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Research Note on Major Assumptions About the Probability of Failure (Pf) & Consequences of Failure (Cf) Related to Critical Infrastructures in California's Sacramento Delta

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Abstract:

A problem arises when the assumption that the higher the Pf and Cf, the greater the pressure will be to reduce one or both confronts a reality where Pf is high because Cf is high, and Cf is high because no one has been able to agree over what to do about the critical infrastructures in question.

The impasse arises because of the zero-sum nature of the high-stakes conflict, which in turn leads to long-term inaction where thereby increases the probability of something awful happening when disaster finally strikes. Reliability of the critical infrastructure, accordingly, ceases to be the driving priority in decisionmaking.

This note examines how to address such a problem within the interactive framework for the risk assessment and management (RAM) the instruments of a Quality Management Assessment System (QMAS) and a System Analysis Risk Assessment System (SYRAS).

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The UCB RESIN initiative examines the Pf and Cf associated with critical infrastructure systems in the Sacramento Delta, with specific focus on failures of key infrastructures that are spatially adjacent and/or functionally interconnected (we term these I_3CISs—interdependent, interconnected, and interactive critical infrastructure system).

To start with an I_3CIS example. Analysis of one Delta island, Sherman Island, identified several sites where an important underground gas line was covered by a vulnerable stretch of levee, on which a major Delta highway had been constructed and over which passes regional traffic, all nearby significant electricity transmission lines for the region and state.

Were a major storm to occur (the focus of RESIN 2010), water might overtop or breach the levee as well as wash out the road, thereby hindering recovery personnel and equipment. If overhead power lines also fell during the storm, the local and wider impacts would be even more substantial.

The RESIN initiative assumes that the greater the risk and impacts associated with I_3CIS failure, the greater the pressure on the public and private entities involved to address the problem beforehand. Why? Because the existence of a chokepoint of interconnected infrastructures means the failure of one critical infrastructure (CI) there increases the risk others fail, thereby leading to multiple losses of revenue and services.

This note questions the preceding assumption and offers an approach to the difficulties.

I

If one were to add to those already listed the other impacts associated with a levee failure at Sherman Island—e.g., the State Water Project would have to correct for major salinity problems and the ports would likely have to close one or both deepwater shipping channels—the potential consequences of levee failure are major. What many outside experts consider an already high Pf is associated with a high Cf, given the strategic location and role of the Island. A major earthquake, in other words, would be a major disaster here.

There are reasons to believe the relationship is actually reversed: Pf is high *because* Cf is high. The earthquake would be "major" precisely because the consequences have rendered failure so likely.

The argument runs this way: Since the stakes are so high with respect to what happens to the Delta generally and Sherman Island in particular, a stalemate among the involved parties has arisen as to what should be done. There is, as has been reported, a zero-sum game in the Delta, where what any one party wins at the expense of the other parties losing (Hanneman and Dyckman 2009). An impasse has arisen, where the resulting inaction, so the argument concludes, has increased the probability of levees failing in the prolonged absence of the necessary corrective measures for the Delta levee system.

Our 2009 discussions and Sherman Island site visit suggest at least five factors are at work making for a large Cf and *thus* large Pf when it comes to levee failure:

1. Free-riding is going on: Why should Delta residents and workers repair more than they are already doing since someone else ("government") is responsible for the rest anyway. . .?

2. Moral hazard is evident: Since California Department of Water Resources (DWR) has repaired a private levee like that for Jones Tract in the past, they'll have to do it again. . .

3. Liability conflicts are present: If I, a Delta resident or worker, make an urgent but unapproved levee repair that doesn't work, then am I liable for the failure that may result. . .?

4. Cf includes not only costs: Some types of levee failure actually benefit the parties involved. You finally get to replace that equipment or structure you could not replace before on the island, because, *inter alia*, insurance now pays for it or regulations did not permit it before. . .

