TROUBLES PEOPLE HAVE TO SUFFER WHEN LIFELINES FAIL TO FUNCTION AFTER EARTHQUAKE

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ABSTRACT

In the rehabilitation stage of lifelines after earthquake, there would be no room for argument that people tend to experience various kinds of inconvenience due to the functional failure of lifeline systems. However, we do not know yet the exact nature and degree of such inconvenience people may experience during the lifeline functional failure. In order to make it the optimal the rehabilitation processes of lifelines after earthquake, we need to have some empirical data for the quantitative understanding of the incontinences. In this paper, we would like to present a model that describe the inconveniences due to lifeline functional failure based on the experiences by those who lived in Noshiro-city at the time of 1983 Nihonkai-chubu earthquake.

INTRODUCTION

Lifeline systems are one of the indispensable infrastructures for those people living in cities, and they include water supply systems, energy supply systems, disposal systems, transportation systems, and telecommunication systems. Lifeline systems are, however, vulnerable to earthquake. As a result, lifeline services in those cities located near the epicenter were sustained at the every major severe earthquake occurred in Japan for the last 30 years. For example, those people had to suffer severe inconveniences due to lifeline functional failure in such cities as Niigata city at 1964 Niigata earthquake, Sendai city at 1978 Miyagikenoki earthquake, Noshiro city at 1983 Nihonkai-chubu earthquake, and Kushiro city at 1993 Kushirooki earthquake. Thus, the maintenance of reliability of lifeline services became increasingly important issue in the field of urban earthquake engineering along with the rapid development of urbanization of society.

In this paper, we would like to propose a new perspective of lifeline earthquake engineering which integrates the present perspective based heavily on mechanical engineering and system engineering with social scientific perspective which take into account how people would respond to the suspension of lifeline services after earthquake. After explicating our basic assumptions of human behavior as need-reduction sequence, we present our "management model of lifeline earthquake engineering whose goal is the minimization of the inconveniences experienced by the people living in city. Based on the data taken from our intensive survey that asked about 3,000 Noshiro-city residents for their experiences of Nihonkai-Chubu earthquake (1983), some data will be shown to examine the validity of our model.

LIFELINE EARTHQUAKE MANAGEMENT PERSPECTIVE

Lifelines sectors have being taking the every effort to protect the system from earthquakes in all the stages of disaster mitigation, preparedness, responses, and recovery [1]. The prime goal of these efforts has been the minimization of the damages, which is evaluated by the post-earthquake service restoration curve. The main path to achieve this goal is to make the components of lifeline system physically robust and/or to make the lifeline system reliable as network. In this paper, this approach will be called as "pure engineering" approach. Pure engineering approach has been successful in reducing the magnitude of lifeline functional failure. Based on the present state-of-arts and practices in Japan, it is expected in such cities with the population of less than 300,000 people that the normal post-earthquake service suspension period of electric power would be for one day, that of water supply for one week, and that of gas for one month.

Even though pure engineering approach has been successful in reducing the magnitude of lifeline functional failure, it is too expensive and/or virtually impossible to make the lifeline systems free from any damages due to earthquake. People living in cities still have to suffer some inconveniences due to the suspension of lifeline services after earthquake. In case of the earthquake that hits some big city where millions of people live, is it possible or realistic to extrapolate the present level of post-earthquake lifeline performance? The answer would be negative if we take into account the size and complexity of lifeline systems operating in metropolitan regions like Tokyo and Osaka. In any case, it remains as an important issues how to minimize the inconveniences experienced by the people living in cities because of the suspension of lifeline services after earthquake. In challenging this issue, we need to have a new approach which take into account how people would respond to lifeline functional failure after earthquake. In this paper, we call this approach as "management approach".

