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ADVANCED BUILDING REGULATIONS

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Abstract

Engineering differs from pure science, as it is directly connected to social affairs. For example, building regulations provided against earthquake disasters are the fruits of structural and earthquake engineering, and, at the same time, the reflection of the social conditions in the concerned areas. This paper shows a method to utilize both natural and social data in making seismic regulations for houses and buildings of a nation and/or region, with the proposed concepts of life-risk related to average lifespan of inhabitants and efficiency of investment related to number of saved life. First Japanese natural and social conditions are explained with a brief history of the building regulations to show their relations, and, then, the proposed method is illustrated with an assumed model of a developing region. A comparison of building regulations are made between Japan and the assumed region, to show that both natural and social conditions of regions give big effects on their regulations. Japan, a very active earthquake country with high population, keeps low risk-level of people's life, despite its high disaster potential. It requires high safety-level in the present building codes, and still needs to invest for an expected huge earthquake at the "Nankai" Trough. At the same time, measure against "committing suicide" is essential to decrease its life-risk. In the assumed region, where the earthquake is not active, population density is not high and the life-risk is high, seismic regulations need not aim a high safety-level. One of the proposed solutions is to recommend means to escape from damaged structures, instead of reinforcing the structures themselves. Availing the knowledge of the modern seismology and earthquake engineering, the life-risk caused by seismic disaster can roughly be estimated nowadays. Comparing the risks of various causes and their efficiency of investment, rational distribution of funds to increase the number of saved life will be realized. (In the assumed model, big portion of the funds will be shared to improvement of education, sanitation and medical cares.) Making building regulations is included in the distribution-step. The proposed method is illustrated in the form of a flow chart in the last figure.

Keywords: building regulation, life-risk, social data, developing country, Japanese codes, efficiency of investment, investment function of age, natural disaster, human-instigated disaster

1. Introduction

All kinds of engineering, including that of earthquake, deeply relate to social science; they are directly connected not only to natural science and technology but to social matters.

This paper explains how to apply both natural and social data to making seismic regulations for buildings and houses, and this method is applicable to developed and developing regions as well as high and low seismic activity areas. It is a matter of course that regulations differ from each other in various regions because of difference of input data to the method.

2. Application of Social Data

Authors are not the specialists of social science, and will not insist that the method used in this paper is the best concerning the analysis of social data. The part where improvements need with the help of the specialists is marked as ‘require research in social science’.

2.1 Risk

The simplest definition of ‘Risk’ of a matter is the product of the probability of the occurrence the matter and the damage caused by it. For example, Japan had the life-risk of about 100%x16 thousand (=1.6 million %man) and financial risk of about 100% x 170 million$(=17 billion %$) (calculated as 1$=120￥) just before 2011 Tohoku Earthquake. The risk of earthquake disaster is enlarged as time goes on: as the strain energy is gradually accumulated, and both the probability and damage increase on the approaching way to occurrence of the phenomenon.

2.2 Regional Risk

The estimation of risk, that a certain region (or a nation: hereafter only describe as a region) holds, ‘requires research in social science’. Even a life-risk only has many causes like: wars, crimes, accidents, illnesses etc. In this paper, authors selected the average lifespan as the simplest parameter to express the regional risk. Though the biological lifespan of human being is a subject for discussion, 100 years may be commonly acceptable at present.

For example, Japanese average lifespan is 83 years old at present (man 80.05, woman 86.83) [1] and 17% year (=((100-83)/100) x 100) is the risk that present Japanese have. It was about 57%year 90years ago, when their lifespan was 42.6, and the remarkable improvement has been made because of no-wars, raised living standard and progress in medical care. Fig.2.2.1 A shows the ideal ‘age-dead’ curve (delta function) and Fig.2.2.1B that of real Japanese. Fig.2.2.2 shows age-dead curves classified by the cause in 2015. Those in 2011 are very close to the data in 2015 despite a huge 2011 earthquake. They show that one of the effective investments to decrease the life-risk is for the extension of the aged life affected by cancer (or malignant neoplasm). But this cannot get people’s agreement. The value of everyone’s life is entirely equal, but the investment-effect depends on the age of the investee. Obtaining the best shape of the investment-function to age-variable ‘ requires research in social science’ In the paper, a logistic function (Fig.2.2.3) is adopted as an commonly acceptable ‘investment- function L(y): where y stands for age. Multiplying the age-classified number of saved lives by L(y), one could get the real effect of the corresponding investment on the life-risk.

It is not only the life but also the quality of living that we should protect against disasters. When the life-risk is kept in a lower level, measures against disasters accompany with less damage in every item. Therefore, the life is focused in the paper.

2.3 Effects of Seismic Regulations on Life-risk

Out of a budget of a region, items directly relate to people’s life are: armaments, security police, disaster prevention including firefighting, social welfare (including medical services) etc. Though indirect, effect of education is great. Fig.2.3.1 illustrates the 2016 budget of the Japanese Government. Budget for armaments and security police (in the item of ‘others’) have a ‘complicated and special’ back ground at each region, so only the comparison between building regulations and medical services plus man-made disasters is explained in the paper, though the method is also applicable to other items.

