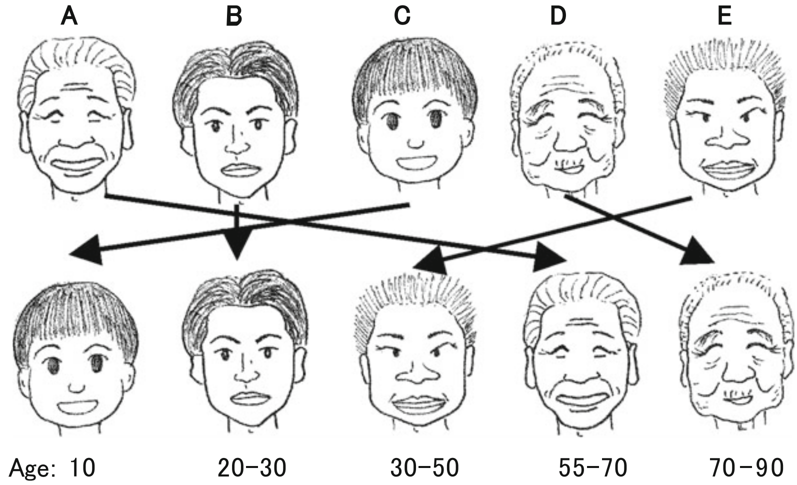

Fig. 2 Estimating age through faces between five people, A–D

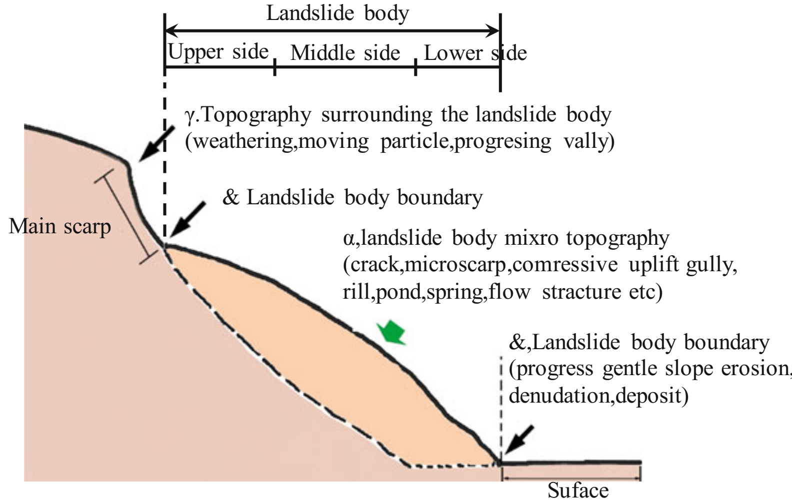

Fig. 3 Diagram of interpretation items (Miyagi et al. 2004)

displacement traces remaining around the landslide circumference.

γ. Topography surrounding the landslide body (index related to the topographic area). Factors impacting stability of the landslide body's displacement. Here, topographical area refers to the topographical location where the landslide is occurring.

3.2 Categories of Evaluation Criteria and Weighting

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 1982 as topographic landslide maps with a scale of 1:50,000 (Fig. 5). In addition, the Tohoku research group of the Japan Landslide Society has developed a risk assessment system based on aerial photography maps (Hamasaki et al. 2003; Miyagi et al. 2004; Yagi and Higaki 2009, Hamasaki 2013).

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

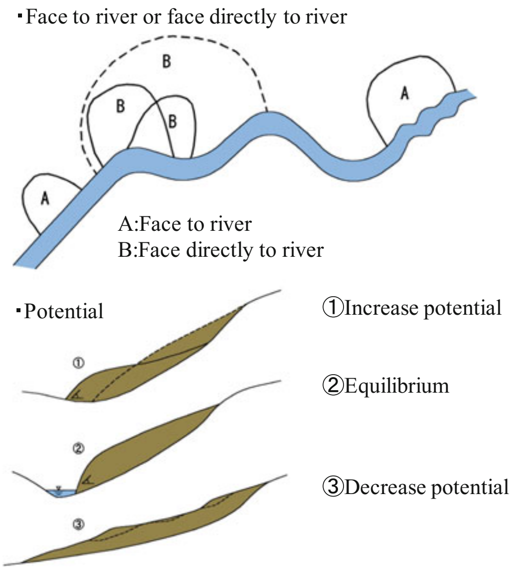

Fig. 4 Landslide topography and surrounding environment written by Mr. Tsurumi (Miyagi et al. 2004)

areas. Building on these procedures, evaluations of the weight of the decision standards have been discussed. In principle, this approach applies the AHP absolute evaluation 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.

