Nuclear Construction Contract Risk Management

Suggested Reading: This webpage was written for those with an interest in nuclear construction contract risk management. This may include owners, contractors, developers, regulatory bodies, third-party intervenors, consumers and their attorneys. It is also recommended to the finance, surety and insurance market.

Executive Summary: The nuclear industry should use both qualitative and quantitative risk management techniques to the extent practicable, including utilizing contract risk management as a project control in real time. This will enhance management's ability to control cost, quality and schedule while demonstrating prudence, in turn reducing the cost of financing and ultimately that borne by the customer.

This webpage was written in anticipation of the new round of domestic nuclear energy facility construction, "the renaissance," in order to advise of the probable convergence of certain concepts and disciplines. While it is also meant to facilitate a merger of legal and quantitative risk management concepts in regard to construction projects generally, conceptual breakthroughs typically occur on large, high-risk projects such as the nuclear new build renaissance, and this is somewhat specific to those projects. It synthesizes this book: Risk Management and Construction [1], the following three papers from the International Journal of Project Management: Risk analysis and management in construction [2], Modelling risk allocation decision in construction contracts [3], A Risk Register Database System to aid the management of project risk [4] and Expert elicitation and Bayesian analysis of construction contract risks: an investigation [5] from the Journal of Construction Management and Economics. It is also informed by a few recently published books on decision-making, statistics and human cognition, which may be familiar. While recognizing that some of this borders on the esoteric, it is expected these concepts will eventually become more widely understood and adopted as the renaissance proceeds, just as the critical path method (CPM) and other project performance measurement methods considered "new" in the last round or nuclear construction are now commonplace. There are also certain insurance, probability and legal ideas presented in a new light, as well as discussion of the traditional construction management concerns and, of course, the prudence question.

In all likelihood, the reader has a general understanding of traditional construction performance risk management techniques and how those are applied to the nuclear new builds. These techniques are broadly addressed to the nuclear industry here Surety Bonds for Nuclear Energy Facility Construction Cost-Savings [6], wherein it is suggested that as much of that risk as is possible be shifted to commercial sureties, for a number of reasons. In fact, it may may be instructive to read that webpage first unless you are intimately familiar with the subject of construction contract performance risk management. Another key theme running throughout this webpage is that of "prudence," which will be explained and addressed as well. Some readers may prefer to understand that concept first and skip to **Litigation and Prudence: In Hindsight**.

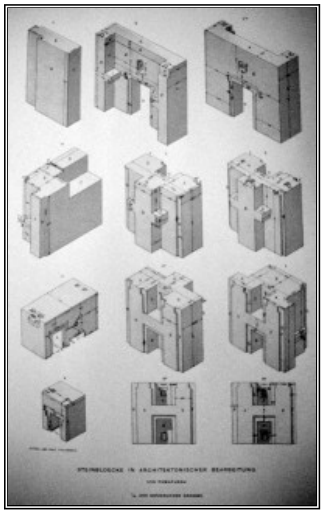
This webpage was written around notations of Risk Management and Construction [1]. "The book" hereafter, served as its template. "The authors," also mentioned throughout this page, did all of the heavy lifting. It is basically a glorified book review, appended and annotated. But it also strives to emphasize the most practical information and concepts relevant to the topic while condensing the exhaustive details of their academic underpinnings. For example, the highly practical "types of bias" are explored in favor of highly theoretical "fuzzy math" applications, most of which is beyond conscious human application, even in such a complex endeavor as nuclear construction.

Therefore, some of this is very dry and slow going. Please don't be off-put immediately by the mention of fuzzy math, the blog-like indulgences, certain colorful language or what may seem like conclusions put before the horse. Skip over that should you encounter it and look for the free good advice and eye-openers, such as the tools and concepts which you may not have previously considered. While it is highly recommended that this webpage be read in order, you may click on a subject to your right to skip to it immediately. Please note that much of this is a rehashed engineering text book with some comments. It is not a legal brief. While analyses and arguments are made and conclusions drawn, some of it is just informational.

Putting Risk in Perspective

As with many disciplines, there is a gap between the tools developed in theory and those used in practice. Every day, science gets further ahead of engineering at a seemingly increasing rate, as does

management theory and practice. The book and this page acknowledge this repeatedly, but also advise that we must endeavor to keep up with these concepts before we are overtaken by them. As an example, consider what has occurred with critical path method (CPM) and construction productivity tools since the the last build. What was considered a cutting-edge and expensive "nicety" then, is very much standardized now. In general, large efforts tend to justify investment these newly cost-efficient tools, and the potential downside of a little preventive medicine makes it advisable. The recent adaptation of "Building Information Modeling" (BIM) software is an example where the nuclear construction industry has shown a continued willingness to integrate new ideas.



"Risk and reward" is a simple concept we learn very early in life. Just this morning, did we decide to bring the umbrella or not? Did we buy a lottery ticket along with last night's newspaper? Why? What about last year's personal investment decisions? These are all examples of a routine activity, but how much do we really know about this process which, it is said, is the very ability that separates man from a "2001: A Space Odyssey" cinema ape? "Risk management" which is almost interchangeable with "decision theory," is described as "willed action" beyond mere instinct. It is an investment of some kind which is offset by a potential reward or loss, adjusted by the probability of the achievement of the loss or reward. That is the reason we made a spear out of a stick, because there was something in it for us. But be it for greed or altruism, our pre-frontal cortex exists primarily to perform the risk management function. And when a healthy brain rewards itself with dopamine when we get it right, we feel good. End of story. [7] This feeling of accomplishment is clearly applicable to highly complex endeavors like nuclear construction management and why many find it an interesting and satisfying pursuit.

The authors start by describing four very general approaches to construction risk management, briefly:

~ The Umbrella Approach ~ Pay a large premium to avoid as much risk as possible, just throw money. ***~ The Ostrich Approach ~*** Bury your head in the sand and muddle through with what's a "going to happen" and "way it's gonna be" attitude until the "it is what it is" inevitably results. ***~ The Intuitive Approach ~*** Rule by intuition from the divine right of clocking time, Peter-principled along the path of least resistance. ***~ The Brute Force Approach ~*** Rely upon naive notions about what is within one's control, e.g., the sub-busters and others blissfully unaware of prudence standards and shareholder litigation.

As soon as I saw how the authors named these approaches, I knew this was going to be a very practical read and well-worth the effort. Some of those embellished characterizations may sound a bit harsh, but the purpose here is to provide useful information without the sugar-coating.* We see that last approach, "brute force," commonly with large public owners and large general contractors, with too many dollars and not enough sense. This approach could be especially problematic in the prudence arena, for a number of reasons which will be discussed throughout.

Finding the comfort zone amongst those approaches involves a mindset always maneuvering somewhere AGAP and WHIF, i.e., "all goes according to plan" versus "what happens if." That means knowing the correct vantage point at the right time as the goal posts keep moving. By example, the authors gleefully cite the "euphoria, optimism and excitement of a new project," no doubt inspired by London's Canary Wharf mega-project which graces the book's cover. Certainly, that very same general feeling corresponds with the nuclear construction renaissance and the promise of the new smaller, modular reactors on the boards. That is only natural, but also often begets unrealistically optimistic cost estimates and schedules in the name of "No Silos," "Git R' Done," "There's No 'I' in Team," and the other happy horse*feathers* bumper stickers this kind of opportunity breeds. It is precisely for this reason that the authors recommend "brainstorms of destructive thinking" and the pro-active collection of worst-case scenarios into a risk management system for for analysis. I like their frank realism. I would add that despite the rosy scenario culture one is tempted to adopt, their advice should be embraced and adopted. In hindsight, the wisdom behind it ultimately showed itself in the amount of litigation surrounding the Canary Wharf project.

Like most human endeavors, construction activities can be split-out in to four aspects: people, process, risks and effects. This seems like a tedious conference room snoozer of an observation, but it greatly helps in understanding the basics of risk management and decision-making in construction. (For an explanation of the construction process generally, some might want to quickly skip down to **Risk and the Construction Project: Time Money and Technical Risks**, particularly the footnoted slides pertaining to nuclear build decision risk, or over to Surety Bonds for Nuclear Energy Facility Construction Cost-Savings [6] at this point.) Management must have a firm grasp of those four aspects in detail, starting on day one and maintain it meticulously, managing the risks using the contract and project controls. Decision-makers in construction will need to focus primarily on that as well as the "big three," i.e., *time, cost and quality*. Almost every decision, i.e., risk analysis, has a potential impact on those. Unquestionably, the risk management "philosophy" will be a prime target for prudence inquiries. Developing a coherent, sound, easily communicated framework is essential. And it also presents an opportunity to utilize the very concept of risk management as essential to "prudence." Both should be used as project management tools, in real time, as suggested by the Executive Summary. By thoroughly understanding these concepts and using them appropriately, one can cause desired behavior changes in others. They can be applied effectively, perhaps not by quoting the Reverend Thomas Bayes on "final causes for the existence of the Deity," but by translating his complex principles to people in a way that will have a desired outcome, to wit, "break balls," if you will.

The authors close out this introductory section with even more seemingly unsupported conclusions, platitudes, preachings and opinions, each well-placed to make you want to read further and understand how they got there. Many will recognize some of these "politically incorrect" observations as things they themselves may have thought about an organization or an industry at one time or another, and enjoy reading the theory and fact behind why it's all generally true. So I'll follow the authors' lead, but add the "prudence" factor complication attendant to nuclear construction in an attempt to make the purpose behind this exercise even more evident. Management of these complex projects is going to be difficult enough, and far more so with the prudence filter added to mix.

The industry will be second-guessed about why it didn't land the plane in the Hudson River more smoothly, without spilling the drinks, or seemingly so. Unlike typical construction litigation, the prudence scenario is set up to bring the construction decision-making process itself into the light, using an entirely different process and set of rules. The system is set up to protect the end user, the littlest little fish in the supply chain, the rate-paying customer at home flipping the switch. The normal rules of the game do not apply, and most are ill-equipped to quickly adjust. So, despite onerous and unrealistic, yet elegant contracts and instruments drawn to manage the risk, certain parties to the construction process may ultimately be held responsible for risks they might have normally been able to justify, control, insure, transfer, or otherwise "get rid of" in the day-to-day arena. The reality is, no amount of wood-paneled contract language, industry clout, cash-on-hand or heavy lawyering can change the fact that, in the end, the truth will usually out. The prudence filter allows a much broader variety of matters to come under scrutiny and indeed the management process itself. The net result is, this places a very heavy burden on the upper end of the supply chain, which can be easily portrayed as having had control over the entire process. Liability which may have been avoided elsewhere is more likely to be found. In this vein, the authors warn that “It it pointless imposing financial burdens on company that cannot afford to pay,” and I would add that the same principle extends to schedule and technical performance requirements as well. Contracts will need to be realistic about this up-front, and the projects managed in real time with this in mind. Below, this page explores how the entire contract risk management system can be quantified ahead of time, used effectively in real time and later unwound, using both cognitive inquiry and quantitative analysis not often considered in the normal construction arena, if ever. It attempts to address how many construction disputes in the renaissance might be easily avoided with the addition of a few simple techniques described here. A great deal of construction litigation is really little more than juvenile bickering, finger-pointing, poor communication and personality disputes, much of which might be easily resolved using cognitive inquiry and quantitative analysis in an informal manner. Hopefully the ideas on this webpage will seep out into that more general realm and eventually reduce some of the needless burden on the courts.

Some Background on Risk and Uncertainty

We the words "risk" and "uncertainty" constantly, but do we really know what they mean? In this context, probably not. This section starts out at square one with those definitions, then explains how we misuse knowledge by tainting it with bias. It is explained how to remove bias (from others, if not ourselves), and why decision-makers may be derailed by misplaced "styles" of risk and how to remove “ignorance” to become an efficient decision-maker. Where possible, I have put this into everyday terms and described nuclear construction examples.