First, Japanese case will be briefly explained. Revision of seismic regulations changes the resistibility of buildings. In Japan, the first earthquake resistant code carried into effect in1924, after 1923 Kanto Earthquake, which demanded 143 thousand victims. Design horizontal seismic coefficient k=0.1 was adopted in the code. During 2WW, the safety factor of materials deduced to 1.5 from 3, k became 0.2. In 1950, all laws were revised to erase the war memory, but k=0.2 survived and lives on in present regulation as 'base shearing force coefficient' C=0.2, showing that values once determined in regulations are difficult to be changed. According to the report of General Insurance Rating Organization in Japan [2], effective code revisions are 1971 (RC foundation for wooden houses and hoop space of RC columns), 1981 (new seismic code were put into effect) and 2000(seismic resistant wooden wall). Fig.2.3.2 [3] shows the effects of regulation-revision.

One of a simple and accurate method to analyze a phenomenon is statistic estimation. A region, where statistic data of earthquake insurance are available, the cost-performance of building codes can roughly be obtained. Earthquake victims are decreasing, but not reaching to zero in Japan. Average number of victims is 2064 per year even those of 1923 and 2011 big earthquakes are included, and is only 0.16% of the total annual death in Japan, 1.3million. It seems, Japanese building codes need not have any fundamental revision more. On the other hand, estimated maximum number of victims of 'Nankai Trough' earthquake expected in 2030 ~ 3000 can be reach to 323 thousands [4]. Assuming its return-period as 100 years, and subtracting the number of victims of the same area of 1944 and 1946, the average ratio of annual victim-number is raised up to 0.4%. Reckoning together the financial loss of 1840billion $s, equivalent to or more than 40% of GDP, counter measure to this surely coming earthquake is indispensable. Besides, the quake will hit the central area of Japanese industry and give a fatal damage to its economy, so the financial circles will be active for the relief. About 2/3 of total victims will be caused by tsunami, whose maximum height will be 32ms. 2million386thousand houses and buildings will be lost, and their evacuation plus rebuilding, seawall construction, or reinforcement of structures will be required. Total cost is unclear, but it will be around 500billion, more than 60% of the present national annual budget. If the earthquake return period is 100 years, (the latest one occurred in 1946), and if 30year-relief-project will start in 2017, then additional 2% in the annual budget will be possible and the earthquake risk will be like Fig.2.3.4, provided that 1. The probabilistic density function of an earthquake–occurrence is related to logarithmic normal, 2. Number of victims linearly decreases to 1000 for 30years (Fig.2.3.3).

2.4 Effect of Investment to Medical Care in Japan

According to the Ministry of Health, Welfare and Labor [5], total Japanese medical cost is continuously increasing like Fig.2.4.1, and is now over 10% of GDP. The average annual cost per person is about 2500$s ; 913$s for age15~44 and more than 7430$s for 75 and older. (The medical cost excludes the cost of preventive cares like vaccination or natural cares like childbirth.) The tendency will not change for many years, though the investment is wasteful. Japanese economy cannot afford this waste, and it seems that the quality of the care should be improved like 'more prevention and less care'.

2.5 Effect of Investment to Prevent Accidents in Japan

The peak of traffic accidents was in 1970, when 16,765 died, then after they have been gradually decreasing [6]. The number of the victims was 4,117 in 2015, though those of aged (older than 65 year old) have been almost the same (2500~3000 persons per year). Not only making penal-regulations severe but technological progress are the cause of the decrease. Fires have slowly been decreasing, and about 30thousand fires break and 1.5 thousands die per year [7]. Number of victims caused by criminal acts also has been decreasing in Japan, now more or less 1000 [8]. Investment in education may be useful.

2.6 Suicide in Japan

The most serious problem in Japan is the big number of suicides. Though degrading, it is around 25 thousands per year [9], one digit bigger than other man-made disasters. It could be bigger, as some counted in missing might have commit suicide. It is very grave that the suicide is the top cause of death at age 20-40, and improvement of the social system may be essential in order to make young generation willing to live. It is a problem that 'requires research in social science'.

2.7 Effective Investment to Decrease Risk in Japan

Japan is located at the joint of four big plates, which are broken into smaller blocks, and one of very active earthquake country in the world. Besides, it is between the biggest ocean and continent, and weather changes accompanied with other natural disasters like strong wind, heavy rain and snow and high tide. The land is narrow and stiff, filled with high population. Therefore it has very high potential of disasters. But its present life-risk is not high, thanks to the peaceful, sanitary and highly educated society. To make the risk lower is desirable, but not realistic in the present financial crisis (See Fig. 2.3.1). Human-instigated disasters like traffic, fire and crime are relatively small, except suicide. As described before, cancer is one of main causes of Japanese death, but more investment is meaningless. Instead of it, investment in improving social system to prevent the suicide of young people is the most effective to decrease the life-risk in Japan. (cf. L(y))

Among natural disaster, earthquake is very risky because of the difficulty of prediction. Admitting the possibility of the waste, Japanese building codes have been revised to claim the high safety-level. No more investment is required except in the area where an big earthquake along a trough is predicted in the near future: construction of sea-walls, evacuation, and reinforcing structures built before the 1981 regulations-enforcement are expected.

