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Political Issues for Sustainable Hazards Policy

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Abstract

All communities and countries are subjected to some array of natural hazards, and these threaten the long term sustainability of those areas. Yet history has clearly demonstrated that the potential consequences due to these hazards have not been fully incorporated into development decisions regarding growth patterns, land use restrictions, building codes or mitigation plans. Much of this shortcoming can be related to the inability of individuals, or society in general, to extrapolate to un-experienced low probability, high consequence events. Beyond this, however, there are basic pressures and incompatibilities between the motivating rational of elected decision makers and optimal policies for long-term sustainability. Issues of incompatibility of lifetimes, psychological discounting, cost evaluations and equitability and justice all play a role in the tension between short-term rewards to decisions and long-term sustainable actions.

1. Introduction

An important aspect of a sustainable society is the resilience to natural hazards. Most developed areas of the world are subjected to one or more natural hazards, such as earthquakes, tsunamis, typhoons, tornadoes, landslides, wildfires, costal inundation or river flooding (Corotis, 2007). This is exacerbated by the fact that historically desirable locations for communities are often ones that are especially susceptible to hazards. For instance, the desire for safety and security led to the development of some towns on hilltops where they are susceptible to high winds and landslides, and to others on islands or peninsulas where they are subject to inundation from typhoons and other coastal phenomena such as sea level rise. Proximity to the most suitable agricultural areas has led to the settlement of some communities in floodplains, whereas others have developed at the confluence of navigable rivers that are vulnerable to flooding. Often, cities develop in areas with dramatic scenery, which itself is a manifestation of dramatic forces of nature.

From the beginnings described above, many metropolitan areas have grown geographically beyond their original boundaries. Thus, construction has proceeded closer to rivers and coastlines, or up steeper grades of surrounding hills. Unfortunately, the driving forces of development have rarely incorporated realistic assessments of hazards. This may be due in part to the rationale of the following quotation of Kathleen Tierney (2004), Director of the Natural Hazards Research and Applications Information Center at the University of Colorado, "Human settlements are based on the principles of short-term growth and profits for privileged segments of the population instead of safety and sustainability for the society as a whole." Whatever the reason, there has been very limited success in convincing communities to integrate natural hazards issues into their planning and development plans (Burby 1998; Godschalk et al 1999). Research implies several underlying reasons for this, including: 1) The public generally has trouble extrapolating from experienced scenarios to ones of vastly different conditions; 2) The public is generally reluctant to divert funding from immediate and definite returns into uncertain possibilities sometime in the future; 3) Discounting historic preservation, morbidity and mortality is unclear since their present net worth is generally not considered less than it will be in the future (Corotis and Gransberg 2006); 4) Political accountability focuses on immediate, demonstrable effects, not statistical future; 5) The allocation of resources is strongly dependent on the multidimensional aspects of perceived risk, rather than simply probability; and 6) The realities of uncertainties in our built environment have not been successfully communicated by engineering professionals to lay persons and policymakers.

New understanding, tools and computational power have enabled the field of structural safety and reliability to broaden into one of engineering decision for risk in the built environment. This has allowed engineers to assume a more central role in the societal decision process, but has also made it incumbent upon such engineers to understand and incorporate issues of social justice, social psychology and political reasoning. Several of the aspects that must be fully addressed are discussed in this paper. These are the incompatibility of infrastructure and political lifetimes, the psychological aspects of the un-experienced, the need for financial instruments to address risk and return, public accountability of elected or appointed decision makers, and issues of equitability and justice (Corotis, 2009).

2. Incompatibility of Lifetimes

The political system is based on election cycles on the order of five years whereas structures and infrastructure often have economic lifetimes of 100 years or more. Thus major disasters, which are low probability events, are unlikely to occur during the term of office of a particular elected or appointed official. Therefore, the politically "astute" office-holder will find that he or she is much more likely to satisfy constituents by spending limited resources on activities with immediate, demonstrable returns, rather than investing in reduction of risk that has already been ignored by most people. Unfortunately, while such logic may be appropriate for a particular decision-maker, it is not often the best in the long-term. In order to overcome this paradox in the case of the built environment, it is necessary to adjust the cost and benefit reward system so that each sequential decision leads toward the optimal long-term solution.