Bear with me now and take a minute to examine your own personal attitude and behaviors. Consider the "your state here" Super Free Money Mega Power Ping Pong Ball Lotto Lottery. Some of us also call it the "idiot tax" and gleefully "play to win" daily, knowing it is but a certitude we will lose. Of course we will lose, the past performance gives us an insight to the future. No one ever wins, except the occasional florist in Pig's Knuckle, Pennsylvania. But yet our gut feel and rational judgment are in conflict over this futile effort anyway. Why is that? It's because the emotional brain is flipping back and forth with the analytical brain, while aversion shoots stressor chemicals into the blood and anticipation rubs dopamine around your skull like the foamy soap brush at the dollar car wash. [7] All the uncertainties of life abound in that decision. Is it a threat to your intelligence to play that lotto or challenge to your “gut?” Brainless or gutless, which is it? How do you view that opportunity, like a coward or a fool? Or maybe its just a "habit." Yeah, that's the ticket. How’s that working out for you? "Only a buck a day," was $500 last year. Admit it. Or perhaps like me, maybe you proudly maintain a habit of ignoring it completely, that is, until it's an office lottery. I don't want to play, but nor do I want the others to win without me. At some number, I break, just like everybody else. If they all win $200,000 without me, I can live with it, but at $450,000, I'll throw my $3.75 share right down the rathole with the rest of the other sucker chumps. Many of us live in that gray area, yet never ask why. We fret more over that daily decision to buy a lotto ticket than the two seconds we took distributing pension funds or considering the effect of that fifth DiTech dot com mortgage. Risk management and decision-making such as playing the gas station lottery plague us at every turn, just on a much less dramatic level. Let's face it, people are fascinatingly stupid. It is important to start with that observation, because it's precisely that sort of chaos we want to avoid when building these projects.

Why? Because the industry confronts a "first of a kind" (FOAK) nuclear construction renaissance with billions of dollars at stake. There is little historical data and a dearth of collective experience to assist in

Nuclear construction projects involve what’s known as *dynamic risks*, with both a potential downside and upside, as opposed to *static* risks, with only a downside, such as an insurance claim. They are ultimately *financial* risks, though with different emphases for the parties at same project, yet all sharing the lingua franca, money. The contractor wants to make a construction profit, the owner from generation, the supplier from supply chain. It's the same goal achieved by different means. It's as if everyone is saying something different for different reasons, though in the same language and while attempting to reach the same conclusion. In these projects, as with capitalism generally, money is simply the common language of risk.

At some point a challenge becomes a threat, an opportunity a problem. Timidity or bravado can be tempered by experience, intuition and common sense, or the lack of it. It is no secret that management and organizational politics is often stacked in favor of pleasers, path of least resisters and heir apparents all duly voting present, instead of those that are truly focused on the organizational goals. You can learn that in any airport bookshop. Perhaps most important is knowledge of the decision-making process itself. All too often in management, this is sorely lacking if not entirely overlooked. I would argue there is absolutely no place for business as usual in the nuclear renaissance, a point so critical to the industry. A substantial amount of project politics and construction disputes, as well as prickly interactions with "strong personalities," regulators and shareholders can be avoided, defused and deflected by understanding these concepts, tools and techniques.

understanding and managing the risks. Using mental exercises such as card games, dice-rolling, and similar quantifiable measures to prove exactly how easily-duped we are, the authors describe a few scenarios and riddles just like I did in the in the paragraph above. They do this to prove to us the bases of their advice and come up with what looks a collection of old sayings. Then they proceed to show things such as how to determine the value of information. We'll take what ever we can get for free, but just like a bettor would pay some amount for a little information about a horse or jockey, we'll also pay for an advantage in business decisions, but only so much. At some point, I will be suckered into wasting that $3.75 on the lottery, even though rationally, I don't want to be. And therein lies a crucial tipping point for any issue undergoing prudence analysis, where engineering and construction management decisions will be judged retroactively. "Why didn't you buy a tip sheet?" they'll be asking from over both shoulders while wearing 20/20 green-eyeshade hindsight glasses, "everybody always knew Seabagle was a shoe-in." Lucky you.

The problem is, we all make mistakes. The good news is that but the prudence standard allows for it. Where it may be less forgiving is when the prudent action was taken, but things went wrong anyway. Kelly's Law, that's called. You can always count on it, the unkindest cut of all. The best we can do is "today," and actively using these risk management principles will have no result other than the best possible positive cumulative effect.

It's also going to make explaining things later much easier.

A surprising amount of what sounds like "pop psychology" or "ancient wisdom" is actually entirely quantifiable and rational. You engineers deep in the design weeds need to think about that if someone seems to be chanting buzz phrases at you all the time. You might want to listen up before someone drops one of these proofs on you. I can think of few of you I'd like to go back in time and visit right now, in fact. Sparing you these proofs, here's a few truisms right out of the book, although somewhat paraphrased. I like these best in the run-on format straight out of my notes:

" – don't risk a lot for a little – always plan ahead – always analyze both the source and the consequences for risk – devise alternatives and contingencies – don't use others as excuse for inaction - don't risk on purely on principle - or to avoid losing face – or more than you can afford to lose – be prepared to seek expert advice – consider odds realistically in light of your experience and intuition – consider how much control you really have- "

Every single one of those can be demonstrated well-beyond the most hard-headed engineer's ability to keep yapping or upper management's propensity to keep droning. Take the old saw about "decisions made by committee." How many of us have complained of others doing it, only to turn around and do it ourselves, over and over again? Typically, a blowhard makes a decision and announces it in a meeting in order to garner the sufficient on the record "me toos" for the ego folder in the CYA file. This is precisely the wrong approach. Not only is it true that groups make riskier decisions, it can be proven so mathematically. Be aware of the fact that bravado often, if not always, effects "group think" and especially group decisions. That's called the "risky shift" and there are a number of reasons for it. All too often, people are either too timid to reconsider what they've said in meetings or simply unable to admit they are wrong. Research proves this happens time and time again. But more importantly, the potential loss from a reckless group decision is felt to be a "shared" loss. People always tend to be more conservative when considering a potential loss personally than they care to admit to a group, especially one with which they feel they can share the potential loss. This is even more prevalent when the group is cheering itself on and upping the odds. In the heat of contract negotiations, the critical path wars or burgeoning legal disputes, this can get out of hand very quickly. You should always have a cooler involved and a fixer around, and try to make them both you. Simply having the kind of background knowledge gives you the ability to change the dynamic. The same advice goes for those other old saws above in green. The book takes us through a few proofs to show us why these are indeed truisms and not merely motivational posters adorned with adorable cats and dogs. And it does so with convincing mathematical rigor.

Another highly practical application of this way of thinking comes in handy when considering the variables in group dynamics. Risk-taking is clearly correlated with, e.g., creativity, so attitudes and flexibility in regard to both vary widely across the disciplines. People are often constrained by their "role," or want to live up to them. How many times have you heard, "Well you're an engineer, so..." or made a similar remark yourself? This is often an afterthought floating around in the background of consciousness but withheld because it seems a little unfair at times, or used precisely for that very reason. Now, imagine the utility of a graphic with "risk taking" increasing on the x-axis and "creativity" on the y-axis. It generates points like: "Challenger – Innovator – Practicaliser – Synthesizer – Modifier – Planner – Repeater – Dreamer" and shows where roles like "Architect – Electrical – Mechanical – Consultant – Developers – Quantity Surveyors – Landscape Architects" land. This book is full of handy little graphics like that, most of which are not mentioned on this page, and well worth the investment. There will be more on this risk-taking and role concept discussed later.

In order to minimize risk, we need to better understand it by "removing ignorance." I like that phrase. It's a lot clearer than "value-add actionable information logistics going forward" because it reveals the state we are currently in and what we need to do about it, rather than rewarding us for simply parroting yet another buzzword. It's far less preemptively self-congratulatory and is an attention-grabber. (Sometimes the British use English even better than we do.) In fact, we need to learn to embrace ignorance and become brazenly proud of being "risk hating, risk averse and highly ignorant" and counter those that would "scorn the abstract." [8] So how how do we go about this? Most of us are aware of

the "scientific method," and the correlative lingo for that in this field describes four steps, *analysis, synthesis, simulation and test.* This is the amusing part of this endeavor, where so-called rational beings are easily shown to behave more like mice chasing cheese through a maze than we'd ever like to admit. But it comes in handy when analyzing our decisions and in interacting with others for a favorable outcome in these nuclear construction projects. But to do that, we need an overview of probability first.

Probability and statistics, commonly called chances or odds, is such a huge and practical body of knowledge and field of study I am barely comfortable addressing it. There are two basic kinds, "objective," like throwing dice or drawing cards, and "subjective," where human perception is a factor, such as with stock picks, weather forecasting or construction applications. These are also called "quantitative" and "qualitative," interchangeably. In construction we must be aware that our personal “beliefs,” called *biases* go into these highly subjective, qualitative formulations and often foil our desire to be "accurate, reliable, calibrated and coherent." [1] Please note that biases as discussed here are not personal or cognitive defects, they are simply the false constructs we use to process information that all-too-often go unrecognized and unchallenged. In nuclear construction, we can try model our way around them with estimates, CPM and risk registers, all of which will be discussed below. Now you've learned you're ignorant and biased. The upside is, this knowledge in itself is making you more prudent and a better manager already .

"Uncertainty," is converted to "risk" through knowledge, i.e., by removal of ignorance. In the face of utter and complete uncertainty, even the slightest shred of information coverts the situation into a risk, e.g., that returned phone call after the first date or job interview. That's the "removal of ignorance." If you finally get an answer, and she'll go out with you again when hell freezes over, then ignorance has been removed and you know that at least there is a chance. The value of that information can be quantified using elicitation techniques such as Savage's Method, a series of questions comparing, e.g., betting on roll of dice vs. a certain business decision. It also explains why the value of even the slightest bit of normally trivial hearsay, silly tidbit of gossip or misread body language can seem blown out of proportion in certain situations. How does all this apply to a nuclear construction program? Consider this quote: “The subjective probabilities of different individuals with the same experience and information may be very different. The decision-makers experience, education, values, personality, and perception, as well as preference for a particular event, will be reflected in the subjective probability.” [1]

What that tells you is that the person who has not experienced or immersed themselves, or found someone engaged extensively in the widest possible range of construction contract performance failures, is walking into a minefield.

As we know,
There are known knowns.

There are things we know we know. We also know
There are known unknowns.

That is to say
We know there are some things
We do not know.

Secretary Rumsfeld was right about that, regardless of whatever else one can say about him. "Did I like the way he asked himself questions and them answered them in one sentence? No, I didn't." But that impromptu poem resounds and reflects the kinds of management skills that are going to be needed in the nuclear renaissance. “Knowledge includes both empirical data and insights obtained by observation,” the authors advise. That's how we learn to identify the "known unknowns." Yet the complexity and uncertainty inherent in nuclear construction projects seems to breed unwarranted confidence nonetheless. I say that as one that has worked on two of those, as well as thousands of worst-case construction scenarios, backward, forward and in real-time, with a sideline in financial Ponzi schemes and similar frauds. The bolder the blowhard, the higher he rises and the harder he falls. The higher the stakes, the dumber the moves, usually. It's happened countless times and will be no different during the renaissance unless unfounded confidence and similar "black boxes" are immediately challenged. Verify, do not trust. Ever. That jaded observation said, I was pleased to see this leap off the page at me from book: “Bankruptcy courts are filled with people who ‘knew’ things that just were not so.” Not the sort of thing one expects from a dry academic engineering text, is it? And it was followed by this gem as well, “Life can only be understood backwards but must be lived forwards.” I would add that life is often misunderstood backward as well, particularly in court. [8] If you are going to be subject to prudence examinations, you can certainly count on it.