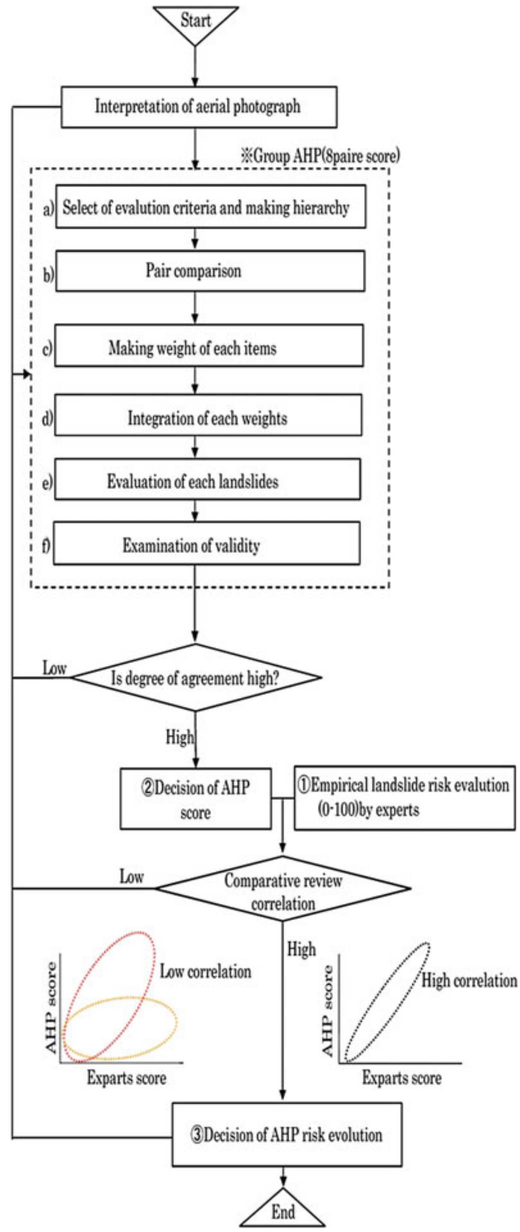

Fig. 5 Flow chart showing the determination process for the analytic hierarchy process score weights in Tohoku district, Japan (Miyagi et al. 2004)

3.3 Definition of Landslide Topography and Occurrence Risk, and Scope/Perspective of Interpretation

1. **Definition of landslide topography**

Landslide activity forms a characteristic "landslide topography" that can be distinguished from other topographical units. In other words, "landslide topography" is the topographical structure of the main scarp and landslide body formed by the landslide.

Consequently, the "landslide topography" used here for risk assessment is the most exterior part within the region topographically distinguishable from the surrounding slope as a result of past landslide displacement (including all micro-topography formed as a result of displacement).

Although bedrock fluctuations, such as bedrock creep, are sometimes mentioned among phenomena that lead to landslides, they are basically beyond the scope of the risk assessment considered here (Fig. 6).

2. **Definition of occurrence risk**

This refers to the probability of occurrence of the next landslide phenomena (including repeated displacements) somewhere within the "landslide topography" as defined in (1) above. The unit of risk evaluation is the entire "landslide topography," regardless of the location where the phenomenon occurs. However, this limit does not apply when the unstable portion is small in area, and the phenomenon is disconnected from the overall landslide failure chain. Also, the occurrence of landslides due to human impact, such as artificial land modification, is a major geological factor, but is beyond the scope of this evaluation. Here, "occurrence risk" refers only to likelihood of occurrence, and is not an evaluation of scale of occurrence or impact on surroundings at the time of movement.

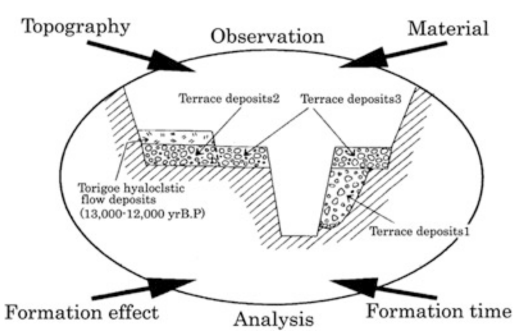

Fig. 6 Relationship of four elements controlling the topography of a river terrace

In cases where the entire "landslide topography" is evaluated using a partial, unstable region within it, the interpretation figure will clearly indicate said region; the presence or absence of other such regions, and its position and relative relationship with regard to the entire earthquake topography will also be noted in the "Landslide causes, other" section of the chart.

The items below are given for background information. The majority of landslides that occur in Japan are due to repeated displacement of past landslides.