3. General Process

As Japan is so special as earthquakes are felt every day in somewhere, the authors image a developing region to show general process for making seismic codes. The imaged region has a city with 200 thousand citizens, located by a fault. The fault is neither deep nor active and latest destructive earthquake took place in 1900. There are historical descriptions of big quakes in 1300 and 8th century. The possible magnitude is estimated 6.5. The houses and buildings are made of adobe, brick and RC. Their ratio is 5/4/1. Assumed age-picture diagram is as Fig. 3.0.1.

3.1 Regional Risk

Earthquake data are globally accumulated and analyzed. New kinds of information are daily obtained from artificial satellites and deform of the land has much more been clarified than before. Though precise prediction is still difficult, seismologists are hoped to tell more useful information to earthquake engineers. At present, we can roughly guess the return period of big earthquakes. (600 years in the model) and a function related to logarithmic normal distribution may be used as the probabilistic density of earthquake occurrence.

Nowadays, people are apt to live in urban area, and the detail investigation concerning to seismic risk can be confined to urban areas to minimize the task. Study of the urban history, checking the existing near-faults, high-level estimation of accumulated energy etc. can be made under global cooperation. The sizes of big earthquakes (in the model, M=6.5: equivalent energy= 3.5×10^{14} J) are uncertain, but may be re-estimated in the future. In the assumed model, 116 years have passed since the last big earthquake, and if it will take place now, energy almost equivalent to M=6(about 6×10^{13} J) will be released. Seismic maps made from probabilistic and fault analyses may be available.

3.2 Resistant Ability of Building-Structures against Earthquakes

Building-structures in each region maintain its own history and characteristics and, at the same time, international technology. Therefore their resistibility against earthquakes has less generality than seismology and needs individual study. At least, typical ‘P-δ’ (=force-deformation) diagrams of the structures are required for further study. When there is no earthquake insurance system, data are insufficient to estimate the future damage, and there is no other way than to make rough estimation on many assumptions, and increase the accuracy according as the accumulation of experiences and data. Assumptions allowed to use for estimation may be:

1. Building-resistibility makes logarithmic normal distribution
2. The resistibility a building relates not only to its strength but to its deformability.
3. The total resistibility includes both that of the structure itself and environmental conditions.

For example, an earthquake-resistant structure is unsafe when it is built in tsunami-attack area, on an unstable hill or liquefiable area. The problem is the concentration of population to cities, which results to shortage of the land, and houses are built on unstable places.

4. Building Structures have their own Life-span

A lifespan of a building is determined by both of functional and structural problems. Even a structurally safe building is often demolished and rebuilt to satisfy newly required functions. Where building codes have been revised and high safety is claimed like Japan, and when age effects weaken structural material, building ages concern the risk.

5. Building-damage ratio to the intensity can approximately be expressed by a logistic function (cf. Fig. 2.3.2).

Structures in the model region are weak; Adobe supplies moderate inner space in a dry area, but it killed many people in earthquakes, and stones and bricks are similar. They have low strength and low ductility. Reinforcing them to survive at earthquake region is expensive. If a brick house will be newly built, reinforcement with RC columns and beams are recommendable, provided that anchors of steel bars are properly designed. But it should be noticed that its lifespan is much shorter than unreinforced, because of steel-rust in neutralized concrete. As for the RC buildings in the model, they are probably important and the number is limited. Then, it is not very difficult to grasp their resistibility with the help of specialists.

If an earthquake takes place now, we may meet an earthquake-damage, illustrated in damage ratio of Fig.3.2.1, provided that RC buildings were properly designed and constructed. Estimation of the ground movement made by an earthquake M=6 is possible to some extent, though requires much more data. The fault-mechanism is usually assumed so that the maximum damage may occur at the population concentrated area. In the model, authors simply assume the intensity like Fig.3.2.1, and the damage estimation will be roughly obtained with potential of disasters.

3.3 Medical Care

From the assumed age pyramid, one may say, it is a population–increasing area, and many babies and infants die young. Average lifespan is about 37 year old, and the risk is 63%year: very high. In order to decrease the risk, to invest to education is the best, but result comes later. If one needs a quick effect, to stop war (if it’s on), improve sanitation and medical care, etc are essential. Deciding ratio of distributing the funds and expenditures to the items ‘requires research in social science’.

A recommendable method is to draw ‘investment and effect diagram of each item like Fig. 3.3.1, taking the following steps:

1. Select items: like to educate people, to build a hospital, to build a water-supply system, etc. (item A, B, C…..)
2. Estimate the investment-cost (including the construction and running cost of each item.)
3. Estimate the number of persons saved by the investment.
4. Calculate the efficiency: The investment-cost divided by total number of saved persons: (cost-performance).
5. Repeat the estimation for additional investment: For example try to build the second hospital, and calculate efficiency.
6. It is usual, the efficiency drops, if repeated many times.
7. Then draw the diagram of ‘summation of saved people and efficiency’ (curves A, B, C…in Fig.3.3.1)
8. Change the item, and repeat the same steps.
9. After completed drawing all diagrams, draw a line of a constant value of the efficiency.
10. Read the number of persons at each diagram and the cross-point to the constant line, and sum the numbers. (summation of a, b, c…)

11. If total cost of total number of saved persons does not meet the demand, draw another constant line, and repeat the work from step 9.
12. Calculate the total costs.
13. To compromise might be necessary between the cost and number of persons.
14. Determine the value of efficiency 'H', then, proper investment-distribution will be fixed.