Both probability of occurrence and consequence must be presented in such a way that the public comprehends the true risk. Therefore, it is necessary to present the probability of occurrence in absolute or comparative forms that allow people to understand and appreciate the magnitudes. For example, for all probabilities can be expressed as a multiple of some common reference statistic. One might consider, for example, the annual probability of death due to natural causes for a person who has attained the age of 50 years (ARD, Annual Risk of Death).

In assessing risks for the built environment, it is important that return periods not be used in conveying information to the public at large. Their concept is often misunderstood, leading to false confidence concerning the occurrence of the next event. Thus, even if the concept of the preceding paragraph is not adopted, events such as the 100-year flood should be referenced as the annual 0.01 flood.

3. Psychological Issues of the Unseen

Experience has shown that aversion to risk is not a constant, but a function of the perception of choice and aversion to large consequence events (Slovic, 2000). These psycho-physical factors of risk perception and acceptance need to be included in any attempt to provide a more global evaluation of the trade-offs of risk, costs and benefits for various activities (Corotis, 2003).

For events whose probabilities are less than a few percent, many people classify them as equally unlikely, and often even consider that they have no chance of occurring (Khaneman and Tversky, 2000). This is especially true for political leaders, who as explained above have career milestones that are measured over a period of just a few years.

In evaluating the risk of rare events, it is not uncommon for individuals to set the likelihood of occurrence by relating to the availability of comparable events. This phenomenon means that the ability to recall situations that are judged to be meaningfully related to the risk at hand affects the perceived probability. If the hazard under consideration is judged similar to a situation for which the individual has either personal experience or sufficient information, he/she will equate the two. Decisions will then be made on the surrogate situation, and this is subjective based on the availability of such scenarios. It has been shown that media coverage of events strongly affects the availability of "comparable" events.

Another aspect affecting perceived risk is that of anchoring and adjustment. If a situation under consideration differs sufficiently from the available reference, individuals will set the new probability by anchoring to the probability of occurrence of the reference, and then attempting to adjust for the new situation. This new computed probability will then be used to calibrate for decisions. There are two major problems with this approach. One is that the reference situation may be sufficiently different from the one under consideration so that false impressions are obtained by using it. The other is that people strongly underestimate the shifts in probability necessary when adjusting to new situations. That is, they remain too closely tied to the anchor probability.

4. Financial Instruments for Risk and Return

It is necessary to develop financial instruments that allow the public as well as political decision makers to understand the balance between risk and return.

It has been established that the public uses several standards to assess future benefits and risks, and these must be taken into account in order to establish a system that will be effective in involving the public in the political decision-making process. Fischhoff et al (1979) have identified four basic comparisons commonly used by individuals. One of these is a cost-benefit analysis, using future benefits and expected cost. This requires a comprehensive accounting of both costs and benefits, and an ability to fully accept the concept of present discounting. Another is revealed preferences, whereby an analyst can infer the tradeoffs of current and future risks and benefits from other decisions. This is hampered by the difference of up to three orders of magnitude in willingness to accept risk when the action is viewed as voluntary. A third approach is that of expressed preferences, whereby individuals explicitly express their willingness to trade off risks and benefits, including those that involve future expenditures and rewards. This method has the political advantage of having the public state direct values, rather than trying to infer them from other actions. On the other hand, such decisions are known to be inconsistent, and there is no simple way to reconcile them. The fourth method to assess risk and reward is to use the natural environment to calibrate values that are based on some sort of natural standard. This is an especially promising approach when it comes to flood risk and other land use decisions (Burby, 1998), but may not be applicable to issues of infrastructure improvement, such as location and design of bridges (Tierney et al, 2001).