Causes (or contributing factors) of landslide occurrences that formed the current topography may include sudden events, such as earthquakes. However, in keeping with the goals of risk evaluation (determining the likelihood of the next displacement) described here, contributing factors such as earthquakes and rainfall will not be included in our considerations/evaluation.

3. **Scope of interpretation and positioning of items within landslide topography**

The scope of interpretation is essentially the "landslide topography" as defined in (1) above, its internal micro-topography, and its surrounding environment. Bedrock creep will also be considered, but basically only for reference; it should be recognized that landslide risk assessment is a difficult matter. We will attempt to use the Analytic Hierarchy Process to rank and score each item, but in aerial photo interpretation, it is rare for there to be just one category in each item category; in most cases, there will be many. In

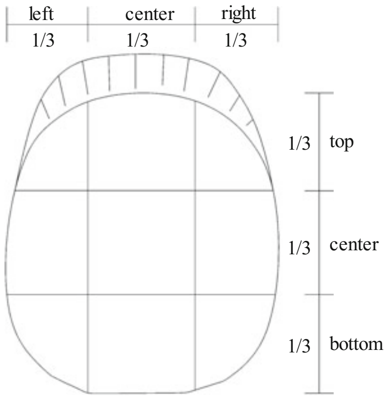

Fig. 7 Grid for defining positions within a landslide

terms of making judgments on safety, it is advisable to focus on instability checks, even in the middle of the category. In order to show the micro-topography that is subject to interpretation, the position of the landslide interior is defined in Fig. 7. The length and width of the landslide have been divided into thirds—right, center, left; top, center, bottom. Positions in the description will follow this pattern.

4. **Perspectives on interpretation**

(1) Natural slopes are subject to continuous, constant topographical fluctuations, caused by processes such as weathering, erosion, and sedimentation.
(2) Landslides occur intermittently and suddenly. Actual landslide topography is structured by a combination of landslide-prone topography and the above-mentioned topography. These two topographical phenomena are rigorously distinguished in photographic interpretation.
(3) The risk of landslide occurrence is high for newer and more recently active landslides, as repeated activity occurs easily. The scope of the above two topographical phenomena are compared, and the amount of elapsed time since landslide activity is sought.
(4) The landslide body degrades with repeated activity, leading to increased viscosity of soil, and a higher tendency toward repeated activity. Part of the micro-topography that structures the landslide body displays physical properties of the landslide body.
(5) For locations where no landslide is occurring, evaluations cannot be performed for initial landslides, nor for landslide topographies where the main scarp and landslide body have been mostly lost.

In topographical approaches to risk evaluation, (2), (3) and (4) above are performed via photographic interpretation.

3.4 The Analytic Hierarchy Process Method

1. **Abstracting and classifying evaluation criteria within the Analytic Hierarchy Process**

The working group should brainstorm to abstract evaluation criteria related to landslide risk, and classify them as shown in Fig. 5. First, separate base-line items for “landslide risk evaluation” into three general levels.

General categories are: (α) “landslide body micro-topography” as an index related to movement characteristics, (β) “landslide body boundary” as an index related to time elapsed, (γ) “topography surrounding the landslide body” as an index related to the topographic area.

Further subdivide each of these into six intermediate elements: (a) mode of movement, (b) landslide body micro-topography, (c) head boundary, (d) toe boundary, (e) tip of landslide body tip, (f) potential.

Create categories (minor elements) for the intermediate elements that will be the check indexes of the actual chart, and use the Analytic Hierarchy Process method to make paired comparisons for each of the major elements, intermediate elements, and minor elements. For practical purposes, the categories shown in Fig. 8

are arranged by intermediate items so that risk level increases from bottom to top.

These items were organized from left to right when the chart was created, to facilitate understanding of topography formation mechanisms. Incidentally, this structure permits the position of checks for categories to be placed between categories. In other words, in Fig. 8, if item F was determined to be between "talus" and "large scale talus," a check could be placed between the two.

However, when it is clear that multiple categories exist, the contribution of the one with the most weight is given priority.

2. **Paired comparisons, determining and integrating weights**

First, each person in the working group implements Analytic Hierarchy Process evaluations. The results are used as a springboard for creating the group's Analytic Hierarchy Process weights.

Here, we have set the Analytic Hierarchy Process paired comparison values as follows.

1: Both elements are about equally important.
3: Previous element is slightly more important than following one.
5: Previous element is slightly more important than following one.
7: Previous element is much more important than following one
(Other: 2, 4, 6, and 8 are interpolative values).

