CRISP Ideas

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INTRODUCTION

Engineers have an obligation for the wellbeing of society, and it is impossible to separate the technological issues from the political and sociological ones (Corotis, 2019). In particular, investment in infrastructure, both existing and planned, must include an assessment of the risks that a community is willing to assume.

Individuals within society generally have a clear desire to maximize utility. In democratic countries, the oversight and limitation of consequent activities are entrusted to elected officials, and the laws and policies they create. In the United States professional societies are ultimately responsible for codes and standards that guide development of the built environment to serve the needs of society while respecting natural resources and the rights of individuals (e.g., ASCE 7-98, 2010). Then elected officials are, ultimately, responsible for the allocation of public funding to ensure the sustainability and resilience of new as well as existing infrastructure. This is the intersection of public policy and engineering, and a place where engineers can and should take a more active role. There is an inherent tradeoff of immediacy and sustainability. In particular, society can realize immediate benefits for investments such as those for new facilities, medical care, education or transportation, or it can invest for possible future risks from hazards. It is these tradeoffs that are at the core of societal decisions with respect to long-term planning, sustainability and resilience.

The natural environment contains uncertainties and risk. The structures that comprise our built environment introduce their own uncertainties and alter the natural environment, thus modifying these risks (Mileti, 1999). The consequent hazards are a combination of natural and society-induced factors, including the fact that the built environment is superimposed on the natural one, and thus is often at odds with forces of nature (Corotis, 2018). The degree of risk that is acceptable to a society, the role of immediate benefit versus future risk reduction, and the alternatives of safety and service are legitimate issues for society as a whole, not just for the engineering or planning professionals. Measures of economic investment and future costs and returns should be part of the decision rhetoric. The concepts of tradeoffs for society, and the political as well as engineering implications are of key importance to both engineers as well as elected officials. That tradeoff includes the increased risk of new facilities, of inadequate maintenance and retrofit of existing facilities, and of insufficient design for low probability-high consequence hazards, with the concomitant challenge of resiliency.

POLITICAL ACOUNTABILITY - CRISP

For society to bring concepts of lifetime, sustainability and resilience to the built environment, it must find a way to meld these concepts with the realities of our political process, which tends to be based on a relatively limited time horizon (*Are we Planning Safer Communities*, 2002). We need to recognize the conflicts of immediacy and future uncertainties, including workable definitions of sustainability and resilience (Corotis, 2010).

One way to bring the concepts of life cycle and sustainability into the public conversation is to produce some sort of public accounting of these principles. Our accounting for infrastructure co-mingles capital and operational expenditures, generally has no clear depreciation policy, and fails to measure return on investment. A proper accounting must start with a value analysis of the infrastructure within a region, including not only the current benefit/cost analysis for any new structures, but also any change in value to existing infrastructure due to retrofit.

It is hoped that the fundamental concept of infrastructure accounting statements, as part of a total public trust report card (CRISP – Community Resiliency Infrastructure Sustainability Protocol), 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 capital and operating values, 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, including measures of resiliency. This approach 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 (Szanton, 2001).

CRISP, A PUBLIC TOOL

CRISP is a process for public accounting of the above-described principles using value analysis of the regional infrastructure including benefit-cost analysis for new structures as well as any increase in value to existing infrastructure resulting from retrofit measures that increase hazard resilience. Its potential use can be understood through analogy with the ASCE report card.

The concept of the ASCE report card to grade the nation’s infrastructure originated in 1988 as a reporting tool used by a commission titled the National Council on Public Works Improvement. As a method to guide the authors when evaluating the infrastructure, the first reporting system titled *Fragile Foundations* took the form of a report card and assigned letter grades based on infrastructure performance and capacity.

Nearly a decade after the first report card was published, ASCE issued the first infrastructure rating titled the Report Card for America’s Infrastructure. Unlike the 1988 report, the new reporting rated the current state of infrastructure based on 14 different categories, and also provided solutions for improvement. Each state could focus on specific infrastructure categories that are of most importance, and develop individual goals and objectives. With the primary goal of educating the public and political leadership, the desired outcome of the ASCE report cards is to essentially raise public accountability for such risks and increase support of infrastructure funding initiatives and fees (see, e.g., ASCE California 2011, Bonstrom et al, 2012).

The ASCE Infrastructure Report Card is a useful tool to communicate to the public and government the case for increased investment in the nation’s infrastructure. It is interesting to consider whether additional information sharing by ASCE might advance the message for investment in resilience and sustainability, by enumerating the benefits from such an investment, and accounting for the implicit future costs of current infrastructure and the change in future costs with such investment.

A community-based philosophy can enhance understanding if it accounts for the future probability-weighted costs of current infrastructure and their changes with investment (Corotis, 2002; 2010; 2017). Such a benefit/cost analysis will only be effective if it is founded on robust probabilistic estimates and acceptable discounting assumptions. These are the fundamentals of CRISP, the proposed Community Resilient Infrastructure Sustainability Protocol. CRISP is an accountability method for public understanding of implicit costs and risk in built environment decisions for safety, vulnerability, performance and maintainability. CRISP could be updated on a regular (at least election cycle) basis, and would relate to individual communities. A simple example of the framework for such a computation is given in Table 1.

Table 1. Sample CRISP format

Infrastructure Balance Sheet: Credits and Debits in Present Discounted Value			
Category	Prior Reporting Status	Current Reporting Status	Net Change
Cash Assets			
Bonding Liens			
Taxing Changes			
Outside Funding			
Existing Infrastructure			
New Infrastructure			
Etc.			