5. Organizational decoupling is taking place: The organization behavior literature repeatedly documents that organizations try to decouple themselves from a turbulent task environment as a way of stabilizing their operations. For example, in an environment as dynamic as the Delta, PGE worries about PGE infrastructure, DWR worries about DWR infrastructure, and so on. . . (Roe and Schulman 2008; Kahneman and Klein 2009).

Point 4 is especially pertinent, as it implies Pf might be large because Cf includes the benefits that come from levee failure, not just its costs. That the failure of one infrastructure might actually benefit other infrastructures in terms of their own Pfs and Cfs must always be treated as an empirical question rather than assumed away outright as as a possibility. That said, all five features represent a mix of strategic interaction among parties in the Sacramento Delta that help account for why levee reliability is not equally a priority in the same way across all the parties involved (more in the next section).

Now such considerations may not be a large or determinate part of levee issues elsewhere or for the Delta as a whole (Robert Bea, personal communication). But if they are important for Sherman Island or other islands or stretches of levees or parts of the Delta, then special care will be needed to confirm whether the extrinsic factors just enumerated (and other to be identified during 2010) are driving the intrinsic uncertainties associated with the levees (for more on QMAS and SYRAS, see Bea 2002).[1] This is especially so, since we are prototyping advanced versions of QMAS and SYRAS on Sherman Island.

II.

Critical infrastructure reliability is the central RESIN issue, because it revolves around the probability of developing an acceptable level of infrastructure serviceability, safety, compatibility and durability—the four quality factors focused on in the RESIN risk assessment and management (RAM) method of interest, known collectively as QMAS/SYRAS.

In what sense is levee reliability actually the priority for the major parties involved in the Sacramento Delta, including the constituent CIs involved in chokepoint reliability at the I_3CIS level?[2] For a principal feature of the controversy over the Sacramento Delta is the large dose of unreality when it comes to issues of infrastructure reliability.

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[1] There are reasons to believe that certain parties, e.g., some Sherman Island residents, believe that because Cf is low, so is Pf low, e.g., they always see the need for minor repairs, which when made seem to work. For more see Roe, RESIN White Paper xx/10. The focus of this research note, however, is on large-to-large relationships between Pf and Cf.

[2] I thank Paul Schulman for help in thinking through and writing this section.

It should be no surprise to those parties in favor of a Delta water conveyance option—be it a “peripheral canal” or some other large structure—that such megaprojects are habitually underestimated in terms of their cost, overestimated in terms of their benefits, and undervalued in terms of their actual environmental impacts (e.g., Flyvbjerg et al 2003). Proponents of an independent Delta governance structure presumably already know that nothing like what they are proposing has actually worked elsewhere in the form it would be applied in the Delta. For their part, proponents of comprehensive Delta habitat and fish recovery offer up adaptive management interventions that in no way reconcile the conflict such trial-and-error learning has for large systems whose first error could be their last trial (e.g., Van Eeten and Roe 2002).

Now, the immediate counter is that large water tunnels can be found elsewhere (e.g., New York), regional governance structures are possible (e.g., the Netherlands), and wide-scale ecosystem management plans are working (e.g., Chesapeake Bay). But that is precisely the point. The Sacramento Delta is not its own country with dike construction dating from the 13th century or with floating houses because of climate change nor is the Delta an entire state with a long history of water canal and tunnel usage nor for that matter will what works by way of ecosystem management in one region work in another region, given ecosystems are by definition uniquely complex.

In short, in the absence of implementation details and demonstrated better practices that have emerged across a wide range of sites and cases, it is impossible to distinguish what is the most frightening mega-experiment Californians now face: a massive conveyance structure, a Delta-wide governance authority, or a comprehensive Delta rehabilitation plan.