How do we handle uncertain situations? *~ ignore them ~ get more information ~ use more rigor on forecasting methods ~ consciously adjust for bias ~ revise ROI by adding risk premium ~ transfer the risk ~ seek alternatives to even assuming the risk ~*

"Trust your gut," sounds about right. Why is that? Because it sounds good? Because it's the easy way out or precisely the opposite? How do we distinguish a lofty, wise intuition and a vulgar, ingrained bias? These are the questions we wrestle with by day and dream about at night. How often do we see a challenge we know will not go away, yet we don't attempt to manage it? Instead, we put it away somewhere and let ourselves be haunted about it. Almost everybody knows they could use more self-examination, but who has time? Here's a place to start, the work place. For example, we all know the other guy is often full of it. It's just not easy enough for most of us to prove that in daily life, so we routinely overlook the same nonsense repeatedly and "give it a pass" because we always have. How do you tactfully explain (perhaps at a heated meeting, in front of passionate people on an emotional topic) that the single example of the worst case of an of the stupidest thing you've ever freakin heard is not just a "cherry picked sob story," but a cognitive bias. Say it with me "cognitive bias." So, how do you react to this ahole? Do you "pound the table," or simply explain something to the effect that the "Law of Small Numbers does not apply here?" You know that the poor sap would never understand "you are bifurcating a

But there are also unknown unknowns, The ones we don't know We don't know.

Feb. 12, 2002, Department of Defense news briefing

representativeness heuristic," when he's already too stupid by half. What you are politely easing into is the fact that he is misusing a tiny statistical sample to illustrate a broader point. This counter-productive, ridiculous predilection is repeated so often in our culture it is considered acceptable, despite the fact it is entirely pointless and juvenile. The same can be said of the other biases. When this tactic, identifying biases, is used judiciously, it can have a highly productive effect. The example given above was merely illustrative, of course, and no noses were broken in the production of this webpage. The chart directly below is copied word-for-word from the book. [1] Though it is not easily absorbed (at least for me) and takes some effort to learn, it may well be the most important thing you take away from this page. It should be committed to memory by everyone involved in the nuclear construction renaissance and anyone who wants to make the best decisions possible, winning every argument along the way. Beware. Warning. Master these and you may never see "management," pundits or especially politicians in the same light again because it becomes so painfully easy to cut through all the nonsense. Use it quietly and without arrogance or hubris. If married, consult your divorce attorney now, before you read further.

BIAS	EFFECTS
Availability	Judgments of probability of easily recalled events are distorted
Selective perception	Expectations may bias observations of variables relevant to a strategy
Illusory correlation	Encourages the belief that unrelated variables are correlated
Conservatism	Failure to revise forecast based on new information
Law of small numbers	Overestimation of the degree of small samples
Wishful thinking	The probability of desired outcomes is inappropriately high
Illusion of control	Over estimation of the personal control over outcomes
Logical construction	'Logical' construction of events which cannot be accurately recalled
Hindsight bias	Over-estimation of the predictability of past events

Few things in life are certain, but one thing in nuclear construction is. Prudence reviews are going to be shot-through with every kind of bias under the sun, coming and going. So when you come to a major decision, always ask how sure you are and why. And get some serious feedback. Are you going to be able to explain the decision out from under a biased question posed in hindsight? Mastering bias and being able to demonstrate its absence will go a long way in real time project management, keeping prudence issues from developing in the first place. Likewise, biases should be identified and removed from the project management *culture* as a whole, be they optimistic rosy scenarios or otherwise, such as a continuing tendency to facilitate the "blame game." Attorneys will want to see a very high level of genuine self-awareness and preparation on both an organizational and personal level. A general grounding in the use of these tools and techniques will go along way.

Very, very simply, neuroscience tends to show that we are often biased because it makes us feel good physiologically. We like reward to ourselves ahead of time, because we always knew we were right all along and controlled the outcome all by ourselves, we think. Let's face it. No one knows as much as they try to pretend they do. We're all like that, we know it and dislike most it in ourselves, consciously or not. It is unpleasant dealing with this unfortunate fact, and we struggle to do so. It is even more unfortunate dealing with those that do not recognize it in themselves. This is why we admire the successful people that are humble, likewise those whose circumstances are fortunate or "lucky," and they acknowledge it. Behavioral science reveals our transparent weaknesses and the lengths we'll go to in order to feed ourselves the "common currency" of dopamine. It's explained in the "The Predictions of Dopamine" chapter of How We Decide [7], with vivid eye-popping descriptiveness. I can not recommend that book highly enough, and do it great injustice with my bumper sticker shortcut remarks, designed to just get the basic concept across. When understood in conjunction Risk Management and Construction [1], proving

how decision-makers may be very easily derailed by misplaced "styles" of risk, "ignorance" and most importantly, "bias," you come to appreciate the fact humanity hasn't self-destructed yet. Our brain cells are literally hungry for a instant reward and will take every short-cut to get there. They are also very easily duped unless they are disciplined. How We Decide [7] also explains that since the world is far more random than our emotions allow us to admit typically, when we must, we go with our gut. It explains why and when we can and should skip the math of the risk analysis altogether and quickly land that plane in the Hudson River without thinking too hard about it. The brain has its reasons for keeping its primitive part, as well as continuing to expand the ability to perform the contemplative risk analyses relevant here. If you thought those last two sentences seemed to cover a lot very quickly, they do. That book is a must read, plain and simple.

** Attribute substitution: making a complex, difficult judgment by unconsciously substituting an easier judgment*
** Attribution theory, especially:*
o Salience
** Cognitive dissonance, and related:*
o Impression management
o Self-perception theory
** Heuristics, including:*
o Availability heuristic: estimating what is more likely by what is more available in memory, which is biased toward vivid, unusual, or emotionally charged examples
o Representativeness heuristic: judging probabilities on the basis of resemblance
o Affect heuristic: basing a decision on an emotional reaction rather than a calculation of risks and benefits
** Adaptive bias*
** Misinterpretations or misuse of statistics.* [9]

The above is just another way to summarize the biases using more technical terms. It is taken directly

from Wikipedia, where there are numerous others ones listed, all variations on these basic themes. At its simplest, it is a complication of common shortcuts and mistakes. These "mistakes," as we see daily, are often intentional and for the benefit of the party making them.

Most of us use certain heuristics, e.g., "Rules of Thumb" to try to get around our own biases by over-ruling ourselves at times. We use Rules of Thumb to override our instincts in specific situations, such as when we ask “what worked last time?” Usually, we do that when its a convenient question with a preferred, easy answer and rarely do we perform rigorous self-examination. While the complex decision-making and risk management models discussed below far outstrip our ability in to apply them to day to day use, and even in our most complex decision-making, the authors urge us to do the best we can to improve these abilities. At the very least, these techniques can be used to stimulate thought and facilitate conversation during project management, especially in dispute resolution and avoidance. Strides made with CPM, risk registers and cost forecasting have shown positive results. I would add that general knowledge of this topic will be helpful in a prudence review, as well. The costs involved and ultimate responsibility to the customers and shareholders make the effort advisable.

All too often, we extrapolate our own past onto others' futures, relying too heavily upon our own personal experience. Use experts or consultants from last time around, and not simply experts in their own successes, but in the failures of many others or even their own. In construction contract surety claims, many of our best consultants come from failed firms, oftentimes their own. There is no shame in it, as knowledgeable people know how truly risky the construction business is. When examining a potential claim, they provide the benefit of experience with the industry, stripping out the bias-causing “experience” burned into the subconscious of the troubled firm's management, which is usually completely blinded by visions of rosy scenarios and desperately looking for a way out of trouble. If for some reason that sort of expertise is not available, at least adopt a "keep your enemies closer" or Lincolnesque "Cabinet of Rivals" strategy. Gain insight through case studies of construction claims, as well. Consider the hypotheticals, the *AGAP vs. WHIF* and prepare for the Black Swan event, when the most unlikely variable has its the greatest possible impact. [8] Generalists, consiglieres and trouble-shooter types were around last time, usually called "consultants" on "special projects" and the like. I would suggest that this is advisable again, but of course I am *biased* in this view, aren't I? See, you picked up on that right away already. That's good.

But the Black Swan event, isn't that just for dreamers, poets and Levantine philosophers? It can't happen in such a rational undertaking as nuclear construction, can it? Yes, it did, in fact. Imagine a perfectly framed and statistically analyzed foundation core drilling sample for the third nuclear facility in the same general site area. What are the chances these absolutely flawless samples could be wrong? The answer, my friends, is 100%. Because when they started digging, the wrong things were in the precisely the wrong places, defying all odds of the sample, which all parties to the eventual litigation agreed was absolutely, metaphysically perfect. I know this because it was one of my issues in a nuclear construction prudence case. Fortunately, in that instance, the "Black Swan" nature of the event was recognized by the auditors and the court. I don't recall if the plant had to be moved eighteen feet for thirty million re-engineering dollars, or if it was thirty feet for eighteen million, but those were late-1970s dollars. Imagine if that happened today? Because it will.

The book [1] and Lehrer [7] both demonstrate that we use as many mental short cuts as possible to achieve acceptable, but not optimal solutions, in both construction and our everyday lives. We also repeatedly tend to avoid even *considering* unacceptable outcomes outside of our experience, especially the worst case scenario, even when we've been through a similar situation. It is entirely natural. But considering what is at stake with these projects, now is the time to "think outside the box." But since that expression is beyond tiresome. I'd rather think of Alice in Wonderland and remember how she attributed her triumph, finally getting herself out of the rabbit hole, to of her habit of "thinking of six impossible things before breakfast each morning." Oddly enough, Lehrer [7] suggests we can probably balance only seven concepts actively at once, due to the current state of the pre-frontal cortex. That leaves just enough multitasking ability to plug-in the coffee at the same time.

At this point, the book gets into the tall weeds about forecasting models, well beyond what I can do here, all to make this point salient. “Indeed, just as we use past experiences to infer the future, we may also use past experience of risk to infer the future riskiness of decisions.” That's just another way of telling us to continue to learn from our mistakes, the very essence of intelligence, and that there are techniques (discussed below) which can help us do just that.

Having said that, here's a convenient little summary checklist to close out this section.

	The approach of an efficient decision-maker
Frame	*Surveys the full range of objectives to be fulfilled and the values implied by choice*
Alternatives	*Thoroughly canvasses a wide range of alternative courses of action*
Information	*Carefully weighs whatever is known about the costs and risks of negative consequences, as well as the positive consequences that could flow from each option.Intensively searches for new information relevant to further evaluation of the options*
Evaluation	*Correctly assimilates and takes account of any expert judgment and risk exposure, even when the judgment does not support the course of action initially preferred*
Implementation	*Makes detailed provisions for implementing or executing the chosen course of action, with special attention to contingency plans that might be required if various known risks were to materialize* [10]

Risk Management Systems

Our conscious decisions are rooted in intuition, intelligence, education and experience in the real world. We combine those to "think," which can be modeled as a mathematical process to an extent. The decision machine we call a brain performs the same kind of risk analyses as the computers at an insurance company or credit card provider, and it can be shown that we calculate a number representative of a risk in much the same way. This is our way of coping, managing the possibility that future events may cause adverse effects and balancing that with the potential reward or loss. A quick look at these Google images or these may refresh a few memories or provide an introductory glimpse of these models. Those graphics describe what would take far too many words in this introduction, although the basic steps will be described in following paragraphs. When explaining this process, I've found that most-commonly, people seem to recall understanding this at some point in reference to diversifying a portfolio of investments, buying insurance or choosing mortgages. Many attorneys will have first learned this concept as part of the negligence theory of tort law.

Entire support industries have been built around risk management as it applies to construction, including insurance, contract surety [6], project management consulting and specialized practices in construction law. Commercially available software packages [11] offer some of the most advanced risk management techniques for use in capital projects. The academician authors revealingly make that point that, unfortunately, conventional education and does little to prepare us for unpredictability and worst case scenarios, as it stresses the ideal. Conventional education and does little to prepare us for unpredictability and worst case scenarios, as it stresses *the ideal*. I repeated that sentence purposely to make the point that the proverbial school of hard knocks is where the most valuable lessons are learned, even for those intimately immersed in the theory. The book goes on to prove this mathematically when it gets to the more advanced models which continuously re-incorporate new information, and the ever-changing reliability of that information in an endless feedback loop. Each time more data runs through, the more times the model self-adjusts and "learns." On a practical level, in the case of new nuclear construction, there is very little recent domestic experience. These are mostly new designs and there are simply not going to be enough people still around from last time. It is highly suggested that decision-makers read the old prudence case records, or similar project management case studies of projects gone wrong, large and small. They should surround themselves with those that have seen the worst in construction performance disasters, because those are the folks that are going to be the best at avoiding the pitfalls of the past. Not only is that common sense, but it is a demonstrable fact.