Both the management approach and the pure engineering approach share the same aim to maintain the quality of lifeline services even in the time of crisis. These two approaches, however, set different goals to actualize the common aim. In the pure engineering approach, the goal is the minimization of the damages. The efforts of the lifeline sector is organized in order to reduce the initial service suspension rate as low as possible and to make the restoration curve as steep as possible. The management approach aims at the minimization of psychological dissatisfaction experienced by the people living in the city with the inconveniences due to the post-earthquake suspension of lifeline services. Even though the minimization of damages itself is the tactics used for the front attack, the management approach also try to reduce the psychological dissatisfaction by providing the information that people want to know.

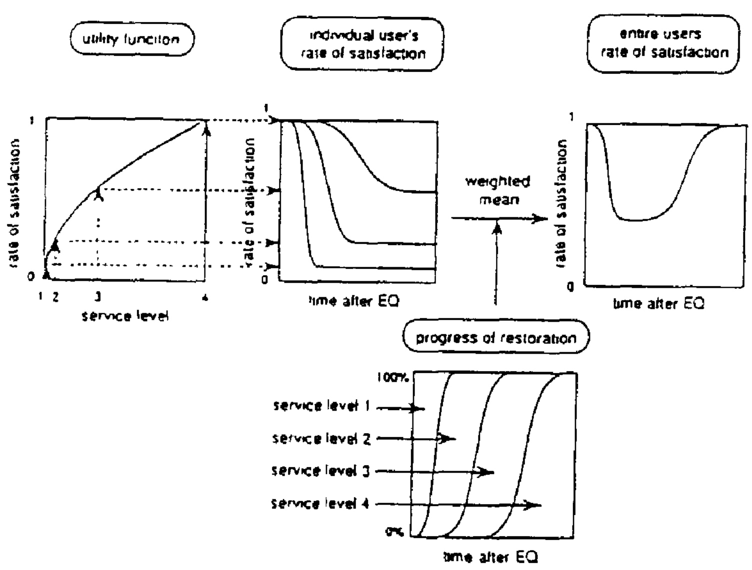

Fig. 1 Schematic Illustration of engineering/Psychological Evaluation of Post-Earthquake Performance of Lifelines [Adopted from Kameda & Nojima (1992)]

Kameda & Nojima [2] introduced a new framework of post-earthquake lifeline performance based on the management approach. They evaluated the post-earthquake lifeline performance not in terms of the in-service rate of lifelines, but in terms of the rate of user's satisfaction, as depicted in Fig. 1. Right after the earthquake lifeline service level is the lowest, at the same time customers' demand is the lowest. As time goes by, both lifeline service rate and customers' demand gradually go back to the normal level. The post-earthquake lifeline performance is determined as a joint function of temporal changes in customers' demand level and those in lifeline service level. There would be no room for argument that both human factors and engineering factors should be included in the management approach for a better understanding of post-earthquake lifeline performance. Based on this framework, what we need to do next is to elaborate these two factors to have a more specific model of post-earthquake lifeline performance. First step should be the clarification of human factors.

HOW HUMAN FACTORS SHOULD BE INCORPORATED INTO LIFELINE EARTHQUAKE ENGINEERING

Lifeline systems provide the satisfaction of human motives. Basically, there are three kinds of human motives. First, there are such biologically based motives that are essentially unlearned and that pertain to the individual alone rather than to his/her interaction with others. Examples are hunger and thirst, the desire for safety, and the need for rest. Second group is no less biologically based than hunger and thirst, but it involves motives that transcend the individual alone and focus on his/her relations with other persons, such as sex, filial love, and aggression. Third group concerns social desires that are acquired through learning, such as the need to achieve, to attain prestige, or to amass possessions. Lifeline services may be deeply concerned with the satisfaction of the first two groups of biologically based human motives.[3)]

The organism including human exist in an internal environment as well as an external one. This internal environment is kept remarkably constant despite considerable fluctuations of the outside environment. The striking consistency is shown by the salt and water balance of the body, its oxygen concentration, its pH, its temperature, and so forth. In healthy organisms, all of these oscillate within very narrow limits and these limits define the organism's conditions for health and survival. This stable internal equilibrium is termed as homeostasis.

