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Estimation on how much anxiety people feel in underground urban space during earthquakes

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ABSTRACT: This study aims at discussing measures to be taken in underground urban spaces utilized by many people for disaster prevention during earthquakes. The objectives of this paper are; to identify a structural model of anxiety felt by people; to extract major factors which will help to reduce people's anxiety; and to estimate the degree of anxiety by the model through a survey on existing underground shopping malls.
(1)The most effective measures for reducing the degree of anxiety include the training of guides, the construction of emergency facilities an equipment, and training for disaster prevention. (2)Comparison between new and old underground shopping mall shows that the degree of anxiety regarding to information about refuge, and to facilities and equipment for refuge have improved in new ones. However, the degree of latent anxiety and anxiety regarding to leading people to refuge have improved only slightly.

1. INTRODUCTION

The current social background including over-development and a rise in land prices in large cities of Japan requires new spaces to be developed and utilized in order to maintain and improve city functions. Recently, underground spaces have been spotlighted because they are considered to be appropriate to this purpose. The underground spaces to be utilized by general people should be fully examined legally, economically, technically, and from the standpoints of utilization and disaster prevention.

Existing large-scale underground malls in Japan were mostly built in the 1980s-1980s. There have been only a few disasters. Most of them were caused by fires. Although earthquakes are frequent in Japan, no earthquake has ever caused a disaster.

According to the questionnaire(Hiroi 1990), people were most anxious about fire occurrences, then earthquakes. During an earthquake, they were anxious about suffocation by smoke, an explosion caused by gas leak, people in a panic state who are pushing and shoving toward exits, and the collapse of malls. The other questionnaire (Report 1979) showed that about half of them were anxious of an attack by an earthquake while staying underground.

This study aims at discussing measures to be taken in underground urban spaces utilized by many people for disaster prevention during earthquakes. As part of this study, brainstorming(Report 1989) was carried out. The basic points of prevention of disasters caused by an earthquake which are to protect people and to reduce people's anxiety. The objectives of this paper are; to identify a structural model of anxiety felt by people; to extract main factors which will help to reduce people's anxiety; and to estimate the degree of anxiety by the model through a survey on existing underground shopping malls.

2. STRUCTUTAL MODEL FOR ANXIETY

Procedures for making the structural model are as follows:
(1)Extracting factors of the proposition "Anxiety during Earthquakes".
(2)Evaluating the relation between the factors through a questionnaire.
(3)Identifying an objective structural model by the FSM (Amagasa 1988) method.
Based on the results of the brainstorming, major factors for people's anxiety are classified (from A to F in Table 1) with reference to causes for a panic (Handbook 1983), causes for a panic in underground malls (Catalog 1987), and so on. Subordinate factors for each major factor are shown in Table 1.

The structural model is made on the assumption that major factors are independent from each other. Pairwish relations between every major factor and its subordinate factors are determined by questionnaire. Answers for the questions range from 0.0 to 1.0 so that fuzziness is taken into account in structural modeling. The number of examinees was sixteen: nine men and seven women. Figure 1 is the estimated structural model by the FSM method. The estimated structural model is transformed into a inferance model by the AHP(Saaty 1980).

Table 1. Factors for anxiety

A. FACTORS OR LATENT ANXIETY
1. Unfavorable impression in the underground
2. Unfamiliar space (have never been in the space)
3. Closed space
4. Difficult to rescue people under the ground (far from over the ground)
5. Sounds echo(noisy, cannot catch information)
6. Lack of the sense of time (difficult to tell what time is it)
7. Artificial space (power supply, ventilation and supply of oxygen may be cut off)
8. Lack of the sense of direction (position and direction, difficul to tell where you are)
9. Difficult to escape (unable to escape)
10. Secondary disaster may occur. (Ex. a fire, filling smoke)

B. FACTORS RELATED TO DAMAGES
11. Recognition of damages
12. Feeling unusual heat
13. Eyes tearing from the gas
14. Having difficulty in breathing
15. Catching an unusual smell (smell of gas and something burning)
16. Hearing something to get damaged
17. Hearing a scream
18. Things fall
19. Things shake
20. The underground structure cracks.
21. A fire breaks ou
22. The underground space is filled with smoke.
23. Water Leaks.
24. The electric supply is cut off.
25. Hazardous gas is generated.
26. The underground space is closed.
27. Facilities and equipment to protect the underground environment are damaged.
28. Structures are not designed to absorb vibrations caused by earthquakes.
29. Shortage of facilities and equipment for fire extinguishing purposes
30. Things are not made sufficiently fire-proof.
31. Facilities and equipment are not sufficiently waterproof.
32. Shortage of emergency facilities and equipment
33. Facilities and equipment are not sufficiently of seismic design.
34. Fire is used
35. Walls crumble.