One of the serious limitations of decisions for long-term risk is the sensitivity to discounting. While the concept arises from economic theory, there are also psychological issues dealing with gratification, mortality, etc. Decisions might properly be based on two discount rates, one representing economic return and the other psychological discounting. The former can be modeled as probabilistic, while the latter varies about a deterministic temporal trend. This trend represents decreased sensitivity with time. It is well known that psychological discounting decreases with increased time before an event. For instance, someone may apply a 5% discount to defer a benefit for a year, but essentially no discount to deferring a benefit from nine years hence to ten years. This can be modeled by letting r_1 designate the rate of discounting for the first year, and assuming the rate follows a geometric series for additional years, so that the rate in year i, r_i, is given by

$$r_i = a^{i-1} r_1 \tag{1}$$

in which *a* is a psychological parameter. Now assume that there is continuous compounding so that the present discounted value, P, can be related to a single payment future value, F, by a simple exponential expression as follows

$$P = Fe^{-rn} \tag{2}$$

where r is the effective discount rate and n is the number of years in the future for which the value of F is being discounted back to the present. For variable r it can be shown that the product rn can be replace by the sum of the annual returns. Noting the following equality

$$\sum_{i=1}^{n} a^{i-1} r_1 = r_1 \frac{(a^n - 1)}{(a-1)} \tag{3}$$

Equation (2) becomes

$$P = Fe^{-r_1 \frac{(a^n - 1)}{(a-1)}} \qquad (4)$$

Figure 1 is a graph of Eq. (4), showing the present value as a function of the number of years in the future when a unit benefit will accrue, assuming that the first-year discount rate is 5% and the geometric psychology factor, a, varies from 1.0 to 0.5. Note that a=1 is equivalent to the usual discounting with constant rate.

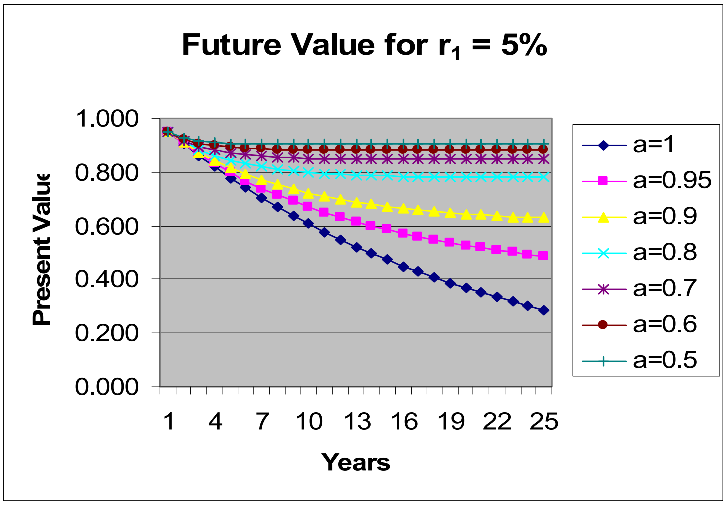

Figure 1. Present Discounted Value for a Future unit value Benefit Utilizing the Psychological Adjustment to Annual Discount Rate.

It can be seen that the effect of the psychological adjustment is significant, especially as the length of time increases. The traditional discounting produces values that continue to decrease exponentially with time, whereas when there is psychological adjustment, the present value decreases slower after the first few years. Since this psychological effect has been observed in sociological studies, it appears to be very important when making investment decisions that are related to the deferral of benefits, especially for risk considerations for infrastructure, which usually has a long design lifetime.

5. Public Accountability

In addition to expressing the probabilities in a form that can be easily used for decisions, there must be an accounting of the various risks to society presented in a public manner. On a regular basis, and at least each time there is any election within a particular community or state, there should be a present value analysis of the public infrastructure within the region. This would include not only the current risk levels for all existing infrastructure, including changes from the prior report, but also the benefit/cost/risk analysis for any new structures, both those completed since the last report and those proposed. If nothing had been done to improve the efficiency and lifetime safety of existing infrastructure, this would be reflected in the report. This report would then present a total risk and expected future maintenance and operation cost picture to the public, serving as an infrastructure structure report card. Such a report might be termed an Infrastructure Risk and Accountability Trust Evaluation card (Infrastructure RATE card), and it could become part of the lexicon of the political process for all government authorities having jurisdiction of public infrastructure. The credits and debits of existing and new infrastructure would reflect the current value, including discounted future benefits and costs.