There are many references on calculating weight for each item in Analytic Hierarchy Process paired comparisons, but when finding the final weight for each category, we used the formula:

Final weight of minor element category = general AHP weight × intermediate AHP weight × minor AHP weight.

Among the coefficients obtained from integrating the weights, when checking the highest categories in the intermediate items a-f, compensating coefficients are added so that the total will be 100.

On the chart, the total of these check scores are termed the Analytic Hierarchy Process scores (total of model weight coefficients). In other words:

$$\mathbf{AHP\,score} = \boldsymbol{\alpha} \cdot \boldsymbol{\Sigma}\,\mathbf{X}(\mathbf{A} \sim \mathbf{I})$$

Here $\boldsymbol{\alpha}$ is the compensating coefficient

3. **Paired comparison and weight determination methods**

The specific steps for determining weight are as follows.

(1) Paired comparison of "general categories" related to risk estimation.

At this stage, 3 × 3 paired comparisons are made, based on:

I. Landslide body micro topography;
II. Landslide body boundary; and
III. Landslide body and surrounding environment.

For example, a matrix is shown below for paired comparisons assuming that "landslide body micro-topography is three times more important to risk evaluation than landslide body boundary." In the Analytic Hierarchy Process method, paired comparisons are performed in the same way for all elements, then geometric means are found for the horizontals of the matrix, and these ratios are converted into weights (Fig. 8).

4. **Final inspection sheet for Landslide risk evaluation using AHP in Croatia**

The Ctoatian working group carried out interpretation and made charts to build a consensus on risk evaluation methods. As a result, they were able to create a road map for a rational, objective quantification method. Moreover, when this method was applied to landslides occurring in the Tohoku region, it was shown to be largely suitable.