C. FACTORS RELATED TO INFORMATION ABOUT REFUGE
36. Inadequate information about refuge (people do not believe the information or listen to it)
37. Information transmitted by word of mouth (rumor etc.)
38. Impossible to confirm information about refuge (or the general public)
39. Low reliability of information about refuge
40. Delayed transmission of information about refuge
41. Means to transmit information is not sufficient. (communication media)
42. Lack of unity of information about refuge
43. Shortage of transmitted information about refuge
44. Impossible to confirm whether information has been transmitted (one-way transmission)
45. Shortage of means to gather information (by store operators)
46. Misunderstanding and insufficient confirmation of information about damages
47. Operators of underground stores are not well trained.
48. The centralized monitoring system is not sufficient.

D. FACTORS RELATED TO LEADING OF PEOPLE TO REFUSE (BY GUIDES)
49. The guides' instructions become unclear. (about route and refuge)
50. The guides become upset. (a panic may occur.)
51. The guides hurry people. (make people run)
52. The guides do not know sufficient information or the information is inconsistent.
53. The guides are not well trained.
54. The shortage of guides (one guide must lead more than the adequat number of people to refuge)
55. Inadequate guidance

E. FACTORS RELATED TO FACILITIES AND EQUIPMENT FOR REFUGE
56. People cannot find routes to refuge easily.
57. People take a long time to escape.
58. Guides cannot find facilities and equipment to lead people for refuge easily.
59. The shortage of routes to refuge
60. Routes to refuge are complex.
61. The shortage of refuges
62. The narrowness of routes to refuge
63. There are no definite refuges.
64. The shortage of equipment to prevent damages

F. FACTORS RELATED TO ACTIONS TO BE TAKEN DURING EARTHQUAKES
65. People do not know how to behave during an earthquake
66. People have not been trained against disasters.
67. People do not know how to use emergency equipment.
68. People do not have a disaster drill in facilities they attend.
69. People have no experience in a disaster.
70. People tend to make light of a disaster.
71. People do not know where emergency equipment is.