The difficulty in drawing curves exists in the evaluation of the investment-effects. For example, investment in education is the most effective and important matter in developing regions; it might contribute to raise up the level of sanitation, decrease the number of crimes and prevention of disasters. Beside those direct effects to decrease the number of life-loss, it will make the regional economy active, raise the living standard up and bring next generation up in good conditions. Estimation of these indirect effects in equivalent number of saved lives needs some rule, i.e., the problem of the price of life.

3.4 Building Code in the Model

As the estimated return period is uncertain, and accumulated energy is sufficient to have an earthquake that can collapse houses and kill some people. Under this situation, the level of building codes may be important subject to determine.

Though the basic assumption is not very reliable, probability of earthquake-occurrence in this model is several percent at present. In the common sense, it is negligibly small. But, because of the weak houses in the assumed city, number of victims may be big, and the life-risk will be raised up. To decrease the risk, investment in rebuilding both adobe and brick houses is essential, in a sense. On the other hand, investment to education, sanitation and medical care looks very effective, though the value of reduced risk cannot clearly be calculated. Even though very rough, estimation of the investment-efficiency shows the solution: One may empirically say that the maximum number of victims might reach to one percent of the total population. Under very rough estimation, more than two hospitals could be built and operated with the money to demolish weak houses and rebuild, and that they can save more lives than those of seismic victims. This shows 'the efficiency of investment is higher in medical care than in seismic disaster prevention in the model. Similar analyses may be possible concerning the investment in education, sanitation, etc.

As the probability of earthquake-occurrence is low in the model, one can afford to invest in items other than disaster prevention, and can provide earthquake regulations step by step, considering the economy of the region.

The best solution in the case of this model seems to make codes not only to decrease the victims caused by collapse of weak houses, but to ensure the life of inhabitants by showing the way to survive. For example, make research and study to invent a safe-bed with a cover, to keep a space for a while against collapsed adobe and brick walls. With a shovel and a bottle of water equipped there one may escape or wait for help from outside. Multistory adobe, brick and stone houses should be prohibited. And the area on or very near to the fault should be kept in green. For multi-story houses and buildings, providing advanced regulations (referring those in other regions) are desirable, as they could be the temporal rescue-points in disasters, and the inhabitants may wish higher level of life-safety in the future. (In Japan, there is such a tendency as the number of stories increase the safety decreases in RC buildings.)

4. Improvement

One of a fundamental difference between natural and social science is that the rules in the former are invariable while the latter variable. The society need be improved all the time. And, like it, engineering, where both natural and social science meet, should steadily be improved. Building codes are not the exception, but their sudden change should be avoided. Otherwise, revision of regulations requires reinforcing or demolition of structures, which are built before the change of the codes.

In the case of seismic regulations, portion directly related to natural science has steadily progressed. Though present seismology is not successful in earthquake prediction, it surely tells people the high earthquake-risk areas.

Even when an earthquake takes place at a place, where the occurrence-probability is low on seismicity maps, some groups of seismologists have usually given cautions beforehand based on some phenomena. In the near future, those cautions will be evaluated properly to inform to public. Under the consideration of the progress in science and engineering, regulations should be provided so that they may not be behind the time.

Regulations have two aspects; one is to escape from danger. For example, people cannot easily escape from multi-storied and/or huge structures, when they are collapsed. Therefore, the number of stories and sides of buildings and houses are limited, when their resistibility is insufficient. It is a cause of disaster that tall RC buildings of weak structural members are built in earthquake countries without regard to coming quakes. Another aspect is to develop and to defuse technology. Conditions provided in regulations can be the aims of technology. An example is a construction method. When a regulation requires keeping the circumstance of a construction site clean and silent, technology to satisfy the conditions develops and defuses and all construction sites are improved.

One of undesirable relations in the regulations to the society occurs when the social economy controls them. In some case, premature technology is forced to put into real construction, and, in another, danger structures are built on the unstable ground. It is important to notice that engineering is science and technology for the people, and has the responsibility to the society.

5. Conclusion

With relation to the social affairs, how building regulations should be provided has discussed using Japanese real data and assumed model in developing region. Proposed steps are illustrated in Fig. 5.0.1. It starts at the recognition of the present risk, and repeats the cycle until the aimed safety is realized.

The steps are:

1. Recognition of the present life-risk from the average lifespan of the inhabitants.
2. Make a target of the risk-level, under the consideration of social and financial conditions.
3. Make assessment of present state, considering investment function of age L(y).
4. If there are some potentials to increase the risk, analyse them, and classify into items.
5. Modify the expected number of victims of the each item.
6. Find the way of investment to measure the each item. (fix the term).
7. Estimate the amount of the fund for the each item and the number of saved lives.
8. Calculate the efficiency, i.e., the amount of fund divided by the number of saved lives.
9. For additional amount of fund, repeat the calculation.
10. Draw the efficiency curves to number of the saved lives on a graph.
11. Choose a value of efficiency, and draw a horizontal line on the graph.
12. Read the number of saved lives at the cross-points of the line and curves of various items.
13. Make the summation of the saved lives.
14. Calculate the total sum of the funds corresponding to the chosen value of efficiency.
15. Compare the total sum of funds and total number of saved lives.
16. If not satisfied, change the efficiency level.