At this point, the book begins to show quite a few construction-specific graphics to express several complex concepts quickly. Some of it it repetitious, but it is well worth looking at. Everything congeals very nicely into the following table, which is easy enough for me to reproduce.

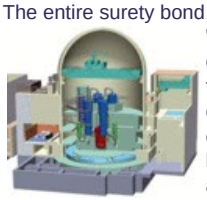
A Risk Management Framework

Risk identification	*Identify the source and type of risks*
Risk classification	*Consider the type of risk and its effect on the person or organization*
Risk analysis	*Evaluate the consequences associated with the type of risk, or combination of risks, by using analytical techniques. Assess the impact of risk measurement techniques*
Risk attitude	*Any decision about risk will be affected by the attitude of the person of organization making the decision*
Risk response	*Consider how the risk should be managed by either transferring it to another party or retaining it*

That table is all-encompassing, spanning almost the entire book. Do not expect to absorb all of it just now. It's here as more of an introduction and a place to review later.

"Risk identification" is what the authors focus on first. Fair enough, but the interesting part is "why." This painstaking step is required at project inception simply because management too often focuses on what *"should"* happen and not what ***could*** happen. Frankly, in my experience these masters of the obvious often fail to have fully understood the "illusion of control" bias outlined in bias table, above. It is worth stating precisely as the authors do, that "an identified risk is not a risk, it is a management problem." That sounds pretty obvious, right? But, in hindsight, isn't failure to identify a risk something we've all regretted at one time or another? Think of those lost opportunities you've had in life, now imagine a prudence examiner over your shoulder saying "I would've told you so," and you're starting to get the picture. To me, that means that every "should" had better have a good explanation behind it and all the "coulds" fully vetted and documented. The authors painstakingly make the point that inevitably, poor definition of a risk will breed further risk, there is always a multiplier and a cascading effect. We saw that in several times in 2008. And let's face it, there will be more finger-pointing than buck-stopping with the billions involved here as well. The authors repeatedly demonstrate our self-oriented biases and how those may effect the construction process . For example, when we look at a map, we always tend locate ourselves first, then look outward. They liken this to the management of large projects. In construction litigation almost every time the parties to a dispute behaved in exactly that manner. Almost without exception, they fail to appreciate the interrelationships, even in the face of indisputable facts. These behaviors need to be managed in real time, as they occur. In other words, it is best to execute projects systematically, if even to a fault, and to monitor any potential dispute as an identified risk. Use CPM planning meetings and the like to cause others to appreciate divergent vantage points when possible, force it if necessary. Use the plan itself to forge and reinforce this mindset.

The sources of risk for a nuclear construction project are too numerous and project-specific to address on this webpage. The purpose here is to consider the contract performance risks globally and offer that it is best to aggressively identify and manage them in real time to avoid concocting explanations for a prudence review later. It is well-worth the effort to consider all possible risks, including worst cases, the inter-dependencies and their effects to develop strategies well ahead of time, rather than after the fact. The entire surety bond industry was built around this notion. [6] While it sounds negative to state that



"We can get closer to the truth by negative inferences, not verification!" it is in fact, correct. [8] "Take away the excuses," said a project manager I worked for at my first engineering job. That's called "negative empiricism" as opposed to "naive empiricism," constantly making a case for yourself, squawking heuristics to wit, cheerleading. While it may at times be good for morale, the industry should get a handle on this propensity right now. The burden of proving prudent expenditures is a positive one, so project management should start with the assumption of a 100% prudence haircut and prove it wrong, rather than assume a 100% inclusion of costs and work backward. It

can also use this very circumstance as a management tool.

The table below to the right shows how construction risks are generally classified, by "Event," "Type" and "Impact." "Type(s)" include *speculative* where there is the potential of either loss or gain, like buying investments, and *pure* where there is no potential gain, such as an insurance company's claim loss. "Impact" is shown across entities, e.g., company wide, market or industry, or by project and individual. Finally, "Consequence," is not shown for the sake of brevity because it spans project-specific classifications by frequency, severity or impact, and predictability. These classifications interact with the left side of the table primarily through *the contract*.

The "big picture" risks, market or industry, pertaining to the renaissance as a whole, are particularly apropos compared to construction generally. The "industry" risks are described succinctly by Archer and Low here: "There are high stakes associated with nuclear new build projects. Project failure impacts more than just the project itself—it jeopardizes the owner's financial well-being and casts a dark cloud over the U.S. nuclear industry as a whole. The failure of a new nuclear power plant project results in long-term significant impact not only to the utility but to the EPC contractor and subcontractors as well. Most importantly, the need for electrical power comes at a time when the U.S. needs to achieve energy independence in a way that does not impact the global climate." [11] "Market" risks, of course, refer to the carefully watched players throwing elbows in the world-wide renaissance marketplace, jockeying for position daily here. "Company" risks include those of the consortia, joint-ventures, contractors and utilities and all the way down the supply chain to Mom & Pop Porto-Potty of Elixir, TX, Inc. "Project and individual" risks hit closer to home. Risk management systems should recognize self-preservation instincts and self-examine for bias in real time, in order to avoid creating prudence issues. We used to call that practice "CYA," but in nuclear construction it must be understood that that the prudence reviews involve going right past the "smell test" and "bull detector" straight for the jugular. The "risk register" is probably the first place for a prudence examiner to make a document request, right along with the contract, lawsuits, claims and change orders. Their attorneys will likely focus on these documents because they will probably be easiest to attack. Evidence of irrational exuberance or brute force might set the stage, "lay a foundation," for an unpleasant pattern or theme. The same might be said of the original construction contract *risk allocations*, shown below on the left. That's how they build the house of cards that looks like bricks.

Some fundamental considerations which govern the allocation of risk:

** which party can best control the events that may lead to the risk occurring*
** which party can best manage the risk if it occurs*
** whether or not it is preferable for the client to retain an involvement in the management of the risk*
** which party should carry the risk if it cannot be controlled*
** whether the premium to be charged by the transferee is likely to be reasonable and acceptable*
** whether the transferee is likely to be able to sustain the consequences if the risk occurs*
** whether, if the risk is transferred, it leads to the possibility of risks of a different nature of being transferred back to the client*

Event	Type of Risk	Impact of Risk
Onerous contract conditions	Speculative	Company
Inclement weather	Pure	Company,Project
Monetary inflation	Speculative	Market,Industry
National strike (UK)	Pure	Market,Industry
Failure to find tenants	Speculative	Company
Failure of consultant to find defect	Speculative	Company,Individual
Injury on job site	Pure	Individual

At this point, the book starts to hint at how it's going to lure us into considering the "consequences," omitted from the right side of the table above. Then it reminds us of the possible outcomes, and probabilities of those outcomes, and moves on to the basic decision matrices, i.e., the familiar "investment portfolio" type charts. They slowly add in such factors as the maximum probable loss, most likely cost of the loss, cost of servicing loss if no insurance is in place, cost of insurance, reliability of the prediction of the event, et cetera and so on. Then they pile on with "likelihoods" and "reliability" pushing us further toward the outer limits of of fuzzy math. It explains how one can go from "improbable," "rare," "possible," "probable,"" very likely" to "I'm 87% sure there is a 65% chance of hail in July." It's simply a matter of adding more and more math describing the risk management processes, with additional matrices and "trees" (more later) involving differential equations which most people have never even heard of. The question is, how much of this is cost-efficient, even when talking about billions of ratepayers dollars? The industry needs to consider that question carefully, internalize the outcome and move on with confidence. Wait, who was it that said, "Whatever is worth doing at all is worth doing well?"

Like a chain of *churrascaria*, the authors begin to churn out all the red meat you could possibly enjoy, starting with simple chart listings and weighing likelihoods of events using improbable, rare, possible, probable, very likely, then simple numbers, e.g., a one-in-ten chance scale, then a 0.0 to 1.0 scale, each effectively used to to move us along into the realm of insurance and actuarial theories, gradually introducing more complexity with each step. Those last two sentences probably represent about twenty to thirty pages and quite a few grueling exams. I've been through all these formulas several times in several ways, as well as in practice, and get a headache now just counting the pages. It is heavy and slow, probably impossible to digest for some, like me reading the details of a thorium salt reaction. Those reading this are probably already familiar with this to an extent, already know it or may never need to know these details. In any case, it is well beyond the scope of this webpage but they are out there if you are interested, which is good to know. [1] The authors wind down it all down to the instructive point that while much of this remains academic, "When active minds are applied to the best available data in a structured and systematic way, there will be a clearer vision of the risks than would have been achieved by intuition alone." That's the sort of thing that will not be lost on prudence examiners or on the bottom line of your competitors, as the case may be.

OK, so you've got "identified risks" to manage, so now what? Once the appropriate analyses are complete, the next step is consider a "risk response." There are four basics courses of action you should know:

~~ Risk retention, absorption or assumption ~~
~~ Risk reduction ~~
~~ Risk transfer ~~
~~ Risk avoidance ~~

Retention, absorption or assumption, are used interchangeably. These are used for small, repetitive, predictable losses, e.g., the eponymous $250 auto glass deductible. *Reduction*, means mitigation strategies like education, protection, systems and preparing with "what if" questions, e.g., safety training on construction sites or driver's education classes. *Transfer*, i.e., "sharing confidence and fears," is achieved through insurance, indemnity, contracts, retention payments and surety bonds (which the book covers later.) [1], [6] *Avoidance*, is self-explanatory, don't build at all.

This section closes with a summary list of bullet points which I've altered slightly.

Summarizing Risk Management

* risks must be identified, classified and analysed before response is determined
* an identified risk is a management problem
* beware of using intuitive, gut feel approach to manage risk
* risk management must be continuous from the moment the project starts until the moment it ends
* a poorly defined risk structure will breed even more risk
* use wide-angle and zoom lens for viewing the future, avoid grandiosity
* use creative and negative brainstorming, not cheerleading, muddling, or brute force
* always have a contingency plan for the worst case scenario
* risk management systems should not be complicated or burdensome lest they add additional risks themselves

Some Tools and Techniques of Risk Management

Once again, the authors open this chapter with the disclaimer that they are simply trying to introduce and illustrate the principles of the various tools and techniques, and not suggesting immediate industry-wide adoption of them. They proceed to squeeze what amounts to four or five industrial engineering or operations research classes, including prerequisites like advanced calculus and statistics, into thirty pages. I'm going to try to condense it all even further here and apply it to nuclear construction issues where possible. If anything, it may give pause to decision-makers and cause them to question their own illusion of certainty from time-to-time. As previously mentioned, one thing in nuclear construction is certain, that prudence reviews will be rife with issues rooted firmly in cognitive bias and they will also probe decision-making techniques generally. It is unlikely that the looks backward will get as sophisticated as some of this does, but forewarned is forearmed. When you come to a decision, ask yourself how sure you are and why. Are you going to be able to explain it when faced with a hindsight bias question? Was the decision in question routine, or were any systems, tools or techniques used? I would suggest that prudence consultants and attorneys prepare for these inquiries using some level of formalized decision theory briefings. Not everybody has to be an expert in the field, but certain witnesses should have some demonstrable knowledge at the appropriate level. In all likelihood, understanding the ***"decision matrix"*** will suffice. Of course, a thorough knowledge of any risk registers or similar project-specific management and control systems will be essential.

The table to the right shows an overview, and is followed by explicative paragraphs with examples.