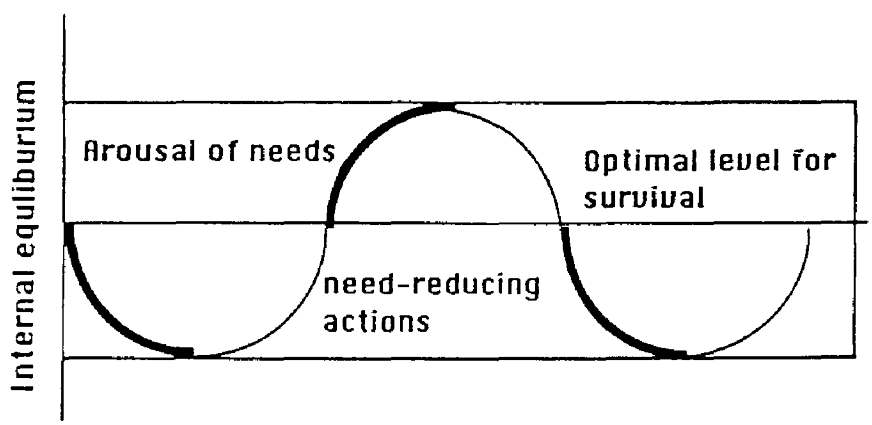

Fig. 2 Conceptual Model of Human Seeking the Internal Equilibrium

Taking human temperature regulation as an example, let us look at how the homeostasis mechanisms work. If our internal temperature is too high, various reflexive reactions such as vasodilation and sweating produce heat loss. An opposite pattern is called into play such as vasoconstriction when the internal temperature is too. These reflexive reactions are called into play when temperature deviated too far from some internal temperature setpoint. The homeostasis mechanisms are essentially involuntary. But there is no question that when the need arises, these reflexive mechanisms are supplemented by voluntary actions. Now the organism actively changes its external environment so that its internal environment can stay the same. This negative feedback system is the biological basis of human motivational actions which regulate most of human behavior, including social behavior.

After major earthquakes, people experience turmoil and losses in many respects. They include the threat to their safety and possessions, the amenity of their living, and their psychological well-being. In other words, the stable internal equilibrium existed before the earthquake is disturbed so that the organism is motivated to restore the equilibrium or to establish a new balance. The suspension of lifeline services following earthquake causes a threat to the amenity of people's living which is mainly based on the satisfaction of human homeostatic needs. If it takes long time to restore lifeline services, it is expected that people may suffer inconvenience related with such biologically based needs.

The Fig. 2 indicates the basis of how we conceptualize the inconvenience people would have to suffer due to the suspension of lifeline services after the earthquake. Because of the unavailability of lifeline services, people are unable to start the action that people usually take when the need arises as their "routine behavior". Under these circumstances, people have to come up with some new measures to restore the pre-existing equilibrium or to establish new balance. There are at least three different measures: (1) Suspending the need itself; (2) Trying new actions; and (3) Displacing themselves from the scene.

A LIFELINE EARTHQUAKE MANAGEMENT MODEL

Fig. 3 shows how lifeline earthquake management approach conceptualize the post-earthquake response and recovery stages. In this figure, temporal sequence is presented by the configuration of boxes from the top to the bottom: pre-event, co-event, and post-event. Lifeline sector is represented on the left side of this figure, and people relying on lifeline systems on the right side. The key concept of this model is the "crisis" that people may experience due to the suspension of lifeline services after the earthquake. The nature and the severity of the post-earthquake crisis may be determined by a number of factors related with the lifeline earthquake engineering approach such as the lifeline dependence, the lifeline damages, and the lifeline recovery operations, which are represented by those boxes with bold line. It also may be determined by the efforts taken by the people as in the forms of the household preparedness and the coping responses adopted by them. It is obvious from the figure that the traditional lifeline engineering approach can be subsumed as a part of the lifeline earthquake management approach.