Yet there is a dog that hasn’t barked in this controversy and it is the one we would have expected to have the most to say when it comes to the levees being highly reliable in real time, that is, right now: the Delta farmers, levee engineers and reclamation districts. Unlike others, these groups live or work behind the levees, and many have done so for years. Yet we have not heard from this group two sets of comments we would have expected given the literature on the high reliability management of critical infrastructures, particularly infrastructures seeking to reduce Pf and Cf.

First, if reliability were the priority for Delta levees, we should have heard much more about how Delta farmers, engineers and specialists have constantly searched for better practices to improve and upgrade levee construction, operations and maintenance. This search goes well beyond seeking funds to build to some kind of gold standard promoted by the state or Army Corps of Engineers.

Reliability managers know that conforming to a government standard is never enough when it comes being highly reliable. They have to do better because their local conditions are not amenable to one-size-fits-all. Yet we have not heard or read from Delta residents and workers anything like “we’re constantly searching for better levee maintenance and materials,” “we never rest on our past laurels, even when we meet government standards,” or “here’s what we’ve learned that’s better than what government proposes.”

Second, if reliability were the priority, we should have heard much more about the specifics about how a conveyance or governance structure or Delta-wide conservation plan would affect the levee system in the Delta. This goes beyond complaining that if a canal were built the levees would not be maintained. What has been missing are the details of how these interventions, if implemented, would actually affect, island by island, levee by levee, the real-time operation of Delta agriculture and water supply. From a reliability perspective, the devil is in such details, because they demonstrate a deep understanding of context and specifics that proponents of conveyance and governance structures do not seem yet to have demonstrated.

Perhaps this dog has barked and we’ve just have not heard it. Or maybe reliability is not the priority for any of the stakeholders? If so, the identification and assessment of extrinsic uncertainties for QMAS++ will have to take these considerations very seriously.

III

Let’s bring points in the two preceding sections together and draw out further implications for Pf and Cf with respect to infrastructure failure.

To repeat: If Pf is high, in whole or in part, because Cf is high, then we cannot expect that the higher the Pf, the greater the pressure to reduce it.[3] Such a decision will only happen if every party agrees that Cf is unacceptably high, and the point of the stalemate is that Cf is not unacceptably high to some parties. Only if the risk (Pf times Cf) were "unacceptably high" to all would we expect infrastructure reliability to be the priority.

There is an important corollary here. Presently, the stakes in terms of Cf are described in the terms of a zero sum stalemate: What you benefit from is what I lose by. This means that in a world were Cf determines Pf, the more Cf is volatile or indeterminate, the more volatile and indeterminate becomes the calculation of Pf. That indeed may be what is driving the different Pf estimates of the different stakeholders, namely, *they see different Pfs precisely because they see different consequences*.[4]

While preceding can be a major problem for other RAM approaches, it should not be as problematic for an interactive RAM such as QMAS/SYRAS. The interactive component of the latter recognizes that Cf used in a prior round of calculations may alter—indeed, should alter—conditions for both the Pf and Cf at work in a subsequent round of calculations, and so on through time.

Still we need to be clear about how this sequential interaction works if we are to avoid our own conceptual stalemate, a.k.a., "everything affects everything." Everything is affected, but not by everything else nor all at once.

I propose four (4) propositions that clarify, at any point in the interaction sequence and over the sequence, how to frame what is affecting what. To that end, I set out the proposition, give an example, and state the stakes involved for QMAS/SYRAS:

1. The original problem definition determines the Pfs and Cfs focused upon and their subsequent trajectories *Example*: To focus on historically more frequent levee breaches due to storms, rather than on earthquake or rising sea level damage to

[3] Even if Pf and Cf were low, other reasons may exist to take the same corrective as would have been taken were Pf and Cf high, i.e., a "no-regrets" intervention because additional factors justified taking action. Such considerations are beyond the scope of this research note.