17. Make compromise, and fix the value of efficiency (=H).
18. The portion of the fund in reinforcing buildings and houses will be determined.
19. Make a policy to save lives (Limit the height or size, and material of buildings, or need resistibility), considering the risk level of the society.
20. Estimate the possible damage and loss of life.
21. Provide regulations regarding the future revision.
22. When the social safety level changes, regulations be improved

In Japan, earthquakes are very active and seismic regulations have been revised for 92 years, and need no more raising the safety-level. When the percentage of “the possible minus average” lifespan of the people is used to express the life-risk, countermeasure to coming Nankai Trough Earthquake and suicide in young generation are indispensable for lowering the risk. On the other hand, gradual improvements are practical in developing area in education, sanitation and life-save methods pus regulations, if outer fund is not available.

Many social problems ‘require research in social science’, when combined with engineering, and that of education, especially, gives big effects in all matters. Besides, 'before, during and after' seismic disaster, the education contributes to minimize the loss. Study about the influence of education is one of important subjects in earthquake engineering.

5. Acknowledgements

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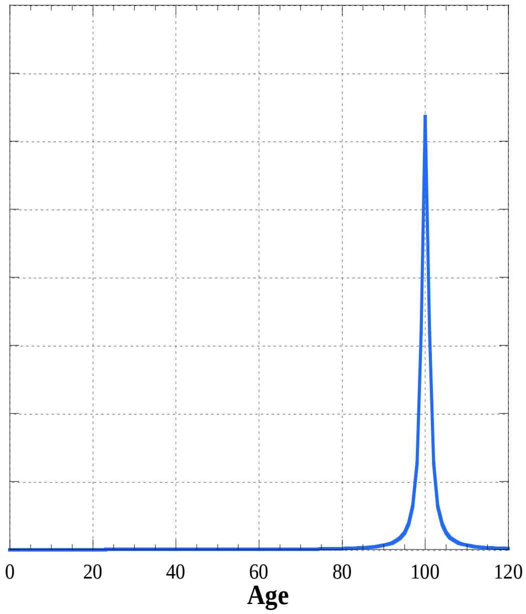