The lifeline dependence is determined as a joint function of the availability of lifeline services and appliances in use. People would not experience any inconvenience due to lifeline functional failure unless their daily living relies on lifeline systems and/or their appliances are vulnerable to earthquake. For example, such powers distributed through lines can be supplemented by other power source stored on the spot. If the damages due to earthquake is small in quantity and limited in space, and If they are followed by quick and efective response and recovery operations, little crisis would be observed.

Household preparedness has at least two aspects: Appliances in use and other preparations for disasters. A good combination of appliances can reduce the inconvenience due to lifeline functional failure. Since it usually takes fewer days for electricity to recover than gas, electric powered appliances can be used as the alternatives for the gas appliances. Preparing necessary goods for emergency situations may be helpful to reduce the severity of the crisis. As mentioned in the previous section, people begin to take such coping responses other than their routine behavior as suppressing needs, trying new actions, and displacing themselves from the disaster scene (or evacuation).

The crisis also can be affected by the availability of social services. For example, let us look at the "island of civilization" found in Hiroshima city in Japan after Typhoon 9119.[4)] This typhoon caused a large scale electric power failure for at most five days. It is designated as the island of civilization those areas which cover the center of social activities of Hiroshima city, where the underground power distributing system has been implemented so that no blackouts were observed due to salt damage which lasted for the last three days of five days blackouts. As a result, there found little social disorder among the people in Hiroshima city because of the availability of social services provided on the island of civilization even in the middle of a prolonged blackouts.