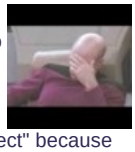
Decision-making techniques	Where they are used
The risk premium	Risk response
Risk-adjusted discount rate	Risk response
Subjective probability	Risk response
Decision analysis	Risk response
* Algorithms * Means-end analysis *** Decision matrix** * Decision trees * Bayesian theory	
Sensitivity analysis	Risk analysis & classification
Monte Carlo simulation	Risk analysis
Portfolio theory	Choosing approaches
Stochastic dominance	Process of elimination

THE RISK PREMIUM: This is the trade-off between risk and return. The best example is an insurance premium, which is simply the cost of shifting a financial risk. But the premium concept can apply more generally than that. For example, a surety bond premium may be paid to shift a construction contract performance risk, i.e., actual performance performance of the contract, in lieu of money, may be obligated. It's a simple enough idea which takes a few words to explain but is rarely considered on more that a superficial level. So let's make it complicated and define it as the rate of return one must earn to justify an investment, considering the balance of the risk of loss with the possibility of gain. And since possibilities change over time, it is the return on investment (ROI) over time, versus the investment itself. In other words, this is the level of effort, financial or otherwise, you are willing to expend over time and all the risk that it entails in exchange for some kind of potential return. This level of effort itself, of course, will change over time and with circumstances. So it makes sense that as the cost of premiums rise and fall, the amount of insurance sold changes accordingly. The authors suggest that we consider that the time value of money of a non-income producing project, which is truly sleep-inducing. But almost anyone that ever purchased a piece of exercise equipment, joined a gym or started a "project" in the garage

understands what that means. It also roughly correlates with a nuclear engineering construction project in its earliest stages, well before it is generating power and income. Early on, conceptual engineering work seems far more expensive than those last few final fixes approaching start-up, so those changes are easier to sign-off on as the risk premium of doing so decreases. As I write this, the first round of federal loan guarantees have yet to be accepted and the *risk profile* of these early projects remains high. As these arrangements are gradually finalized, the risk profile and thence the various risk premiums for those projects will continue to change favorably. As the initial renaissance projects become more viable as cost, i.e., financial risk, declines along with other risk factors, such as regulatory hurdles, the overall risk profile will continue to improve. The promise of eventual inclusion in the rate base should someday make these risks worthwhile, as the premium approaches zero while coming closer to the goal line. It's easier to quit early (or not even start), than after an effort has already begun, as the guilt generated by many a dusty infomercial home gym can silently attest. The authors provide numerous ways to prove all this, and they are all laid out graphically and mathematically. Personally, I like to dumb down the entire concept to the Klondike Bar jingle in any given situation, then work backward.

RISK-ADJUSTED DISCOUNT RATE: This concept recognizes that as a particular project progresses within an economic environment, things might change, i.e., the time value of money, plus inflation, plus the particulars of the project's circumstances. If money suddenly gets cheaper, but unfavorable regulatory changes come, a once-promising nuclear project may be rendered infeasible. This is also how the "overnight" cost is distinguished from the actual cost of nuclear construction, "overnight" being the present value. This is exemplified by the phenomena that when weather gets nicer, the dusty infomercial home gyms come out of the garage. This can be modeled of course, and the book provides details.

SUBJECTIVE PROBABILITIES: This notion of subjectivity is going to be very important during the nuclear construction renaissance, in my opinion (itself entirely subjective), but not in formal decision-making as much as in routine management. Much of the following sounds like common-sense or opinion or pop psychology, but the research in this part of the book bears it all out and provides the Hyde Park soapbox to stand upon. This aspect of contract risk management shows us that people have different views of the same risk depending on their position. Fair enough, but this can not be underestimated, even though it is done so routinely in the construction business and elsewhere. Take the example of an insurance company. The premium side (money-coming-in), is far less risk-averse than the money-going-out side, where the claims are paid. So, by their very nature, these are widely varying vantage points. This is recognized clearly as simply due to the nature of the business, which is itself, risk. From what I've seen, this is not often, if ever, recognized in construction, particularly in large organizations, which easily get caught up in ego-driven turf wars and let's face it, testosterone. This is especially true during high-pressure, large-scale projects like nuclear energy facilities, which are prone to become emotional, whether we care to admit it or not. I've seen the same thing time and time again working with failures of construction firms, and to a lesser extent, in the construction litigation arena itself. As discussed previously, the tendency for group decision-making is inherently risky because everyone wants to be seen as "on board" with the leader, whose own role is often supposed to be bold, and be seen as “not conservative," so there is a tendency for groups to overreach themselves into a "risky shift." The wide variance of "roles" necessary for large projects like these and their inchoate risk profiles clearly invite chaos. Therefore, I would strongly urge decision-makers in the renaissance to consider the principles of Delphi Method, as described in the book [1] and elsewhere, if even informally. That's where, instead of a typical round-the-table meetings, views are taken separately, synthesized, then re-taken in light of the results, then discussed in group. This results in more accurate consensuses and decisions which are "closer to correct" because they are less subjective, i.e., more honest. This is similar to how alternative dispute resolution (ADR) works, but unfortunately, that is always well after the damage has been done. The extent to which the Delphi Method is practical for each and every issue is of course, an matter of opinion. What is important here is simply knowing the theory and its underpinnings well before the inevitable fifty-person project meetings start-up and using it to your advantage. This may well be the second most important point on this webpage, with "bias" being the first. Nothing is more ripe for prudence proceeding pickings than an ongoing narrative displaying a general perception of an out-of-control project management culture.



Decision analysis
* recognizing and structuring the problem
* assessment of the values and uncertainties of possible outcomes
* determining the optimal choice
* implementation of the decision

“Decision analysis is a technique for making decisions in an uncertain environment that formally treats both risk exposure and risk attitude. It provides a methodology to allow a decision-maker to include alternative outcomes, risk attitude and subjective impressions.” [1]

DECISION ANALYSIS: Just as a civil engineer mathematically models why a bridge stands or falls and how to avoid or improve that, an industrial engineer or management expert can model technical systems, such as construction, i.e., the very process itself. This is possible for any system, from a simple manufacturing sequence to complex decision-making. It is how a package gets from A to B, or why the police stations are located where they are. The best examples of this in construction are seen in the decision-to-build matrices (more on those below) and the now widespread use of CPM, especially when used for resource allocation.

* ALGORITHMS: These are the steps taken to accomplish a goal. Anything from: "Lather. Rinse. Repeat" to how Google searches the web and returns its results.

* MEANS-END CHAIN: This simply adds purpose to an algorithm and works its way backwards. To "Get Clean Hair," just "Lather. Rinse. Repeat." Simply put the goal at the end of the first algorithm and draw a circle around it with arrows. Now, ask yourself why Google does it. For the money. Short and sweet, perhaps overly simplistic, yet this model followed carefully resulted in the moon landing. Although this technique has been eclipsed (pun intended), the book gives a few well-designed construction and manufacturing-related examples if you would like to know more about how it might apply.

* **DECISION MATRIX**: As mentioned above, I’ve found that most-commonly, people seem to understand this when recalling diversifying a portfolio of investments, such as their 401(k)

plans, selecting insurance or mortgages, or perhaps learning the negligence portion of tort law. Often, the party selling financial products will explain the choices using a decision matrix. Even the utility function, which sounds pretty dry, is easily understood as investment strategies across the span of one's lifetime are considered, i.e., young-speculative, older-conservative. (More on the utility function below.) The math behind a decision matrix is relatively simple, but I see no purpose in describing it with full sentences here, for the sake of brevity. Have a look at page 22 of this .pdf from Risk and Uncertainty in Construction [13] for a construction-related Expected Monetary Value (EMV) analysis. The steps are described elsewhere in the .pdf and below in green. Since it is likely that an understanding of a "decision matrix" methodology will be explored in some manner during prudence proceedings, the reader may need to a demonstrate an understanding of it, as well as a thorough knowledge of the risk registers or similar project-specific management systems.

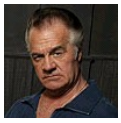
Summary of the steps involved in calculating the expected monetary value (EMV) theory using a decision matrix:

* Consider the various options available
* Estimate the value of each option
* Estimate the probability of each option
* Ensure the realism of the probabilities
* Multiply the value by the probability to get the EMV
* Sum the EMV among the options
* Selected the highest EMV among the options

The EMV theory is the simplest way to learn the decision matrix technique, because it uses an easily understandable risk, i.e., monetary. See also The Decision Matrix for a step-by-step explanatory example with the addition of competing factors to be considered when picking out a leaf blower. That example also introduces the *utility function*, mentioned above and discussed in detail below. For something even closer to home, a superb example of risk analysis within the nuclear renaissance is illustrated by: The Bellefonte Opportunity: Building Smart, Managing Uncertainty, starting at around page 12 [14.1], from a presentation given a the Nuclear Construction Summit, USA 2009 [14] held in Washington, DC. As you try to factor-in the weights, time, costs and probabilities of the various risks (proprietary information, no doubt) it becomes clear how the **decision matrix** tool fits into the industry at its most basic level, where even a CEO can understand it.

* DECISION TREES: Though it may sound poetic, a “decision tree is a means of setting out problems that are characterized by a series of either/or decisions. It shows a sequences of decisions and the expected outcomes under each possible set of circumstances.” So says A very fast intro to decision theory, which models the daily raincoat decision. It's a series of simple "what-ifs" or "either/ors" that can go on forever, so they are easier to model as ever-expanding branches on a tree growing outward, rather than increasingly tiny boxes moving inward on a matrix. The next step is modeling these tree branches with the probability of rain, our certainty of the reliability of the weather forecast and so on. Did you think you actually overheard that 90% chance of snow yesterday out in the parking lot, or did you just check weatherunderground.com site a split second ago? Things like that are thrown in the mix. And, if we can know these sorts of things, *probably not* beyond a relatively basic level in nuclear construction but certainly in marketing or investing, just how much is that information worth to us? These sorts of things are calculated, then put on nodes, also called "decision points," where branches split on a tree.

* BAYESIAN THEORY: "Bayesian theory" sounds like something you wish you already knew, and wonder if it's worth the effort, right? It is a three hundred year old method of sharpening uncertainties on a decision tree through "buying" "trustworthy" information and using a Bayesian tree. Not surprisingly, that link is an example by a consultant, justifying why hiring consultants usually pays off. Ironic, but it demonstrates the value of good information, “good” being substantiated by a past track record. This method puts a cost of reliability factor into the equation in order to get a better result. This is similar to checking and rechecking an investment manager's track record, or another easily quantifiable query supported by a lot of available data. At around this point, the abilities of the conscious human mind are exceeded, perhaps to continue at a subconscious level and drawn upon later, while landing the plane in the Hudson River. But with computers, the analyses performed become a lot sharper than that simple illustrative diagram may indicate, nearly infinite. Even the backstory is good, Thomas Bayes was a Presbyterian minister in an Anglican state, i.e., a "Non Conformist" pushing the edges of rational thinking and faith, writing things like “Divine Benevolence, or an Attempt to Prove That the Principal End of the Divine Providence and Government is the Happiness of His Creatures (1731).” Who knows what he might have done with a supercomputer? He might look at something that did happen and the chances it would’ve happened, perhaps proving history repeats itself and other tautologies. It's angels on pins stuff, yet the Bayesian Theory seems to have withstood all criticism and proved itself time and again. The practical takeaway from all of this is: always update your information and the reliability of that information. Also, be willing to pay the price for good information or prepare to risk the consequences of failing to do so. I don't know that mentioning the Bayesian Theory in a prudence proceeding or project management meeting would do anything but cause groaning, but there you have it, the last word on modeling cognition itself.



STOCHASTIC DECISION TREE ANALYSIS: “When complex decisions are involved, we do not want to compound the problem by confusing the client with highly theoretical techniques.” [1] What this very difficult to explain techniques does is prove mathematically that some options are simply not worth considering further if they are going to have no impact, i.e., the process of elimination. If someone asks for the determining factor as to why a particular option is infeasible, a sensitivity analysis (below) can usually provide enough of a further explanation. The only problem with this is, it invites another visit from the Black Swan, when the most unlikely variable has its the greatest possible impact. [8]

MULTI-ATTRIBUTE VALUE THEORY: In addition to performing these analyses for “cost,” i.e., monetary value or EMV, we can also use other measures of value, such as shown in the leaf blower analysis above. We commonly call these "trade-offs, " since there's more to life than money, such as peace and quiet, uninterrupted by loud leaf blowers. We can also weigh these other factors, "quality of life" "time with

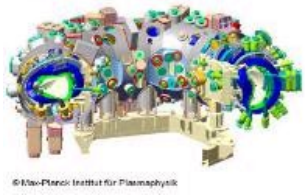
family" and the like and ultimately prove that the "best things in life are free." This done with “utility functions,” discussed in more detail below. For example, in construction projects there are trade-offs, amongst the outcomes we prefer when faced with a given decision. This choice may be among considerations like, cost, schedule, quality, "business decisions" or project politics. The book goes through an example using an HVAC contractor measuring objective client utility functions like such as: cost, square footage used up, as well as more subjective utility functions such as humidity control, user ease, scalability and vendor support.