While the exact nature of such a tool would need significant research and consideration, including the involvement of appropriate legislative and economic experts, the basic approach of the idea can be illustrated by the simple table below. It is hoped that the fundamental concept of an Infrastructure RATE card, perhaps as part of a total public trust report card, could become part of the lexicon of the political process for all government authorities having jurisdiction of public infrastructure. The credits and debits of existing and new infrastructure would reflect the current value, including discounted future benefits and costs. Such future costs should be those associated with operation and maintenance, as well as those reflecting expected losses due to both natural and society-induced hazards.

It is suggested that the above procedure would provide a way to bring together immediate, demonstrable return and optimal lifetime investment in a relationship that recognizes the realities of the political process. An example of such an Infrastructure RATE card is given below.

Table1. Sample Infrastructure RATE Card Required at Time of Elections

Infrastructure Risk and Accountability Trust Evaluation (RATE) Card: Credits and Debits in Present Discounted Value							
	Prior Campaign Status			Current Campaign Status			Δ
Category	Value	Operations	Risk	Value	Operations	Risk	
Cash Assets							
Bonding Liens							
Taxing Changes							
Outside Funding							
Existing Infrastructure							
New Infrastructure							
Etc.							

6. Presentation of Costs

In the pursuit of accountability for elected public officials, it is necessary that the public understands the nature of the decisions to be made. Since elected decision makers are, ultimately, responsible to the public, it is necessary that the public be motivated to appreciate the nature of investment decisions. The Infrastructure RATE card is an attempt to explain the value of investment in reducing future risk and maintenance costs, and in this manner provide the same sort of reward that a more obvious investment such as the construction of a new bridge brings to the elected official. Unfortunately, the tasks are not comparable. Everyone can see the benefits of the new facility (perhaps after enduring delays and inconvenience during its construction). The Infrastructure RATE card provides a mechanism for inclusion of future cost savings into present values. This approach is the basis of decisions utilizing life cycle costing, which is now widely accepted among researchers and policy analysts as the preferred procedure for optimal decision making. Unfortunately, acceptance of life cycle costing for decision making has met only limited success in practice (Federal Highway Administration, 2001; Scott et al, 2003).

One of the problems with acceptance of life cycle costing for public facilities is that communities do not set aside funds for future maintenance, operation and repair of such facilities. Therefore, the present discounted value of life cycle costs appears somewhat artificial or unrealistic. Initial construction costs, on the other hand, represent real budgetary outlays. One approach that may help in public incorporation of life cycle costs is to convert all projects to equivalent annualized costs. In this manner, the amortization of higher initial costs and lower future expected costs are combined and demonstrate that ongoing advantages for a structure that is built in a more robust manner with respect to hazards.

An important issue in the computation of annual cost is the selection of the appropriate design lifetime. When considering only initial costs, this is of secondary importance, except that the use of a shorter lifetime may justify the selection of smaller design loads and thus reduce initial cost, often an unwise decision. With the traditional use of present discounted value for life cycle costs, there is incentive to select a relatively short design lifetime, thus minimizing the present value of future maintenance and risk related costs. The use of annualized costs, however, has a very different effect. For costs incurred annually, the selection of lifetime is of minor importance. For initial costs, the ability to amortize over a longer lifetime provides some incentive to design for a longer design life. Therefore, political reward is consistent with longer-term, sustainable design.

Cost Example

Consider an example of a new facility, with an initial cost of $10m USD and an annual inspection/maintenance/repair cost of $500k USD. The engineer assumes a 50-year lifetime, and a constant discount rate of 3% per year. The present discounted value over the 50-year lifetime can be computed by converting the annual cost to a present value by the following formula,

$$P = A\left[\frac{(1+d)^n - 1}{d(1+d)^n}\right] \tag{5}$$

In which P is the present discounted value, A is the annual cost, d is the discount rate, and n is the lifetime. With the parameter values assumed, the present value of the annual cost is $12.9m, so that the total present discounted value is $22.9m. This compares to the initial one-time cost to the community of $10m.