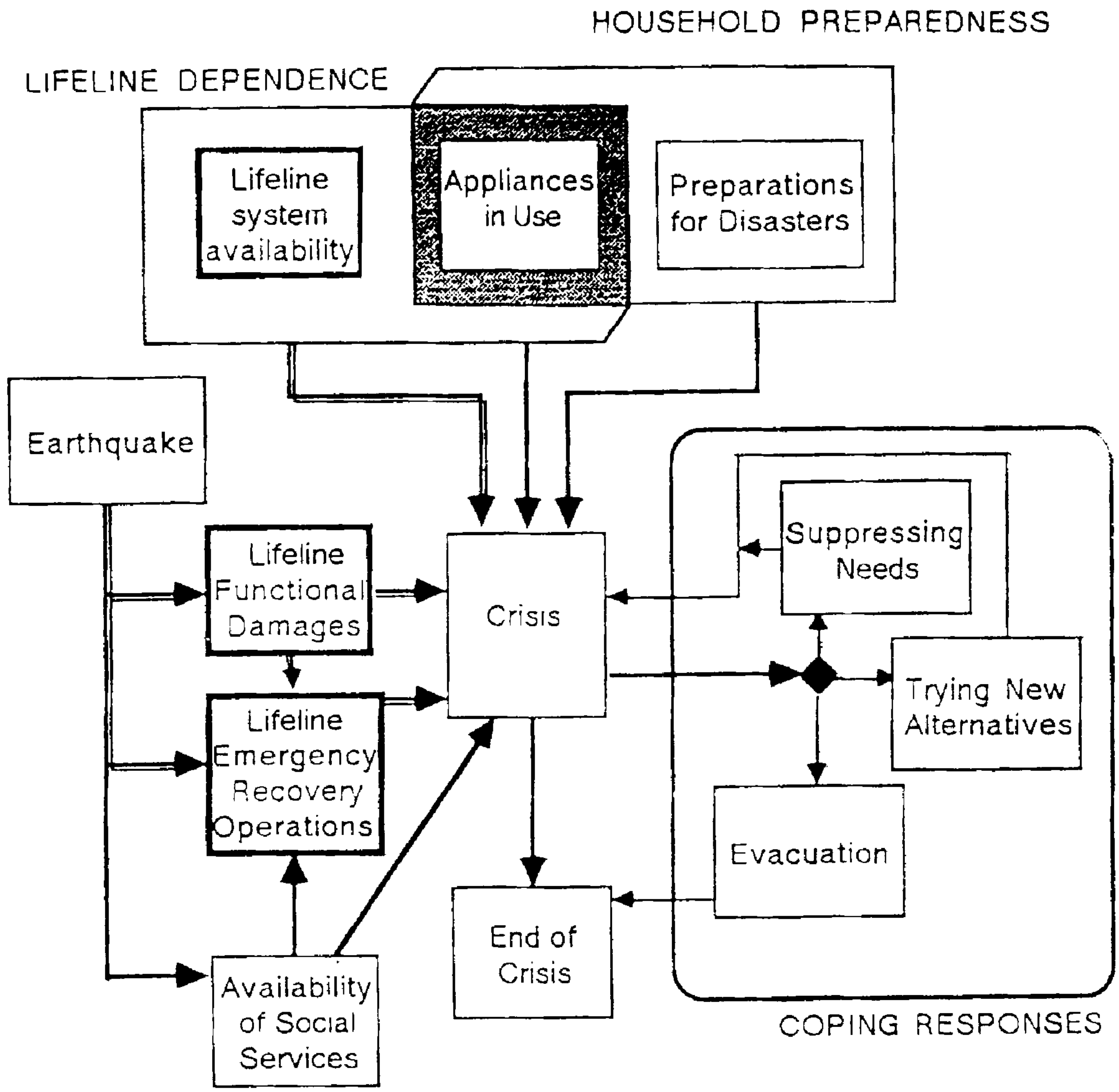

Fig. 3 A Lifeline Earthquake Management Model

THE NATURE AND EXTENT OF CRISIS EXPERIENCED BY THE PEOPLE LIVING IN NOSHIRO CITY AFTER 1983 NIHONKAI- CHUBU EARTHQUAKE

In order to test the validity of our lifeline earthquake management model, we have conducted a questionnaire study with a sample of 1,508 people who lived in Noshiro city at the time of 1983 Nihonkai-chubu earthquake, where a severe lifeline functional failure was occurred after the earthquake. In this paper, we would like to examine quantitatively the nature and the extent of the crisis experienced by the people in Noshiro city after the earthquake. It was assessed by the self report as to the severity of 39 inconveniences and troubles they might experienced. As listed in Table 1, these 39 items were the summary of the facts found in the reconnaissance reports published after various earthquakes.

A factor analysis was conducted to identify the types of crisis people may experience. Based on the scree test, we decided to retain five factors extracted by the principal component method. The total variance explained by these five factors amounts to 0.5700. Table 1 summarizes the factor loadings of five factors rotated by Varimax rotation method.

The first factor can be interpreted as "Water-related activities" because all the activities with high factor loadings on this factor can not be performed without water supply. Some activities rely only on water-supply such as drinking water and flushing water, others need or prefer to have some kinds of heat source. This factor is directly related with the suspension of lifeline services. The second factor can be interpreted as the factor concerning the "Social stability after earthquake". This factor reflects the anxieties held by the people as to the stability of the social services available to them before the earthquake. Thus, this factor is related with the availability of social services. The third factor again is directly related with the suspension of lifeline services. All the items with high factor loadings on this factor would be in trouble directly or indirectly as the results of the electric power supply, or "{Electricity-related activity". Another common feature of this factor is the fact that relatively small proportion of people had suffered on those activities with high factor loadings on this factor. The fourth factor reflects the "Informational needs" held by the people after the earthquake. With the earthquake, lots of information should be acquired before people understand exactly what happened to them as well as to their community to restore their internal equilibrium. Since telecommunication systems and transportation systems provide the basis for acquiring such information, this factor reflects indirectly the suspension of lifeline services. The last factor is concerned with "the property losses" caused by the earthquake. Since houses and real estate comprises of an important part of personal assets for many people, there would be no question people would be deeply concerned with the property losses.