“Management can hedge some bets regarding where some of the main leadership focus needs to occur to identify risks in certain areas. Once the areas are identified, project leadership needs to actively investigate whether the risks in these critical areas are indeed materializing and therefore need to be addressed head-on or can simply be dismissed. Because the impact of risk to the project’s schedule and costs is so high when quality issues arise, hedging leadership focus on quality in all areas is paramount.” [12]

SENSITIVITY ANALYSIS: Yes, it's the “little things that count most.” But don't take my word for it, just listen to any television or radio for more than five minutes leading up to Valentine's Day every year. The aptly named sensitivity analysis mathematically models this phenomena. Like many of you, I first stumbled upon this theory as a lad in the story of the "Princess and the Pea." Speaking of sensitive princesses, think about the effect the wrong Valentine’s Day token may have on your whole year. Sexist remark I know, but highly instructive. And don't blame me, I didn't invent it. Or consider the success of the “Broken Window” theory of crime prevention behind New York City's renaissance in the 1990’s. The same principle applies to the quality of decision-making and risk analyis in a nuclear construction project. This technique simply shows how one tiny pea-sized variable among thousands may have a multiplier effect which is not readily apparent. For example, even a small price increase in a widely-used commodity, rebar, concrete, etc., has a seemingly disproportionate impact on overall project cost. Without going into the math, just look at this diagram of probability contours, or a spider diagram to get an idea of how far this concept can go. Something along these lines, though probably not as complex as those diagrams, will certainly arise during the prudence or litigation scenario, with the best examples being critical path or procurement issues. The various disciplines, organizations and software packages may have a different name or application of the same concept, but it is going to arise by whatever name. It is discussed in more detail below at **Sensitivity, Break-Even and Scenario Analysis**

MONTE CARLO SIMULATION: This technique involves using random numbers where determining even subjective probabilities is impractical, but some number is necessary for a Bayesian calculation. So, it's only marginally relevant here. Read more on this esoterica below at **Risk Analysis Using Monte Carlo Simulation**.

PORTFOLIO THEORY: As it pertains to this page, portfolio theory applies well above the individual project level. Finding a good example is easy in the energy business, it is even mentioned in television ads. This is the method used when there are choices offering different means to the end of selling electricity, such as coal, nuclear natural gas or renewables. “Don’t put all your eggs in one basket,” is the lesson at this level. That's why utilities tend to mix it up, as uranium, coal, and gas prices fluctuate, along with construction and operation costs. This method of analysis may well be how the small modular reactors get into the picture quickly. Certainly in regard to easily fixed construction performance costs, they may soon have a distinct financing advantage. [6]



STOCHASTIC DOMINANCE: This is a fancy, "grand" as the authors say, name for the tool used to chop the branches from a decision tree early in an analysis using “common sense” parameters which identify the stronger trends, tendencies and emerging preferable choices.

For more on these tools and techniques, take a look at Tools for Decision Analysis: Analysis of Risky Decisions, generally. It's written in plain English with simple examples. Also, as an aside, some of you may have seen Bruce Bueno de Mesquita [15] on 60 Minutes discussing his political and foreign-policy forecasts using a model based on game theory and rational choice. As a hapless former hot functional test planner, I cannot resist a final note about forecasting for the other poor saps involved in that thankless endeavor of being "always wrong," i.e., the CPM people. "They built the pyramids without computers," was the complaint we heard last time around. Surely, you will be getting the same grief again this time. Mr. de Mesquita represents a grand extension of what you are doing. Remember his example. It may come in handy sometime.

The extent to which these tools and techniques may be beneficial for different aspects of the nuclear construction renaissance is not obvious. Although a great deal of this is clearly not yet adaptable for the construction industry, let alone the FOAK nature of these projects, the challenge facing large endeavors funded with public money is that someone will ask “Why not?” It is suggested that it would be prudent to at least cover the bases and know where usefulness begins and ends with these techniques, and to establish a comfort level with the omnipresent question, "Should we be doing more?" While a thorough understanding of the decision matrix is essential, demonstrating familiarity with these advanced methods will go along way to showing that the "known unknowns" have been considered. Do not let yourself be limited only to the software or systems in place, lest someone raise the issue of an over-reliance on them, inferring a lack of imagination constraining problem solving.

Utility and Risk Attitude

Because risk registers and related project management software systems will likely come under scrutiny in both prudence and standard construction litigation, it is good to be aware of some of their underlying risk management concepts, even the ones that may be beyond the scope of examination. This chapter drills-down just a little further into some ideas that have been previously discussed.

The concept of risk utility refers to the *usefulness* of an outcome and the concept of risk attitude is simply your *attitude* toward it. A sport utility vehicle (SUV) may be more useful to you than a Corvette, depending on your circumstances or preferences, so while a better deal might be available on the Corvette, you will reject it for the sake of utility. Or, if you were starving on a desert island, you’d likely prefer to have a Happy Meal over a million dollars cash, again because of its utility. Unless of course, maybe your risk attitude is high, and you believe you "can take it with you." Perhaps you see a distinct possibility of bribing the vultures circling overhead for a ride. These types of choices and the thought processes we use to sort them out span business, construction and elsewhere beyond the realm of wild

hypotheticals. The authors demonstrate how they can be formalized and modeled mathematically. These concepts will be at the heart of certain prudence questions and are helpful to understand. Here are the very basic steps:

*** Evaluate risk exposure**
*** Understand risk attitude (which includes risk utility)**
*** Make a decision**

Some readers might wonder these concepts are presented *after* the decision-making techniques. I recall the asking that very question back in college and the simple answer is because it is easier for most people to learn it this way. It's just one of those things you learn one way, and apply in another. The book runs through a few more definitions, and furnishes a construction example which many of you will instantly grasp.

RISK EXPOSURE: What is at stake, potential loss or gain.

UTILITY THEORY: This model reveals the outcomes which are of greatest *use* to you, as opposed to what may have appear to have more value. Recall the quote about gaining the world, but losing one's soul. In nuclear construction, this is exemplified by the "trade-offs" amongst cost, schedule and quality. This technique shows what one would trade, and why. While the answers to the underlying questions might seem to come from mysterious places within our vast experience, the authors disabuse us of our mystic wisdom pretty easily. This is done by measuring utility with dice, cards and the like versus real world scenarios, as we saw previously. Take a look at the book if you'd like to see the differential equations, advanced statistics and other mind-bending math behind all of it.

EXPECTED MONETARY VALUE (EMV): This was concept was previously introduced and used as an example to explain decision matrices. It is easy to understand because it involves pure numbers and is familiar to many who have seen it while buying insurance, making "investment portfolio" decisions or understanding the negligence aspect of tort law. The authors repeat it again here to use in their example of the utility function in construction to follow, and I will also. Again, this concept should be mastered by anyone involved in prudence examinations. There is simply no way around it, in my opinion. The good news is, it's not all that difficult.

Summary of the steps involved in calculating the expected monetary value (EMV) theory

* Consider the various options available
* Estimate the value of each option
* Estimate the probability of each option
* Ensure the realism of the probabilities
* Multiply the value by the probability to get the EMV
* Sum the EMV among the options
* Selected the highest EMV among the options

But money isn't everything. It is entirely subjective to your circumstances. You can't take it with you and you can't eat it. Think of the desert island, the cash, the Happy Meal, the Corvette and the SUV. Why did you choose a Happy Meal and an SUV over a million bucks and a Corvette? You did it because of the utility function.

THE UTILITY FUNCTION: The relationship between an expected decision (despite the great deal on the Corvette) and actual choice (choosing the SUV anyway) is expressed by the *utility function*. In other words, in hindsight, it may be used to explain why a certain choice or trade-off was made. Despite the fact that it is awkwardly defined in hindsight, the utility function should also be considered *a priori*, because that's the way prudence reviews examine decisions. In construction decision-making we routinely consider the cost, schedule and quality utility of the alternative solutions, so it's not as difficult a concept to understand as it is to define. The best choice in these analyses is the one returning the highest Expected *Utility* Value (EUV.) The desert island conundrum while seemingly silly, can be quantified. The authors show us how an architect, consultant and mechanical engineer can look at the same problem and achieve different results based on their perceived utility of the solutions. These differences can then be quantified and put in a meaningful matrix or on a compelling curve for each type of person and role, whether risk neutral, risk averse or risk disposed. Why is this important in the real world? Because the decision-maker should be aware that all this chaos actually has a form to it and be able to synthesize all of these efficiently. That sounds like another motherhood and apple pie statement weighed down by more and more equations, right? Just when it all gets confusing and perhaps too theoretical, the book goes on to drive home the point quickly with an elegant, end zone dancing example. After first admonishing the construction industry for being skeptical of "graphs" and "computers," this was 1993 mind you, they show why a large construction firm will pass up smaller contract with a higher profit margin for a larger contract with smaller profit margins. We all know this makes sense, but why is that? The easy answer is something like: "due to the ultimate contribution to the bottom line and the cash flow." But this "matter of judgment" or "business decision" and the logic behind it is firmly rooted in the utility function. And in the real world, we also know firms will also take on contracts of little importance to the bottom line, but crucial in the big picture in the name of "politics" or a foot in the door. Those too, are utility choices. Think of it as the decision behind a decision and a good place to go astray. It is also fertile ground for prudence issues. On the most practical level here, my advice would be to issue "marching orders" sparingly and carefully.

The authors conclude this section by once again asserting that the material is presented mostly to expose readers to these concepts and that they do not to strongly advocate anything other than understanding. They add, “It is necessary to understand these techniques in order to fully appreciate and be able to interpret risk and uncertainty.” [1] For the purposes of this page, it is not sufficient to simply be aware of the concept in terms of cost, quality, and schedule. Now that the utility function has been identified, let's call it by its proper name in order to use the concept effectively to manage others, and so it gains wider inclusion in day-to-day thinking. These "trade-off" issues will be subject of prudence investigations, so it's beneficial to be able properly identify this concept and understand its applicability. Use of the correct terminology in the hearing room is suggested.

Risk and the Construction Project: Time Money and Technical Risks

In "Risk and the Construction Project: Time Money and Technical Risks," which translates roughly into “Cost, Schedule & Quality” in American engineering and construction parlance, our UK authors delve into the construction process itself, which this page will not cover. Ninety-nine percent of you can recite all that in your sleep, but a few of the subtle concepts merit mention here. Firstly, the fact that schedule and quality are easily converted into a cost value in the minds of most makes money is one of the easiest risk values to understand. “Time is money” and “buy quality” are often instilled in us at an early age. Other risks, not as easily quantifiable, such as safety and environmental concerns are mostly reserved to the start-up and operations phase.

The chapter describes how cost, schedule and quality interact and effect each other, providing thoughtful examples. It was probably written for those with an interest and background in the concept of risk management, but little knowledge of the construction process. It's a safe assumption that anyone reading this page already has a firm grasp of those relationships. The chapter also touches on the investment cycle of a project and the various decisions related thereto, which are outside of the scope of actual construction itself and therefore this page. Those of you interested in a look at how the "new build" decisions are analyzed, which itself is a risk management process, should consider the slides from the Nuclear Construction Summit, USA 2009 [14]. I have noted the most relevant slides by page number.

I would suggest that the reader review the slides, if only to see what your upper management and competitors might be up to. It will also give you a good idea as to what level of analysis is in current usage. You will note the absence of some of the more advanced methods discussed above, which are simply not practicable at this time.

As more and more of these projects move forward, a great deal of risk is going to be transferred contractually. Ideally, it will be transferred to sound financial entities, such as strong and solvent contractors, their guarantors or sureties. [6] The authors themselves endorse the surety bond strategy later in the book, but mention of that concept is also merited here.