Fig.2.2.1A Ideal age-dead curve

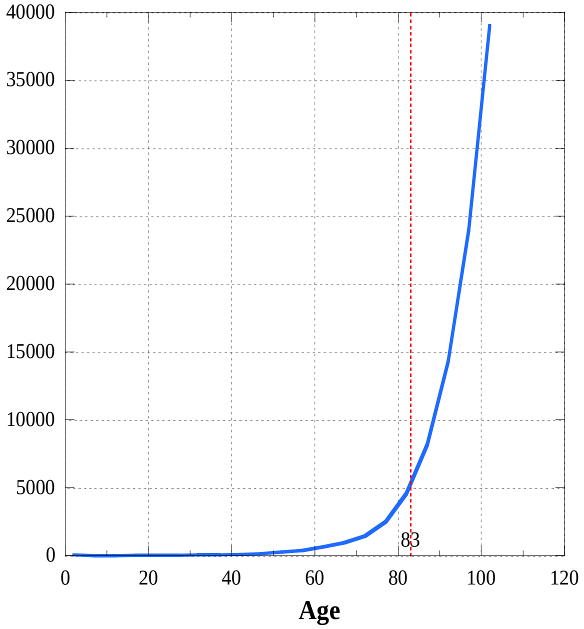

Fig.2.2.1B Japanese age-dead curve

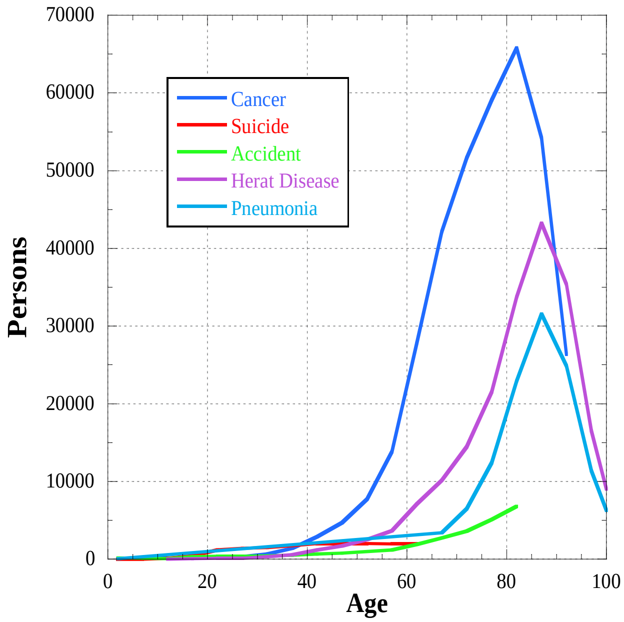

Fig.2.2.2 Japanese age-dead curve classified by cause in 2015

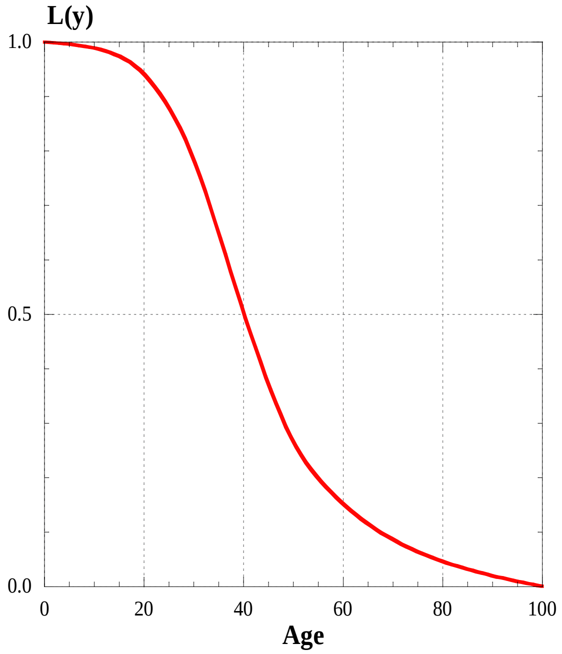

Fig.2.2.3 Investment function to age (L(y))

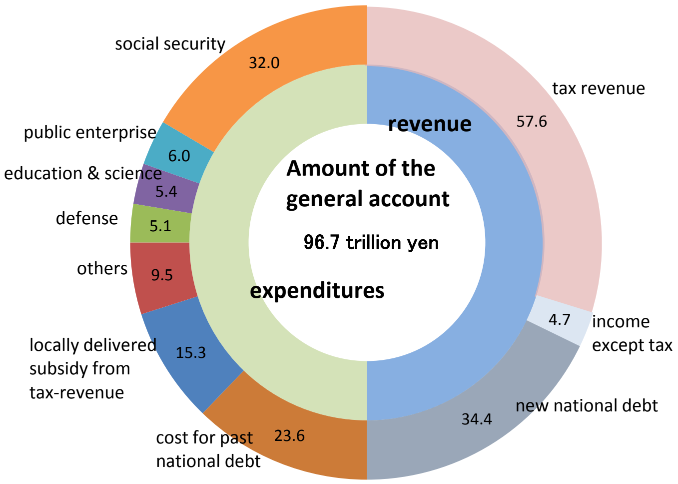

Fig.2.3.1 Budget of Japanese government in 2016

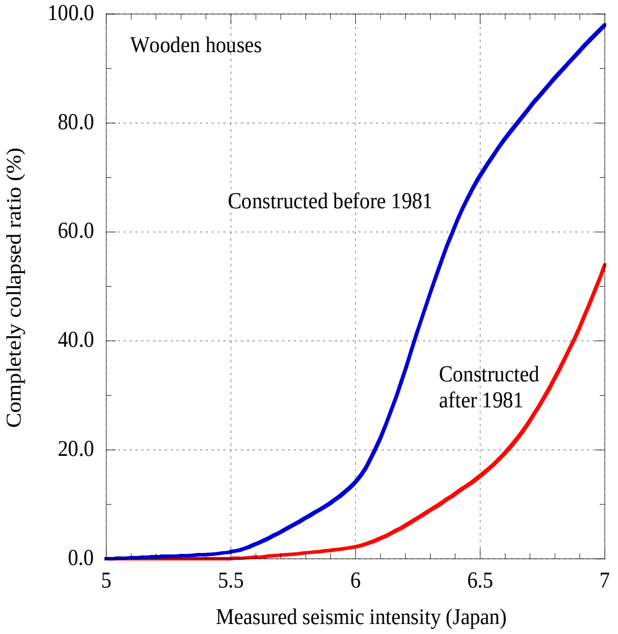

Fig.2.3.2 Effects of regulation-revision

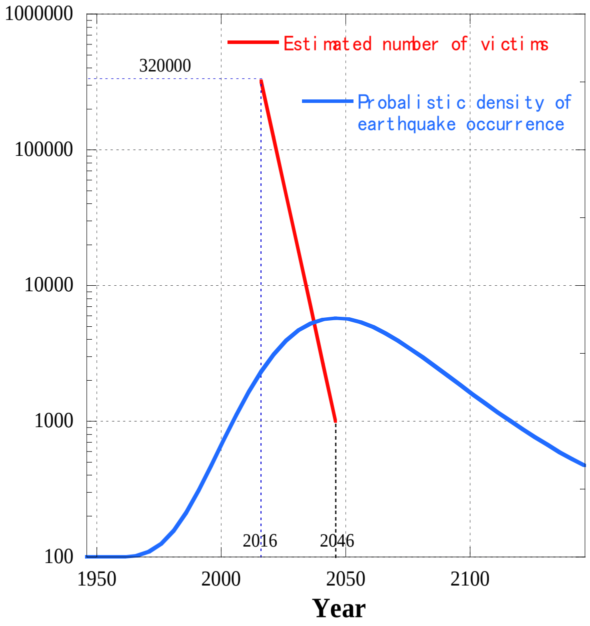

Fig.2.3.3 Estimation number of victims when 2% of budget is applied to countermeasure the quake