CONCLUSION

The results of factor analysis of inconveniences and troubles experienced by the people in Noshiro indicated that there are five different kinds of inconveniences: (1) Water-related household activities, (2) Anxieties as to the social stability after earthquake, (3) Electricity-related household activities, (4) Informational needs held by the people after the earthquake, and (5) The property losses caused by the earthquake. In relation to lifeline earthquake management, three of these factors turned out to be concerned with the suspension of lifeline services directly and indirectly. It found that electricity and water are the two basic supply systems which results in the inconveniences for many household activities. The suspension of services by both telecommunication systems and transportation systems affects the informational needs held by people after the earthquake. In the next step, we would like to clarify the relationships between these three types of inconveniences and the coping strategies taken by the people after the earthquake.

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Table 1 A Factor Analysis of Incontinences and Troubles Experienced by the People Living in Noshiro city at the time of 1983 Nihonkai-Chubu earthquake

INCONVENIENCES AND TROUBLES	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
Doing dishes	0.86584	0.17753	0.06806	0.09941	0.07736
Washing faces	0.86309	0.16889	0.02811	0.03491	0.11819
Doing laundry	0.86012	0.17821	-0.02825	0.03785	0.14984
No drinking water	0.83905	0.16515	0.00806	0.05487	0.13812
Cooking	0.82733	0.14109	0.17603	0.11977	0.00897
Taking a bath	0.81836	0.16672	-0.03388	0.02906	0.20423
Boiling water	0.77551	0.13829	0.23652	0.11684	0.02278
Cooking rice	0.73027	0.11554	0.28622	0.19596	0.00749
Flushing toilet	0.49723	0.01150	0.26798	-0.00135	0.09512
Social Disorder	0.04628	0.74643	0.37002	0.08061	0.10072
Disease	0.26725	0.72174	0.22129	0.13249	0.17003
No merchandize to sale	0.30858	0.70529	0.19265	0.19779	0.08382
Fire	0.02465	0.69957	0.24025	0.12614	0.12336
Inflation	0.05642	0.69550	0.32499	0.08450	0.11260
Sanitation	0.40827	0.67203	0.12509	0.11219	0.16958
Tsunami	0.21962	0.53543	-0.10383	0.28913	0.12831
Child fearing earthquake	0.14903	0.48986	0.04510	0.26226	0.09651
Aftershock	0.30539	0.48041	-0.18941	0.35801	0.18437
No cooling	0.11179	0.16041	0.71388	0.00632	0.10242
No heating	0.14748	0.22234	0.67593	0.01145	0.18495
No radio	0.25105	0.17487	0.65273	0.18705	-0.01007
No television	0.29815	0.14972	0.60280	0.28223	0.01561
No refrigerator	0.47575	0.09224	0.53094	0.22461	0.03648
No cleaning a house	0.47726	0.20973	0.52530	0.09743	0.10206
No lights	0.22810	0.06491	0.49815	0.37432	0.17097
No injuries (personal)	-0.03186	0.07666	0.45030	0.05394	0.12897
No injuries (family)	-0.04454	0.05296	0.38816	0.07650	0.17280
No contact with friends and relatives	0.09854	0.17591	-0.02375	0.76541	0.02520
No contact with family	0.06776	0.18203	0.01150	0.71275	0.04088
No information regarding disasters	0.09625	0.19936	0.12334	0.70885	0.07609
No commuting	0.04609	0.15833	0.33028	0.59112	0.17350
No business communications	0.03775	0.12632	0.31085	0.58641	0.08452
No business	0.07646	0.07430	0.28168	0.53030	0.23384
Repairing the house	0.11779	0.12762	0.04345	0.08046	0.79193
Cleaning up outside the house	0.09496	0.09326	0.15328	0.05285	0.77992
Repairing gates and walls	0.07460	0.12004	0.17020	0.04437	0.73142
Cleaning up mess inside the house	0.20304	0.13875	0.01539	0.15805	0.64999
Repairing furniture	0.15752	0.18348	0.15091	0.11670	0.57538
Troubles in relation to real estate	-0.01641	0.06568	0.32175	0.10172	0.53690
EIGENVALUE	7.00055	4.39759	4.09598	3.41680	3.32015
PROPORTION	0.1795	0.1128	0.1050	0.0876	0.0851