Although private financing is still mostly a distant dream for nuclear energy projects, that may well change, especially with the increasingly likely prospect of commercially viable small modular reactors. See how these construction risk concepts make private financing feasible for large petrochemical projects in Marsh & McLennan's presentation "Project Risk Management Helping Attract Project Finance" [16]. For more information on small modular reactors, click on any of the first line of "Links" below toward the bottom of this webpage where they are regularly discussed in detail.

Sensitivity, Break-Even and Scenario Analysis

His daughter
Was slated for
becoming divine
He taught her
He taught her
how to split and
define
But if you study
the logistics
And heuristics of
the mystics
You will find that
their minds rarely
groove in a line
So it's much
more realistic
To abandon
such ballistics
And resign to be
trapped on a leaf
in a vine.

"Backwater"
by Brian Eno

"Sensitivity analysis" was mentioned above briefly, but like "Monte Carlo" below, also merits further mention of its own. This concept is directly applicable in daily life, as recounted in the Princess and the Pea, the fly in the ointment, the forgotten valentine or the tiny piece of gravel wedged between your shoe and the skin just between the ankle and Achilles tendon, grinding away on the first day of vacation. This models how a tiny factor can have an overwhelmingly disproportionate effect. The concepts below are simply ways of understanding, explaining, proving and using it, presented in slightly different ways.

SENSITIVITY ANALYSIS: This involves tinkering with certain variables to see which are most likely to effect the overall goal, e.g., critical path method and cost analyses. It is used to answer questions like, "What happens if the price of concrete goes up 4%?" or "What if the schedule can be extended six months?" As mentioned above, this concept will be very important in prudence reviews. It should be formally identified and called by its generic name as well as any software or project-specific names.

BREAK-EVEN ANALYSIS This helps us determine which among multiple variables can be adjusted to what extent, i.e., what can be “juggled around” without changing the goal. It's just another way to run matrices and decision trees, forward and backwards, using static constants.

SCENARIO ANALYSIS: A “grand” [1] name for performing several sensitivity analyses at once, including options and scenarios. Examples include man-loading and resource allocations or comparing alternative critical paths.

SENSITIVITY ANALYSIS: AN APPLICATION TO LIFE CYCLE COSTING: This is better left to the NRCs, INPOs and operations vendors of the world. It pushes out the spider diagrams and contours out over time with changing variables. This is not applicable here, especially with FOAKs or new designs.

Risk Analysis Using Monte Carlo Simulation

Monte Carlo simulation was mentioned above in **Some Tools and Techniques of Risk Management**,

and like **Sensitivity, Break-Even and Scenario Analysis**, directly above, merits further explanation. While this concept is directly applicable to daily life, it is not as easily understood as the Princess and the Pea. This is more like purposefully driving your defective Trabant to cash in your winning Mega-Lotto ticket on Friday the 13th during a meteor shower, but may have left in your other green jacket at Black Swan Inn last night. These models go well beyond the decision-making required for even these highly complex and risk filled projects. They are the sorts of things being considered by our subconscious or while dreaming, if at all. So just what is it then?

Monte Carlo! It sounds exciting! Glamorous princesses, wealth, fame and fortune all in an affordable personal luxury automobile. Well, maybe. But here it is only referring to using random numbers in the place of fuzzy math, which is more like an estimate. It is an attempt to model the "crap shoot" of life. And you can tighten-up and modify these inputs based on past probability distribution of “actuals” over and over.

Basically, you plug random numbers into a decision tree or matrix to represent the unknown. Lather. Rinse. Repeat. Modify the model using any actuals, if possible. Ten percent of the book [1] is dedicated to this large chapter and it is a great academic exercise. Though it's interesting to think about, this is better suited if you are looking for a good hedge fund to game or possibly building a large, but fairly standardized type of project repeatedly, somewhere in a future life. That's how the authors demonstrate its potential practicality in some construction applications and they boldly provide an example, but it's about as far away from a FOAK nuclear project as possible. The models are too perfect for the relative chaos of new nuclear and we don’t have the data to plug-in, anyway. By the time you get to the chi-square, Latin Cubes, and beta distributions, the “Rules of Thumb” which may have seemed simplistic or primitive when mentioned way up above, start making all the sense in the world, as does the reason the equilibrium of utility has settled somewhere around the decision matrix. My original summary notes advise “Come back in 200 years for construction applications.” The good news is: you now know more than probably ever need to about this and I can knock off early today.

And now comes some of the more useful information, concepts and questions. This is where I tend to diverge from the book and is written more in the first person.

Contracts and Risks: The Future

This chapter begins with an overview of the construction process, descriptions and roles of the parties, apportionment of risk by contract and a list of the common causes of disputes that may arise. Anyone that has worked in project management, contract negotiation or construction litigation [16] [17] is already quite familiar with this, but it bears repeating in-part here for illustrative purposes.

Points of Conflict	***Risks & Responsibilities***
* inadequate and defective contract language	
* inappropriate contract arrangements	* design, liability and defects
* planning and scheduling	
* inappropriate tendering (adhesion, etc)	
* risk allocation imbalances	* cost of construction
* personnel qualification issues	
* personality issues	* latent defects
* contractor qualification	
* insolvency	* safety liability
* coordination (interferences) - very problematic on nuclear	* schedule responsibilities
* vague and changed contract language	
* ambiguous specifications	* quality
* unresolved construction methods	
* engineering conflicts	

This is not exhaustive, but just an illustrative example provided for you to use within a few less familiar concepts to follow. The book [1] has a very nice graphic about the major different types of construction contracts and how the division of risks is distributed amongst them, as well as the advantages and disadvantages of each. At page 89, it lays out a comprehensive matrix of twenty-four by fourteen items covering the major source of risks and corresponding offsetting tactics, such as contract provisions, surety bonds and insurance. This is not meant as a legal comment on the substance of those, which are plentiful elsewhere. What might be new to you, especially the attorneys, is how the analytical allocation of theses risks may be obtained.

Risk analysis and management in construction [2] breached the notion of formalizing this process quantitatively and laid a philosophical groundwork. While recognizing the difficulty and feasibility of such an undertaking, it also rightly predicted that wider “training,” we might call it “raising awareness,” and the rise of computing capabilities (the internet was relatively new in 1997) would make this pursuit more and more worthwhile. Will the financial risks involved in the renaissance make adaptation of this new methodology even more feasible? Possibly. Recall that it has happened before. Already, Building Information Modeling (BIM) seems to be gaining acceptance within the nuclear renaissance as the tool gets a chance to prove itself in practice. Once considered superfluous by many in nuclear construction, CPM and similar management systems are now commonplace. Project management techniques once used exclusively by NASA and the military are now being touted on radio commercials for painting, roofing and siding in north Georgia. Can standardized contract risk allocation be far behind?

Modelling risk allocation decision in construction contracts [3] presents a quantum great leap forward for risk appropriation in contact negotiations. It

Basic factors relating to risk in contracts

describes a method which quantitatively allocates risk to those that can best control it or share it responsiblily (read “prudently.”) This comprehensive paper demonstrates its method mathematically and provides a railway expansion model example. Anyone that has been through construction contract negotiations knows that “defuzzifying” the other guy’s “functions” is often an emotional process involving door slamming and table pounding. In stark contrast, imagine having this tool or even the specter of this sort of “let’s have a look at it” kind of in-depth and realistic analysis at hand. Imagine the positive impact on sub-busting behavior and the trying to “stick it” contractually to some other, not-here-right-now party, which we all know goes on in the industry. Stop cringing about a little honesty, we’ve all seen it. The counterproductive "how much can I get away with?" mindset can be tamed with this kind of know-how. I see this paper as an example of a way forward out of many of these time-wasting scenarios. This method is worth looking at just to gain a fresh perspective. It is thought-provoking, if only as a model for a more disciplined way of thinking. The "you didn't say it was a real pony" stuff has no place in these projects, too much is at stake.

Expert elicitation and Bayesian analysis of construction contract risks: an investigation [5] explores the next logical step, well into the future. This would involve using elicitation techniques and experts to develop the risk allocation models described above and then running the results over and over using Bayesian analyses.

Aside: Please bear in mind, I may have missed a step in my non-academic, mostly Google-driven research. Looking at the twenty-nine footnotes to Modelling, it's entirely possible. This should be seen as informational, and not the last word on anything other that some guy's personal notes he put on the internet with a few comments. Nonetheless, they are intended to be helpful.

Turning back to the book [1], I was very favorably impressed by the authors’ take on what I have argued is the most cost-efficient construction performance risk-shifter for the nuclear construction renaissance, i.e., the proactive use of surety bonds. [6] While rooted in UK common law, these are mostly a US tool, not as widely used in the UK. I tip my hat to the British authors for including these somewhat obscure instruments in what amounts to an engineering text book. But the concept falls right in line as far as construction performance risk management, i.e., shifting risk to those most competent to bear it, which in most cases, is a surety.

** what is the exposure in the contract*

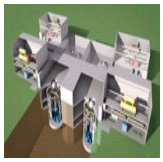
** who is most capable of handling the exposure*

** who has responsibility for handling the exposure*

** who has the power to control and enforce accountability*

** what has been done to manage uncontrollable risks*

** to what extent have risks been transferred*



While reading chapter nine, "Contracts and risks," in Risk Management and Construction [1] I formed an impression that the authors suggest that the concept of contract risk allocation and its management should be considered a project control. In fact, the concept of "law as a project control," there I said it, (but did I coin it?), may be an idea whose time has come. While the book does not come right out and say that in those words, it implies it so strongly that, at least *in my opinion*, this is a idea that should be embraced and utilized in real time. But then, this opinion is informed almost entirely by my personal bias. Similar ideas seem to be gelling over at a new LinkedIn group as well. [19] This may be a good idea for a number of reasons. Too often, misallocations of risk are allowed to metastasize and are simply put-off “for the lawyers to deal with later.” Attitudes are skewed so far toward "this is the contract we have to live with," that situations confounding forthright common sense go unaddressed. Lawyers and contract administrators are seen as sitting in a black box somewhere surrounded by mounds of papers, waiting to resolve matters long after-the-fact. The correlation between control, risk and responsibility is ultimately that of the owner. So, despite carefully crafted arrangements to the contrary, the owner tends to ultimately suffer the consequences. That is how the law tends to function. The "prudence" scenario which nuclear projects face only compounds this challenge. Prudence examiners may not be as understanding of certain situations as the friendly local board of longtime buddy-buddy construction arbitrators. The prudence process itself is a legal risk, with far less of a predictable outcome than typical construction claims litigation. The authors describe it this way: “Naturally, the element of control is associated with a state of circumstances and cannot be looked at in isolation. So, when the state is altered as a result of some intervening act, it cannot be said that the original risk-bearer is still in control. He should be then allowed to transfer any adverse consequences of the intervening act to the party causing the act.” That's an interesting comment which the industry should consider. Why? Because a prudence examiner or administrative law judge safeguarding the funds of the ratepayer may well be thinking along those same lines, chafing at the same old "construction law" thinking. I suggest that a higher level of risk management and dispute resolution consciousness is going to be needed, especially for what will be viewed as deep-pocketed owners with public responsibilities. They are going to be held to vastly different standards and get hammered from both ends, especially in highly litigious jurisdictions such as Florida. The players will not be on the same home team field they are used to, but with new rules and referees under much brighter lights. This will vary from state-to-state of course, with the only constant being an unusual disadvantage.

Risk Register: In Real Time

A Risk Register Database System [4] describes a methodolgy to manage project risk using a “corpus of knowledge” of "unambiguous information.” When I heard the expression “risk register” during the presentation by Dale Lloyd, Project Support Director, Southern Nuclear, at the Nuclear Construction Summit USA 2009 [14], my first thought was to wonder why a project executive was so deep in the weeds with insurance requirements, or why he was talking about the initial build decision. Talking with others during the breaks, I gathered this was operations and maintenance project management software, a new and improved, weighted punch list replacing the typed-in-triplicate "high," "low," "medium," "critical," management reports used last time. I thought I had kept up with the Timberlines and Primaveras over the years, but had missed this. After another sip of coffee and some focus, I remembered some sort of prioritized management punch-list I'd seen in litigation discovery on either Kiewit or Bechtel project default surety claims matters, but little else. I had been involved with the Stone & Webster Engineering Management System (EMS) and its analysis for engineering management summary reports and later,

pulling together various sources for the reports I wrote for the start-up manager. So this sounded like an interesting quantum leap improvement in that area. I made a note to look into what had changed, ultimately resulting in this page. A little investigation uncovered software packages and in-house systems for compiling risks and rankings, impacts, resolutions and strategies. One even features an innovative "opportunities" field. Compared to the "old days," a transparent, online database seems an improvement in project management because it's harder to politicize with platitudes. There would seem to be less of an opportunity to load these down with “every effort is being made” statements, bound and printed on rosy scenario-colored paper and selectively censored via “distribution lists.” Not that it happened often, but a few crybabies managed to do it once in a while. That sort of thing dies hard, I suppose. But overall, these "risk registers" are a very good development.