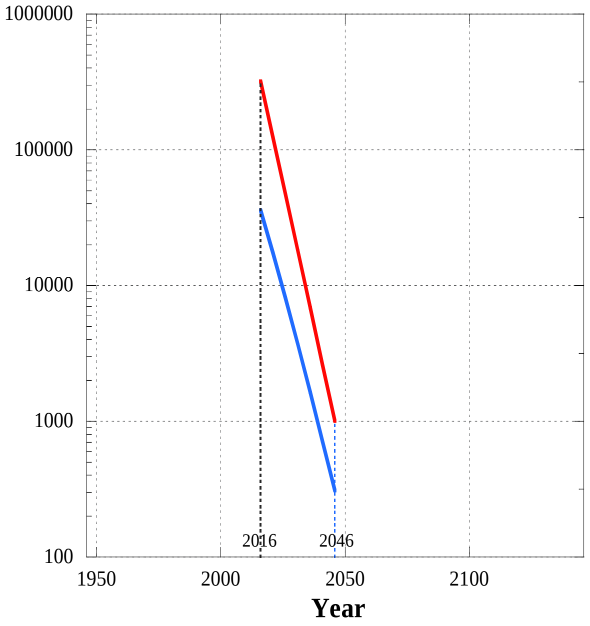

Fig.2.3.4 Decrease of life-risk for 2% of annual budget

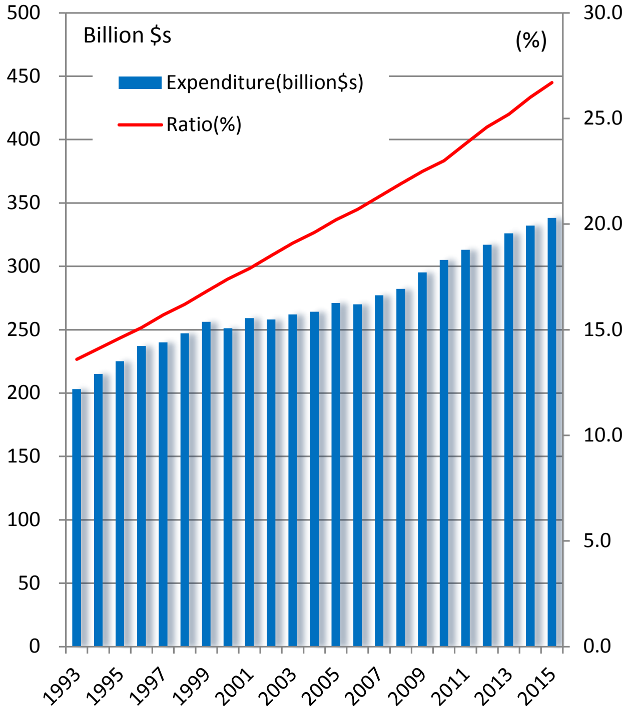

Fig.2.4.1 Japanese medical cost in 1993-2015

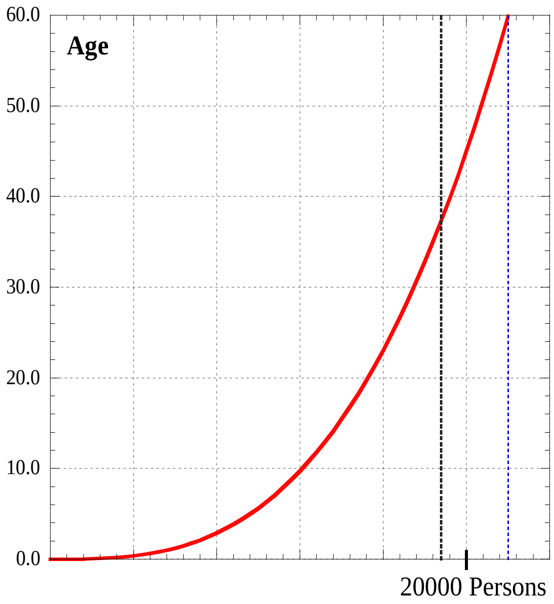

Fig.3.0.1 Assumed age-picture diagram of a developing region

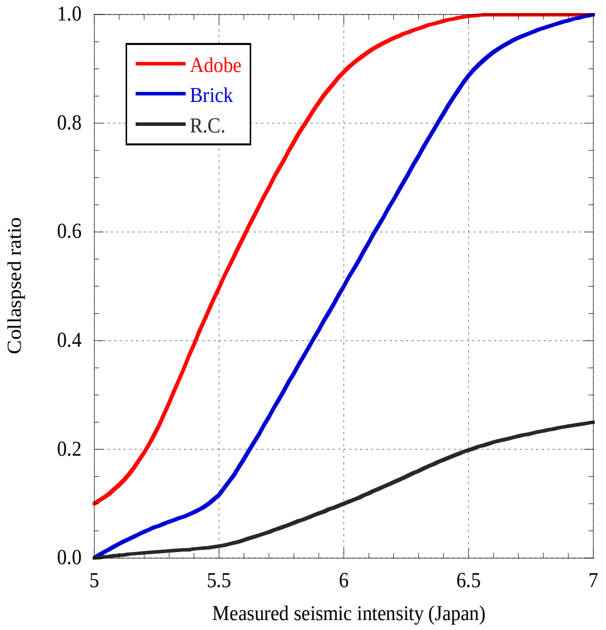

Fig.3.2.1 Assumed collapse-ratio of adobe, brick and R.C. houses to assumed intensity