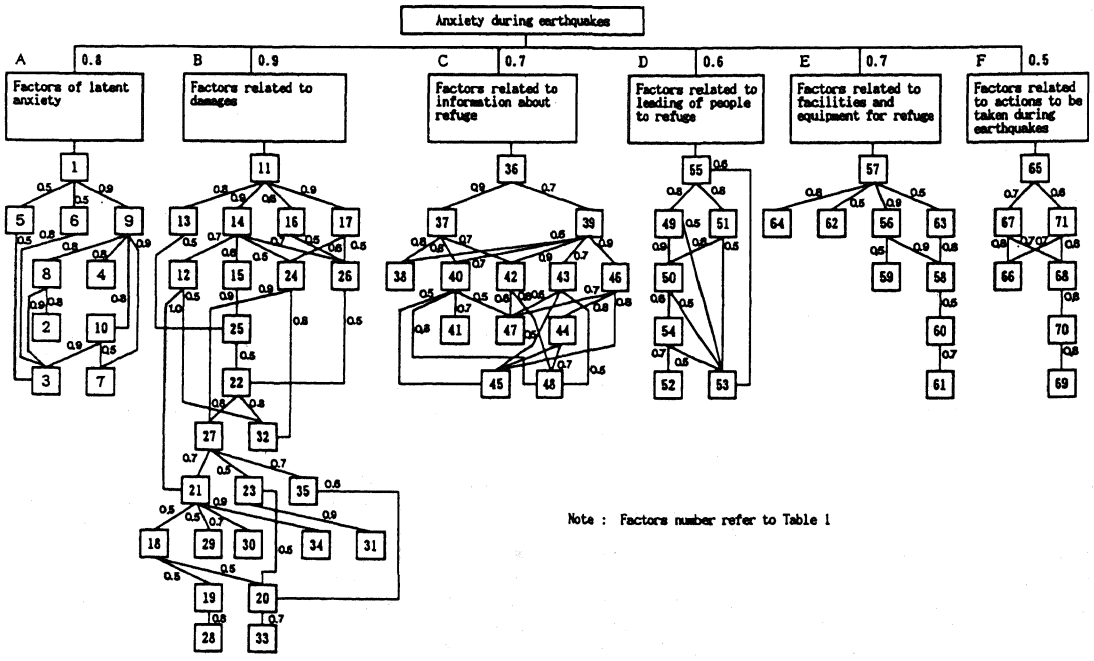

Figure 1. Hierarchy for anxiety during earthquakes

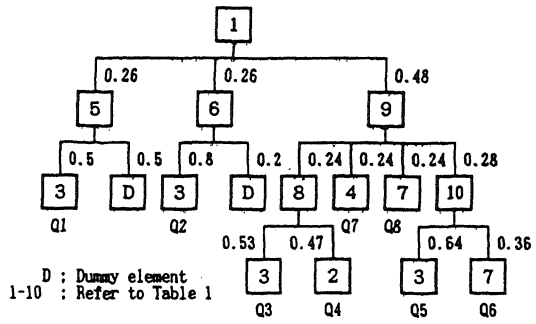

Figure 2.The AHP model of major factor A .

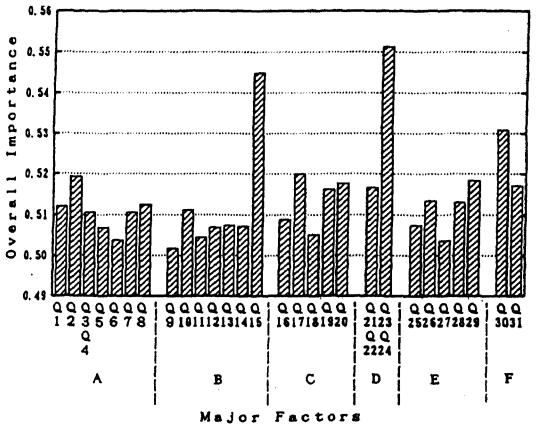

Figure 3. Sensitivity in each major factor.

Table 2. Intensity of importance.

Intensity of Importance		Definition	Intensity of Importance		Definition
1	(0.50)	Cannot say	9	(0.90)	Absolutely yes
3	(0.75)	Almost yes	2	(0.67)	4 (0.80) Intermediate values
5	(0.83)	Yes	6	(0.86)	8 (0.89) between the two
7	(0.88)	Rather yes			adjacent judgements

Note: The reciprocal value is used for the opposite meaning.
( ):Degree of importance of alternative answer

3. AHP INFERENCE MODEL

Figure 2 shows inference model for the major factor of latent anxiety. Factors in the lowest hierarchy act as higher level elements for input elements. In this model, the input elements are from Q1 to Q8. The degree of latent anxiety is inferred by choosing between two options for each question. For example, based on the assumption that you are in a certain underground space, Q1 asks how much one feel annoyed by echoing sounds in closed space. You answer how much you feel annoyed by choosing a number from 1 to 9 for intensity of importance (Table 2). In each binomial matrix of answers, the eigen values is calculated. The eigen vector of the maximum eigen value shows the degree of importance(Table 2).

4. FACTORS REDUCING ANXIETY EFFECTIVELY

Figure 3 shows the results of the sensitivity analysis by the AHP inference model. Procedures for it are as follows:

(1) Enter 1 for all input elements.
(2) Enter 9 for one input element.
(3) Estimate the overall importance (weight), which is adopted as the sensitivity of the input element chosen in procedure(2).

The highest sensitivity in each major factor is Q2,Q15,Q17,Q23,24,Q29 and Q30 (6,32,48,53, 59 and 66 in Table 1). Among these, the factor with the highest sensitivity is "the guide is not well trained" followed by "the shortage of facilities and equipment for emegency"and"people have not been trained against disasters".

Therefore, providing sufficient measures to train guides, furnishing facilities and equipment for emergency and training the general public will help to reduce anxiety felt.

5. ESTIMATION OF DEGREE OF ANXIETY EXISTING IN UNDERGROUND MALLS

Using the AHP inference model, we have estimated how much anxiety people feel about existing underground malls during earthquakes. In the AHP inference model, values for input were collected through questionnaires. A questionnaire consists of 28 questions for all input elements for the inference model. To verify the results of the inference,a question to the proposition about anxiety during earthquakes was added. In the questionnaire, examinees answered the questions after seeing two simulation film of underground mall which were built in the 1950s and after 1985 respectively. The number of examinees was twenty one, of which fifteen were men and six were women. Figure 4 shows the frequency distribution for the estimated degree of anxiety related to each major factor. The abscissa represents the degree of anxiety which is shown in Table 3. For the old underground mall,the sections from "almost yes" to "absolutely yes" showed higher frequency for each major factor excluding factor "F". In contrast, for the new ones, the sections from "rather no" to "rather yes" showed higher frequency. The frequency distributions spread more widely for the new underground mall than the old ones. In particular, major factors "D"and "E" showed wide frequency distributions. This may show that although elaborate disaster measures are expected to be taken for new underground malls compared to old ones, public estimation of these new measures is diversified. Figure 5 shows the average values of anxiety related to each major factor (from A to F). Characters "G" in the figure means values of estimated degree of