[4] Some of these differences are expanded on in Roe RESIN White Paper xx/10.

levees, is necessarily to frame what are the intrinsic and extrinsic uncertainties of interest for subsequent following up. *Stakes*: The intrinsic uncertainties in QMAS/SYRAS are highly sensitive to the initial problem definition—"You wouldn't have chosen those models if you hadn't had that problem." This in turn raises the issue of whether or to what extent the original problem has been mis-our under-specified, i.e., the issue of managing the wrong problem precisely (E3 error).

2. Intrinsic Type II uncertainty associated with analytic models affects what extrinsic Types III and IV (human-organizational and information acquisition-utilization) uncertainties are subsequently analyzed. *Example*: By focusing on seepage and uplift models as a way of helping to understand levee integrity during a storm, we are obligated to ask how the physical factors isolated and used in the models with respect to seepage and uplift information arise and change over the course of levee design, construction, operations and maintenance. That life cycle in turn is essential to computing the extrinsic uncertainties in the Pf of a levee due to a storm. *Stakes*: The identification of the extrinsic uncertainties, which QMAS/SYRAS have shown to be of great importance to the final estimated Pf, is highly sensitive to Type II intrinsic uncertainties.

3. The extrinsic Type III and IV can determine over time the Cfs that are focused upon and calculated. *Example*: By asking what human-organizational or informational factors contribute to a future levee breach in a storm, we are obligated to determine the extent to which differences in past estimates of the consequences of levee failure led to current poor levee integrity in the face of a future storm. *Stakes*: The identification of Cf is highly sensitive to extrinsic uncertainties III and IV selected for attention in any given QMAS/SYRAS calculation.

4. The analysis of how intrinsic uncertainties entail extrinsic uncertainties and how extrinsic uncertainties entail the Cf to be analyzed (propositions 2 and 3) may well necessitate periodic reconsideration of the original problem definition, so as to correct for any E3 error (proposition 1).

The importance of these nested distinctions become manifest the moment we shift to the I_3CIS level of analysis.

Consider the Pf and Cf associated with the failure of a multiple infrastructure chokepoint in the breach of its constituent levee during a storm. Assume the levee breaches and the storm flooding takes out the adjacent road and electric distribution lines, which take out the nearby pumping station used to dewater the island.

This scenario raises at least two very important sets of questions about Pf in terms intrinsic and extrinsic uncertainties and the associated Cf:

1. Is the failure of the pumping station a Cf of an electricity failure that is itself a Cf of the levee breach? *Answer*: No, I believe. If it were "yes," how then can we talk about the intrinsic uncertainties associated with the chokepoint's analytic models, whose sub-models for levees, roads, electricity, and pumping interactions introduce model error into our estimate of Pf of chokepoint failure there? By defining the problem as one of chokepoint reliability, the intrinsic uncertainties immediately involve those models we use to analyze "chokepoints."

2. Is the spatial-physical entity we are calling a chokepoint basically the Cf of extrinsic uncertainties associated with the Pf of its constituent critical infrastructures? Is the chokepoint, in other words, an consequential artifact of individual infrastructural decisions made in the past? *Answer*: Yes, but. . .

   The issue isn't Cf as much as it is Pf. The levee may breach because no one in the past managed the chokepoint as a whole. No one oversaw and corrected for how the human, organizational and informational errors introduced in any one of its constituent infrastructures (e.g., the levee) interacted with like errors in the other constituent infrastructures, thereby increasing the Pf of the chokepoint as a whole.

   For example, if some one were managing the chokepoint as chokepoint, would they have allowed the adjacent road to become a four-lane rather than two-lane highway? Once that road went out because of the levee breach, recovery time for any of the constituent infrastructures may have become all the more complicated.

The point here is that the “effect” in any “cause-and-effect” relationship cannot automatically be assumed to be a consequence, Cf. The effect at issue may in fact be an uncertainty introduced through modeling (intrinsic) or human-organizational-informational (extrinsic) factors, all of which are triggered or entailed, causally, by the initial problem definition.

QMAS++ and SYRAS++ are going to have to be very sensitive to such distinctions, I believe.

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