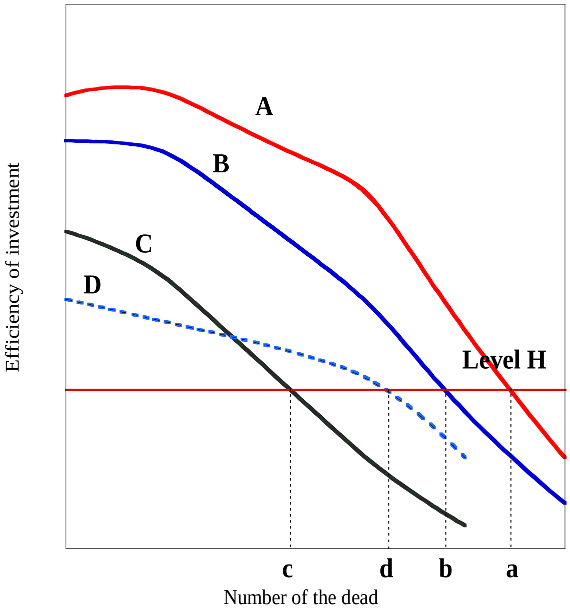

Fig.3.3.1 Investment and effect for items; A, B, C, D …..

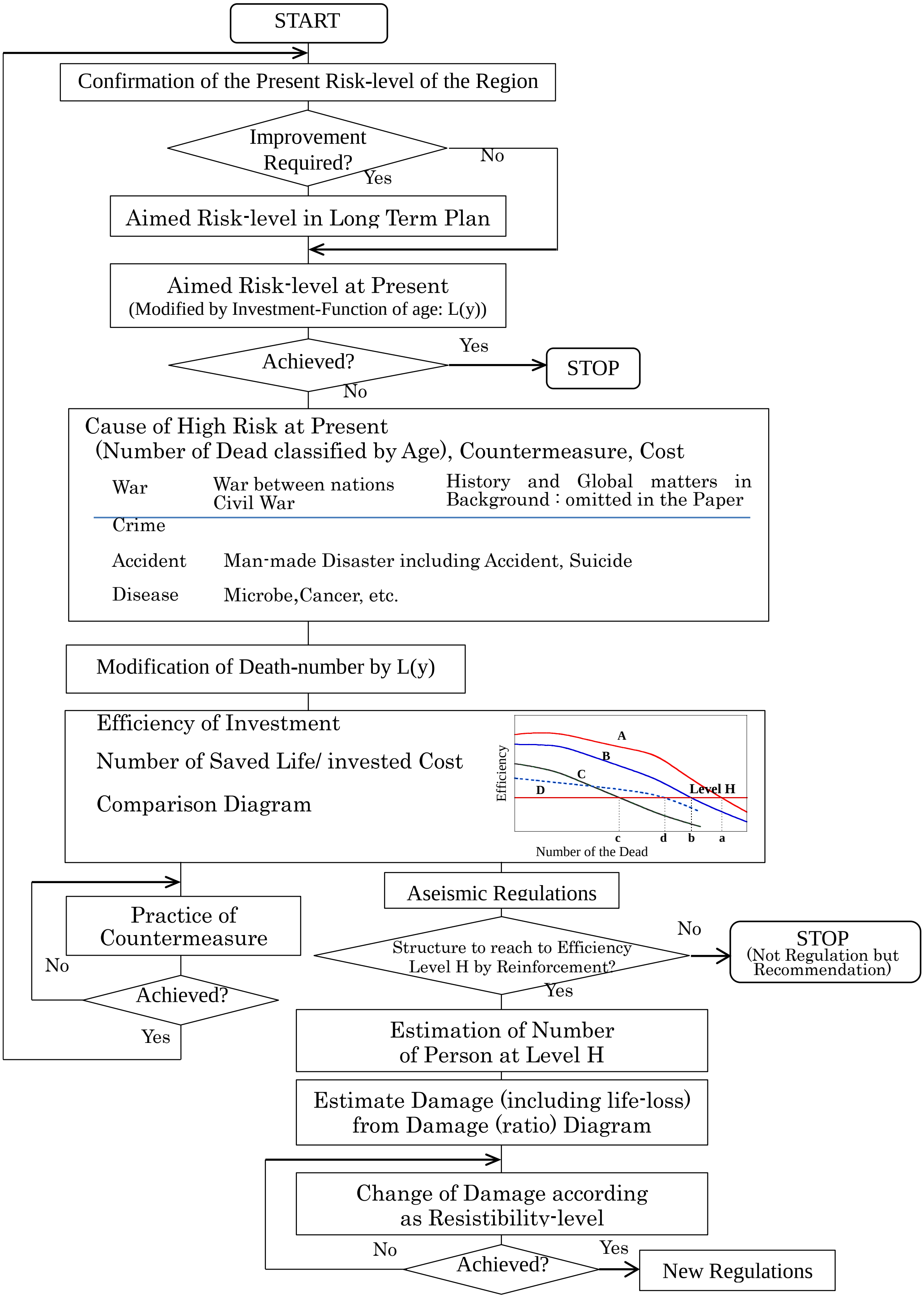

Fig. 5.0.1 Method to utilize natural and social data in making regulations