Having to defend a project of $22.9m rather than $10m places an additional burden on the elected official, even though it is recognized that total life cycle cost is the preferred method. The cost can be converted to an annual cost of $889k, and then the burden on the politician becomes one of "selling" a 50-year commitment of $889k per year rather than a one-time cost of either $10m or $22.9m. It is noted that the $889k is composed of the annual cost of $500k plus amortization of the initial cost.

The selection of an economic design lifetime is somewhat arbitrary, although values of 50 years or more are commonly used. If this is replaced by an infinite lifetime, a political decision maker can claim to be making a "permanent" improvement to the community, and avoid the issue of promoting a project that will be "expected to die". With that change, the total present discounted value increases to $26.7m, from $22.9, a modest but not insignificant change. In terms of annual cost, the value decreases from $889k to $800k, due to the infinite amortization period. Thus, by using annual cost the decision maker can present the project in terms of the lower figure.

7. Equitability and Justice

Funding for public projects involves public wealth in one method or another. Sometimes this is straightforward expenditure of annual funds for capital construction, but often it includes bonding or taxation, incurring a public burden for some time into the future. The costs therefore can be an immediate one to the residents of a community, or they may occur over a future period of time. If the residents of a community do not change over the period of payment, then these two can be reduced to a common comparison by the use of discounting. It is often the case, however that people move to and from a community, and thus the current decision creates a commitment for a different constituency in the future.

Even if there is no change of residents, the economic and social structure of the individuals within a community is likely to change over time. An equitable distribution of the burden must be determined not only for the present, but for the expected duration of the commitment. In a similar manner, the benefits that accrue from public infrastructure are not distributed either equally or necessarily equitably across the community. Therefore, the source of funds and the beneficial use of those funds will not follow similar patterns across social, political and economic strata.

8. Recommendations for Changes

Historical evidence clearly indicates that development of communities has not fully incorporated the risk of natural hazards. The many reasons for this relate to the inherent conflict between addressing short-term needs and optimizing long-term sustainability. This conflict is exacerbated by the difficulty of projecting low probability, high consequence scenarios from experienced events. Taken together, these incompatibilities are manifested in a basic incongruity between the rationale that drives political decision makers and optimal sustainable policy. A strong motivation for the former is being re-elected to power, and this has been shown historically to relate to the avoidance of significant major, short-term policy errors (an example of the minimax principle). Economics theory also verifies that the optimal long-term outcome is not necessarily a consequence of sequential optimal short-term decisions (Lopes, 1981; Stern and Fineberg, 1996).

Given these basic incompatibilities, it is necessary to incorporated changes. Since the occurrences of natural hazards cannot be significantly changed with current knowledge and technology, it is appropriate to focus on mitigation, especially as it relates to community development and structural robustness. And since the political process, including terms of office, is not likely to be changed significantly, the attention should thus be on the nexus of mitigation and political motivation. Political decision makers are responsive to the public, for this is the source of their perceived success and re-election. Therefore, the engineering risk community must develop mechanisms that are understandable to the public at large that allow them to understand the importance of long-term sustainable thinking, and thus to motivate community leaders to follow those paths. One example of this is the concept discussed earlier of an infrastructure accountability and evaluation process that informs the general public of future maintenance and risks and their associated costs.

9. Conclusions

Just as successful economic theory has evolved from a purely mathematical field to one that incorporates the psychology of economic decision-making, so can engineering risk analysis develop from a solely theoretical enterprise to one that becomes more effective by reflecting the psychological rationale that drives the political decision maker. Understanding the limitations of human ability to extrapolate and imagine unforeseen events, and the motivation behind political decisions presents an exciting opportunity for the risk engineer. The next step is to develop approaches and tools that can effectively stimulate and promote short term decisions that result in optimal long term sustainable policy.

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