From what I can tell, these are primarily only used by very large owners, such as the U.S. Army Corps of Engineers (USACE), the California Department of Transportation (CALTRANS) and the Washington Suburban Sanitary Commission (WSSC), as would be expected. The extent to which the contracts themselves are managed this way is unclear. This might come as a new concept to the smaller contractors involved in the nuclear renaissance, and I can see it spreading into the mainstream construction industry, just as CPM did.

But on the other hand and upon solemn reflection, my ambulance chasing construction lawyer side says ”what a great tool to get in discovery and beat someone over the head with it.” It is for this reason I urge caution with these risk registers. Keep in mind that "green" is green and not "apparently" **green**. Will you be ready to run your red, yellows and greens through the bias tables and around the the “Modelling” matrices when the time comes? Yikes! That question is probably framed a bit exaggeratedly, but “keeping it real” and not rosy is going to be the best policy. And qualify the definitions of each classification when appropriate. Keep it as straightforward as possible, because the "risk register" is going to provide fertile ground for potential prudence issue development. Its very name invites scrutiny.

As I suggested above, “law a a project control” will likely come about whether or not it is done intentionally. The renaissance involves too much money and too many performance obligations. It is rife with risk. I *might* suggest considering use of a Project Information Retrieval System (PIRS), whether internal or external, for real-time prudence monitoring and dispute resolution. I say *might* because I really haven't looked into these, but get the impression this is becoming commonplace with large mega-projects, mostly overseas. At the very least, consider a a contingency plan for it, and not just the usual arrangement with the law firm on speed dial *after* the shinola hits the fan. The prudence process itself is perhaps the greatest financial risk of all and should be treated accordingly. Since we already know for a fact these projects will become litigious, so should the prudence folks. But then, while they have the luxury of knowing this in hindsight, you may not. When asked how you prepared for those risks and managed them in real-time, you will want to have the right answer. When it comes to the aptly named "Risk Register," did you keep a “corpus of knowledge” with "unambiguous information” or a CYA spin control document nobody read? Which narrative sounds better?

Litigation and Prudence: In Hindsight

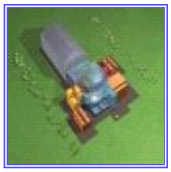
Perhaps the biggest risk of all for nuclear power construction is the potential financial loss due to disallowances resulting from a "prudence" review. They vary from state-to-state, but generally a "prudence review is a retrospective analysis of the decision-making process and the activities performed during the licensing, construction, and start-up phases of nuclear power-plant construction. It uses specific evaluative criteria to determine whether construction related decisions were reasonably made and the activities prudently performed." [20] The risk involved is considerable, "according to a 2005 Lyon and Mayo study published in the Rand Journal of Economics, between 1981 and 1991 there were more than $19 billion of prudence-related rate recovery disallowances associated with three dozenplus new power plant construction projects. More than 95 percent of these disallowances related to nuclear power plant construction delays and cost overruns...A 1986 Department of Energy review of 12 nuclear projects found that the average prudence disallowance for these plants was almost 16 percent of the cost of construction." [21] **Sixteen percent**, you read that right. Keep in mind, that is *after* taking regulatory impacts into account in most cases, and the hits kept on coming well after 1986. In some states, the construction work in progress (CWIP) allowances now in place will probably ease some of the burden, depending on the amount of latitude authorities allow themselves to re-visit previously approved costs. Call me a skeptic, but having directed construction litigation nationally and internationally while holding the ultimate profit center responsibility, I have developed a great deal of respect for that kind of risk.

Anyone that is interested in this topic should read Prudence Revisited [21] in its entirety if they have not already done so. Among other instructive details, the article breaks-out "some of the 'unreasonable practices' that contributed to cost overruns." Through a series of questions, it invites the reader to draw their own conclusion and advises that "Utility managers must remember that history does not have to repeat itself with regard to the disastrous rate-case environment of the 1980s" but it will, unless they take steps to prevent it." I could not agree more. That article compliments what I learned working as a nuclear construction prudence case consultant for the late Joe Egan and his colleagues. Joe, who was a persuasive master at technical details and debunking bias, was something of a role model for me at the time and was very gracious about it. My condolences go out to his friends, colleagues and family.

What the practical solution for contract risk management is for the next generation remains an open question. When does cost-efficient rigor become superfluous bells and whistles? The 20/20 hindsight goggles can be unforgiving, and you must be able to show that contract risk allocation and its management meet the prudence standard. New liability theories have sprouted since the last round of nuclear construction and the creative will certainly exploit them. The "big company" versus the freezing ratepayer scenario goes straight to heartstrings (availability heuristic) and, let's face it, demonization works. It's simple-minded, yet effective if not arrested quickly. True, I sound like a gloom and doom Cassandra, but that's what consultants and attorneys who have seen the worst are supposed to do. A strong risk management strategy working hand-in-hand with real time prudence management is clearly indispensable.

Although the prudence standard itself contemplates excusable imperfection, it is also inherently subjective. After billions have been spent, the ideal is easily conflated with the prudent and the tolerance for human error tends to diminish. Those that will be held responsible for contract risk management must anticipate that. Every decision should be considered today as if the prudence examiner is looking at it in the harshest light tonight, the prudence audits begin tomorrow, and the hearings next week. That is the nature of hindsight, and as we learned, it is going to be shot-through with cognitive bias and ignorance.

Someday very soon, eight years will have passed. Owners and general contractors will want to be able to demonstrate that the contract risk management function was managed prudently during construction from day one. They must be able to demonstrate that the risks were distributed appropriately through the contract and managed in real time, including the financial risk inherent in the prudence process itself.



But enough about me. [22] Please feel free to comment below. Tasteful self-promotion welcome.

Footnotes

[1] Risk Management and Construction by Roger Flanagan and George Norman
Royal Institution of Chartered Surveyors 1993

[2] Risk analysis and management in construction by Akintola S Akintoye and Malcolm J MacLeod
International Journal of Project Management Volume 15, Issue 1, February 1997, Pages 31-38

[3] Modelling risk allocation decision in construction contracts by K.C. Lam, D. Wanga, Patricia T.K. Leea and Y.T. Tsanga
International Journal of Project Management Volume 25, Issue 5, July 2007, Pages 485-493

[4] A Risk Register Database System to aid the management of project risk by Fiona D. Patterson and Kevin Neailey
International Journal of Project Management Volume 20, Issue 5, July 2002, Pages 365-374

[5] Expert elicitation and Bayesian analysis of construction contract risks: an investigation by Francis K. Adams
Construction Management and Economics, Volume 24, Issue 1 January 2006 , pages 81 - 96

[6] Surety Bonds for Nuclear Energy Facility Construction Cost-Savings

[7] How We Decide by Jonah Lehrer.

[8] The Black Swan: The Impact of the Highly Improbable by Nassim Nicholas Taleb

[9] List of cognitive biases

[10] The authors [1] credit "Mann (1977)" for this table,

[11] Coreworx, Enterprise Informatics, Palisade or Risk Decisions.
Also, BowTieXP (nuclear accident analysis) and GenSight (nuclear engineering R&D)

[12] Significant Nuclear Project Risks and Control Strategies to Achieve Success, John Archer, PE and Michael Low.

[13] Risk and Uncertainty in Construction by S. AbouRizk, PhD, PEng.

[14] Nuclear Construction Summit, USA 2009

These are .pdf files. Pages noted are the ones most relevant to this subject.

Strategy and Risk Management for Nuclear Investments (pages 4 - 10)
Christopher Dann, Partner and Director, Energy and Environment, Strategic Decisions Group

New Nuclear Plant Commercial and Risk Assessment Strategy (page 9)
Dan Magmerelli, Construction Manager – New Plant Deployment, AREVA NP

Managing New Build Risk (pages 9 - 23)
Tom Flaherty, Senior Vice President, Booz & Co

Lessons from the Watts Bar Unit 2 Project and Application for Nuclear Construction (page 11)
Masoud Bajestani, VP of Construction at Watts Bar, TVA

[14.1]
The Bellefonte Opportunity: Building Smart, Managing Uncertainty (page 12 on)
Arun Mani, Managing Director, Huron Consulting Group

Meeting the Challenges for Developing and Financing a Nuclear Power Project (page 29)
Paul Murphy, Senior Counsel - Legal & Risk Management, Bechtel Power Corporation

Bringing Certainty to New Nuclear Construction and Operation (page 6)
John Bates, Chief Operating Officer, Nuclear Innovation North America

Learning from the 'Prior Build Cycle' of Nuclear Construction (pages 15, 19 - 21)
Tom Flaherty, Senior Vice President, Booz & Co

What Are the Credit Implications for New Nuclear Construction in the U.S. (page 4)
Dimitri Nikas, Director, Standard & Poor's

[15] Bruce Bueno de Mesquita

[16] Project Risk Management Helping Attract Project Finance

Marsh & McLennan Companies, Inc. (MMC)

[17] Calculating Construction Damages by William Schwartzkopf and John J. McNamara

[18] Construction Scheduling: Preparation, Liability and Claims by Jon M. Wickwire, et al.

[19] Contract Risks Management Group - Construction Industry

[20] Managing Risk: Prudence Reviews and Nuclear Projects Public Utilities Fortnightly

[21] Prudence Revisited Electric Light & Power

[22] Author

***Buzzwords Defined**

Sugar-coating - Shinola.

a priori - Means "beforehand" or "ahead of time" and used by lazy recovering lawyers.

Food Chain - Please see "supply chain," below.

Comfort Zone - Zone between justification and getting away with it.

Supply Chain - FKA the "food chain" pre-globalization.

Outside the Box - The area where people stop obfuscating, despite the fact they'll suffer for it later.

Best Practices - What everybody else is saying right now.

Raise Awareness - Self-righteously promote my own personal agenda.

Motherhood & Apple Pie - An intentionally ironic slang term used in Western Pennsylvania before the great "no silos" breakthrough.

Culture - FKA "the thinking" of "everybody else right now."

Acronyms

ADR - Alternative dispute resolution

AGAP - "All goes according to plan"

BIM - Building Information Modeling

CPM - Critical path method

CWIP - Construction work in progress

CYA - Cover your assets

E & C - Engineering and construction

EMV - Expected monetary value

EPC - E & C plus procurement

EUV - Expected utility value

FOAK - First of a kind.

HFT - Hot functional test

INPO - Institute of Nuclear Power Operations

NPP - Nuclear power plant (renamed "nuclear energy facility" by Frank Luntz)

NASA - National Aeronautics and Space Administration

NRC - Nuclear Regulatory Commission

ROI - Return on investment

WHIF - "What happens if."

Notes

First published to the web as a *draft* on May 10, 2010 and subject to continuous correction, revision, retraction and derision. It is web content designed to draw traffic to a website. It is *not* an article, scholarly or otherwise, or paper or position paper or blog post or advertisement or anything other that what has been described. Say "Hi" and wave to the judge for me, years and years later as I read this back in its entirety.

Links

Idaho Samizdat Atomic Insights This Week in Nuclear Energy From Thorium Nuclear Street NEI Nuclear Notes

What's Really Happening Backwater Umbrella "Dear Prudence"

American Energy Act - Contact Congress - Support Nuclear Energy

KELLY REPORT 2010® Nuclear Construction & Engineering News

Surety Bonds for Nuclear Energy Facility Construction Cost-Savings

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Or, send email comments, errata privately to: Comments.