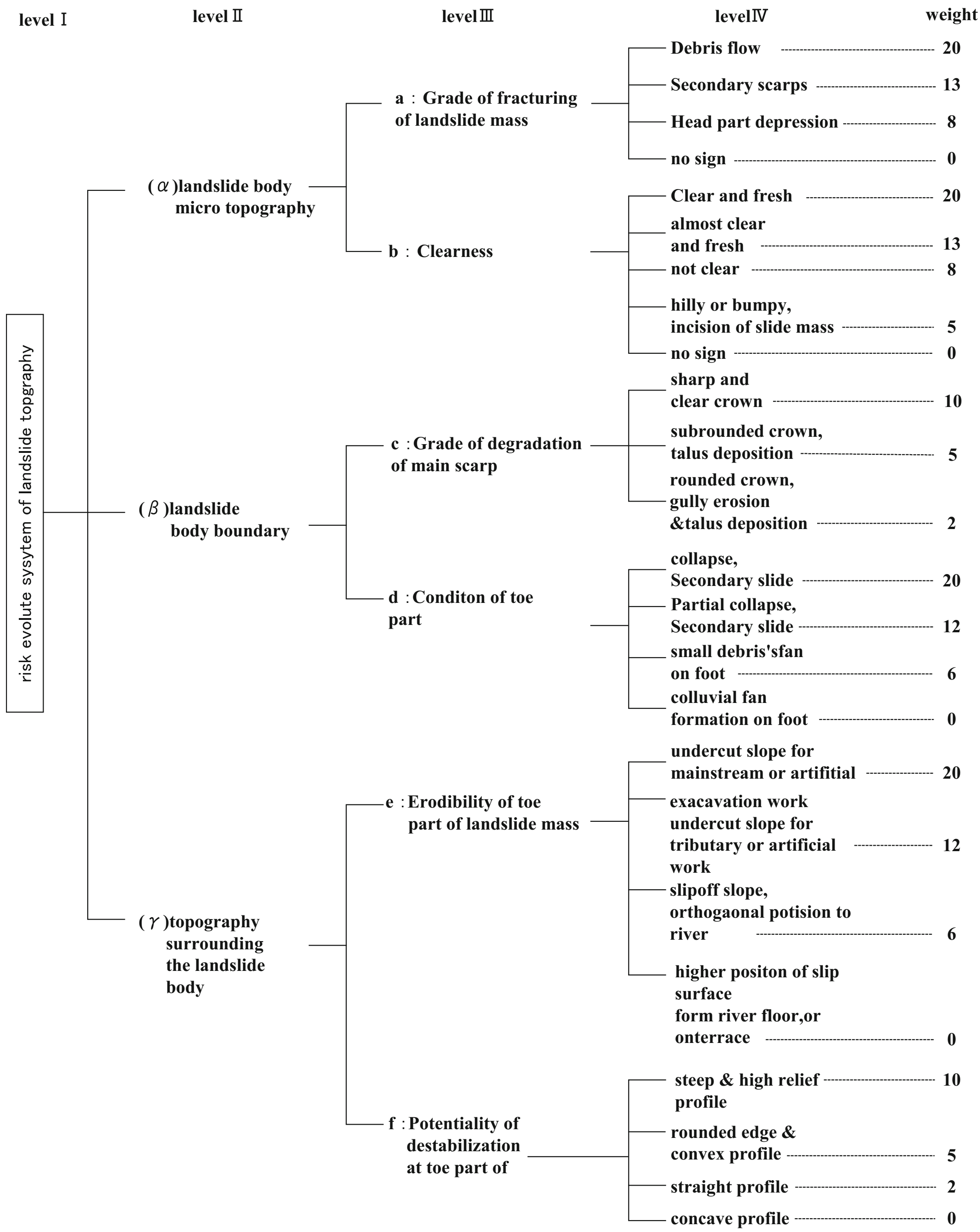

Fig. 8 Risk evaluation criteria for landslide topography

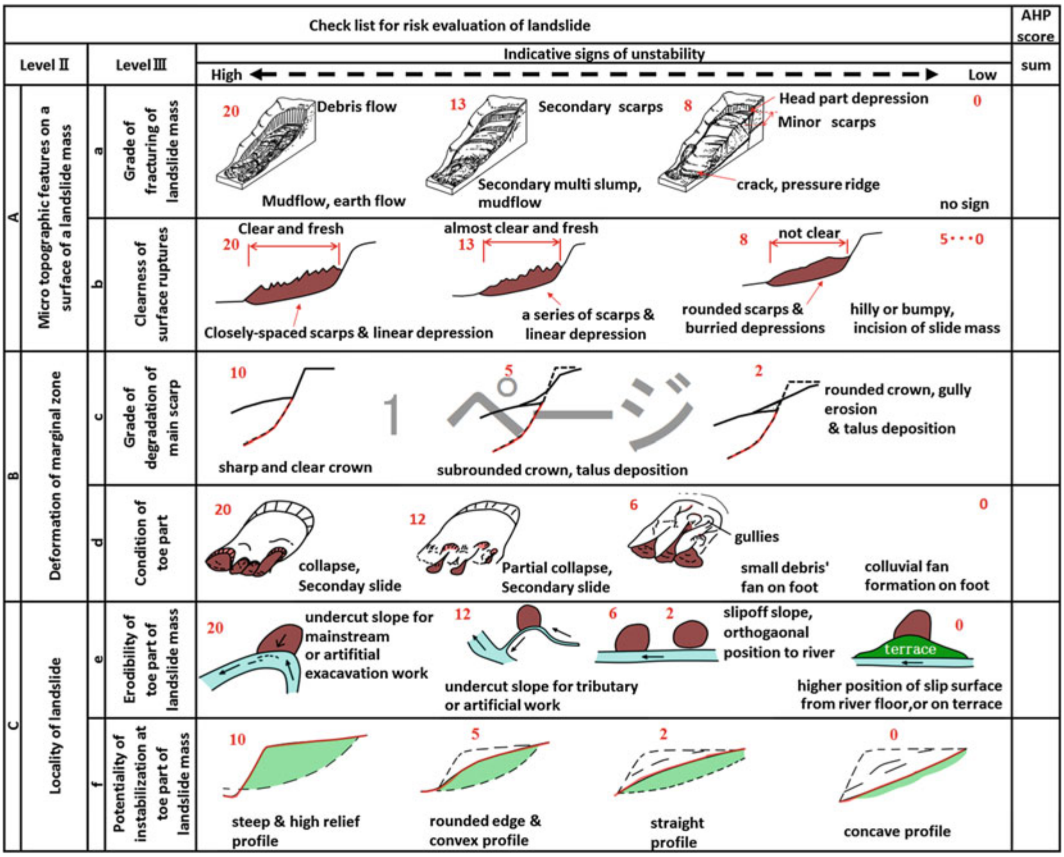

Fig. 9 Inspection Sheet for Risk evaluation of landslide topography using AHP method

During the Croatian disaster relief project, Profs. Miyagi, Yagi, and Hamasaki utilized their experience to rigorously narrow down the number of items and implemented weighted evaluations. To evaluate risk, this system uses an aggregate Analytic Hierarchy Process result, in which 100 is the highest score, and 0 the lowest. In other words, the Analytic Hierarchy Process score is the risk evaluation score for that point in time (Fig. 9).

4 Conclusion

Here, we have explained on the conventional methods in the form of the 'AHP relative evaluation method' and the 'AHP absolute evaluation 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.

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