On a regular basis, like the current ASCE Infrastructure Report Card approximately every three years, or at the time of any election, a community or state official who is running for re-election would publish a present value analysis of the public infrastructure within his or her region. This would include not only the current benefit/cost analysis for any new structures, but also the change in value to existing infrastructure, that is, the costs, risks, and benefits associated with new or proposed structures. Previous risk levels can be compared with current levels of risks, as well as risk associated with proposed structures or retrofit. If nothing had been done to improve the efficiency and lifetime safety of existing infrastructure, then during the time since the prior election there would presumably be a deterioration of these facilities. This loss would be combined with the benefits of new infrastructure to present a total picture to the public. Such an analysis would be based on appropriate stochastic models reflecting current and future benefits as well as costs, including maintenance, repair, environmental degradation, and damage consequences (mortality, morbidity and direct and indirect economic) due to normal and disaster scenarios.

While the CRISP concept may seem difficult to implement, it utilizes the same exact concept that communities are beginning to implement regarding their financial health, especially with regard to future pension commitments of employees. The path of least resistance for elected officials when negotiating with representatives of public employees has been to offer more generous pension parameters instead of an immediate increase in compensation. The latter would appear on the annual budget for the community, while the former is a future obligation. If that future obligation were computed according to actuarially sound practices, there would be nothing wrong with this approach. But as we are learning in many cases, the future obligations can be made arbitrarily small by unrealistic assumptions of future financial parameters. The obvious shortcomings in the current approach have come to light, for example, in many cities (Chicago), counties (Orange County, California), states (Wisconsin) and countries (Greece).

The exact nature of CRISP needs to be developed, with input from engineers, economists and social scientists, as well as the public at large. The credits and debits (benefits and costs) of existing and planned infrastructure, properly discounted and weighted by likelihood of occurrence over a reasonable lifetime horizon, are the essential ingredients. The platform would provide a means to bring together immediate, demonstrable returns and optimal lifetime investments that are based on the realities of the political process.

CRISP AND CRISPER

Infrastructure Lifetimes

Life cycle costs are of course sensitive to the assumed useful lifetime of a facility. In reality, most facilities will be maintained, repaired and rebuilt, rather than being removed. Fortunately, with most common discount rates, the assumed lifetime becomes insignificant for values typically of interest for infrastructure planning (Corotis, 2018). For instance, with a discount rate of 4%, in fewer than 75 years (common design basis for bridges in the U.S.), the lifetime cost reaches 95% of the value for an infinite lifetime (and in 100 years it reaches 98% of the infinite lifetime cost). From the standpoint of communication with the public, therefore, it is possible to talk about the infinite (or at least indefinite) lifetime of a project ("permanent" improvement to the community). Advantages of this approach are that this may be much easier to communicate and that the error introduced is reasonable. It also avoids the difficult issue of trying to explain to the public what will become of a particular project after its design lifetime (Vacheyroux and Corotis, 2013).

Discounted Costs and Benefits

One will need to address the issue of discount rates as well as lifetime in order to take a lifecycle approach for infrastructure. Let it be assumed that infinite lifetimes are taken, and economic discount rates are set according to banking methodologies (around 4% in most developed countries over the past decade), and future costs and benefits related to mortality and morbidity are set around 2% (ISO 2394, 2015). Then all of the public portfolio of structures and infrastructure can be catalogued. For example, consider a bridge that has annual probabilities of damage due to flooding of 1% and due to an earthquake of 0.2%. The consequences of these events (the 100-year flood and the 500-year earthquake) can be estimated by existing fragility analysis (an essential part of performance-based design). Associated costs are computed for direct financial loss (liability and rebuilding the bridge), indirect financial consequences (loss of business to the community during reconstruction), and mortality and morbidity. These costs can be discounted and added to give the net present cost (assuming, for simplicity, that the bridge is reconstructed if it suffers damage). In addition, routine maintenance and periodic repair costs can be estimated and discounted. Taken all together in a life cycle present net worth computation as shown in Equation (1) yields the “pension liability” cost for the bridge.

$$C = \sum_{j=1}^{n} \sum_{i=1}^{\infty} [(1 + d_{i,j})^{-i} P_{i,j} C_{i,j} \tag{1}$$

In which di,j is the discount rate for the jth cost item in year i, and there are a total of n different cost items, some of which are zero in many years. Pi,j is the probability that the jth cost is incurred in year i. There are also excellent arguments that the net present value may not necessarily be the best metric for valuing long-term projects if there are important social and economic impacts, such as metrics based on welfare economics (OECD, 2007).

The same approach can be followed for buildings and for transportation, power, telecommunications, and water and waste systems. Consider, for example, that a city official wants to spend public money to upgrade an existing structure (for instance the flood hazard fragility for a bridge from the 100-year flood to the 500-year flood). The cost of this upgrade is a present value amount, and the benefit is the reduced likelihood of future costs due to flood damage. These can be compared, and the public would then be informed of the change in pension cost due to the upgrading. It is certainly possible that the cost of the retrofit could be financed through bonds, in which case the current cost would be the present discounted cost of the bond re-payment schedule. This approach would of course work as easily for a public-private partnership.

Now consider an alternative scenario in which the public official would like to construct a new facility, such as a school, library or fire station. The cost that should be presented to the public is given by Equation (1), that is, it should include future maintenance and risk costs of the facility. It would also of course include the present value of the benefits of the facility to the community. These can then be compared to present a total life cycle picture to the community.

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