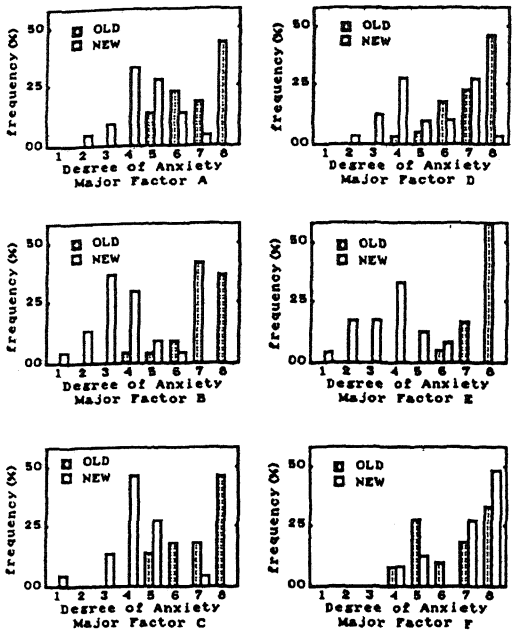

Figure 4. The frequency distribution for estimated degree of anxiety related to each major factor.

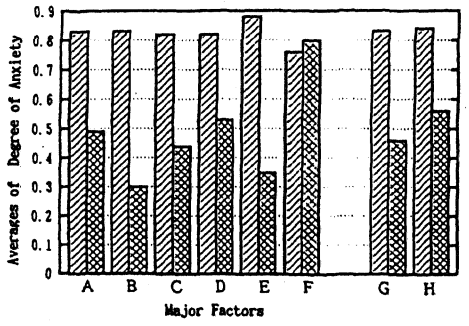

Figure 5. Samples' averages of degree of anxiety (▨ : Old underground shopping mall, ▩ : New underground shopping mall)

Table 3. Degree of anxiety

Scale	Degree of Anxiety	Definition
1	0.10-0.12	Absolutely no - Rather no
2	0.12-0.17	Rather no - No
3	0.17-0.25	No - Almost no
4	0.25-0.50	Almost no - Cannot say
5	0.50-0.75	Cannot say - Almost yes
6	0.75-0.83	Almost yes - Yes
7	0.83-0.88	Yes - Rather yes
8	0.88-0.90	Rather yes - Absolutely yes

anxiety and "H" means the values of results from asking about the degree of anxiety during earthquakes.There are big differences between the new and old underground mall regarding to major factors "B"and "E". In view of this, we predict that these factors for the new underground mall will thought to have greatly improved. However, it is obvious that major factors"A"and "D" have improved only slightly. Moreover,the results of the questionnaire and the estimates coincide fairly well with each other. The figure also shows that anxiety regarding to the new underground mall is weak compared to the old ones in the sections from "yes" to "cannot say" .

6. CONCLUSIONS

(1) The most effective measures for reducing the degree of anxiety in underground spaces during earthquakes include the training of guides, the construction of emergency facilities and equipment, and training for disaster prevention.
(2) Comparison between the new and old underground mall shows that the degree of anxiety regarding to factors related to information about refuge, and factors related to facilities and equipment for refuge have improved in the new ones. However,the degree of anxiety regarding to factors of latent anxiety, and factors related to leading of people to refuge have improved only slightly.
(3) The samples' average of the questionnaire carried out in the new and old underground mall on the degree of anxiety show nearly the same tendency as those of estimation by the structural model. This indicated that the model can be considered to be almost appropriate.

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REFERENCES

Hiroi,O.1990. Great Earthquakes and Underground malls. Monthly Fire Services Journal.
Tokyo Fire Defense Agency and Fire Prevention Council.1979. Report on Research on Actual Conditions of Underground Malls.
Development of Seismic Design of Underground Structures. 1989. Report of DWRI,No.29.
Amagasa. 1988. Thesis on System Structure -Based on Fuzzy Logic-. Moriyama Shoten.
Research Association of the Construction Industry.1983. The Latest Handbook for

Disaster Prevention for buildings.
Catalog of Regional Data for Disaster Prevention, Vol. for Regional Refuge. 1987. Found. of the Center of Fire-Fighting Science.
Saaty,T.L. 1980. The analytic hierarchy process. McGrow-Hill, Book Co.,1980.