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Practitioner Interview

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Panel Discussion:
How to Educate the Next Generation of Environmental and Water Resources Systems Analysts?

Wednesday May 20; Session XI (2:00 – 3:30 PM)
Room 201-202
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Confirmed Panelists: Joe Kasprzyk (JK), Leon Basdekas (LB), David Ford (DF), Chris Dunn (CD)

Moderators: David E. Rosenberg (david.rosenberg@usu.edu) (DR), David Watkins, Jr. (dwatkins@mtu.edu) (DW)

Outline:

1. Introductions (20 minutes)

a. Introduce yourself and define systems analysis

CD: Director of HEC, part of IWR part of USACE. HEC tools to assist in systems analysis. Systems perspective: optimization software, but more importantly looking at interactions between components of projects. Example of Sacramento flood system, performance of levees depends on upstream levees. How do you evaluate the whole project as a system, and what are the consequences of failure? Sort of a "watershed" perspective (holistic) but including management, for flood/environment/etc.

DF: David Ford Consultants, Sacramento. Originally systems analysis perspective was using LP. Different from "systematic analysis"? (Steve Burges) which means: problems that have one or more objectives, constraints, and some relationship between the decisions that have to be made, that need to be solved in a systematic way. Systems analysis is a problem solving approach, more than the particular problem you solve, or the tool you use to solve it.

LB: Colorado Springs Utilities water resources engineer, project manager for IWRP. Agree with systematic problem solving concept, flexible and maybe no formal definition. Look outside model domain to figure out what outside of the system might impact it. Operations includes people, we rely on human experience in addition to computational tools.

JK: U Colorado. Asst Prof teaching water resources systems. A set of tools and analysis techniques, as well as a way of thinking. How do you formulate a problem to understand the goals of the stakeholders, who have diverse interests. Mix of optimization methods as well as probability/statistics/monte carlo. How does uncertainty propagate through design process. Also visualizing and communicating results with other engineers and the public. People are listening and looking for guidance.

b. How are you/your organization currently using systems analysis?

CD: HEC has tools to answer systems questions, including uncertainty and parameter analysis. Driving toward the WAT (watershed analysis tool) used for different projects, not public yet. Used in Columbia river system. Ensemble forecast of precipitation, uncertainty analysis in reservoir operations, hydraulic analysis to design levees, calculate expected damages and loss of life. Single tool to look at a very large system, being used to determine how the US/Canadian governments should proceed with the Columbia River treaty.

DF: Chris described simulation and consequence analysis, used in an iterative fashion (modified and run by humans). This is what systems analysts use 95% of the time. The physical properties of the system are very complicated, and trying to reduce those into the form of an optimization algorithm is very difficult. Not to say that we don't use optimization models, for example used LP to manage dredged material for USACE with branch and bound. THere are opportunities to use both optimization and simulation, but simulation coupled with some clever iteration is the most common tool.

LB: Simulation tool is the MODSIM platform. Water supply planning study is different from operation, which allows some flexibility. This is the key for handling all the differen types of risks of a water provider. Must be able to manipulate the model to explore these in ways that were not anticipated by the developer (add new measures, rule curves, etc). Not limited by GUI, can run in batch, use MOEA wrapper around the simulation model (latter they've had for 15-20 years). Wrap optimization algorithm around the legacy model that has buy-in from stakeholders. Using Tableau for visualization/graphics, to answer questions quickly by looking at data and communicate back to rate payers and the board. These tools critical for a successful project.

JK: Course project for systems analysis class. Simple example (1-2 month), students choose a river basin to analyze, gather data to answer some sort of decision problem. Examples chosen in the pacific NW, colorado, for example what does a river basin face with uncertain/increasing demand. Build a model, for example Riverware, and perform decision analysis. Sometimes formal like MCDA, or framing the problem as if it were a stakeholder decision. Very open-ended project can be frustrating but rewarding for students, such as finding data and designing objective functions. Research, NOAA SARP focuses on how climate information is used to make decisions among stakeholders. Work with utilities to figure out what are best practices for using MOEAs to make decisions. Importance of communication and interfacing with the public. Face to face interactions with the utilities.

2. Current Practices (35 minutes)

c. What systems analysis techniques, software, and/or tools were used?

(See answers above for some of these)

d. What encourages or limits use of systems analysis

CD: What question are you trying to answer, and what tools will you use to solve it? Then, how to communicate it? For years USACE had policy to do risk/uncertainty analysis, systems analysis, but very little guidance/tools for how to do that. Then you get an answer including uncertainty, but how does this influence the solution/strategy that you choose? Many challenges communicating this to the decision maker. WRDA 1986 act specified that you have to have a local sponsor for these projects. These sponsors only care about their specific issue, not upstream or downstream stakeholders. Makes it very difficult to perform a full system analysis, need to get someone bigger than a "local" sponsor to get people interested in a project.

DF: Answering a different question. Work in their firm can be classified as planning. Can't think of any study where they didn't use a systems analysis tool. Not sure how you would do a planning study without this. You have questions to which you need a quantitative answer. Hopefully the tools lead you to that without contradicting your common sense. But it's not clear how you would do planning without it.

LB: Looking at tradeoffs doesn't always mean getting an exact answer. But the tools help you do this. If we don't have a tool, then we build it. Lots of in-house capacity. Still planning the same way they have (with a human element, subject matter experts) just bringing more computing power into the mix.

JK: What is encouraging, you learn skills that are transferable to different domains. In the next few years, working to broadly offer optimization/simulation outside the water area in the department. Avoiding tunnel vision in students to see big picture of what these methods can be used for. Another important thing is trying to disseminate these approaches, by sharing source code, instructions, blog. Trying to lessen the learning curve to get these tools to actually work. Danger is, there's a barrier to some of the computational work for new students. As a field we should try to remove technical barriers, make tools easier to use to expand user base. Working to get educational/tutorial resources up and running. But at the same time, people need to understand what they're doing (not a black box). Graduate and upper level undergrad should have good math/stats/programming background to come to this with an informed view to know what's happening. This is an important limitation. Systems analysis can be limited by regulatory inertia, related to Chris's comment. New students must be aware of tools and studies that came before in the literature.

(Side Discussion)

DW: Challenge because our courses are so compartmentalized, students don't know what to expect from systems analysis course.

DF: Does systems analysis course teach steps of a formal planning study? For example, looking at without-project and with-project forecasts of system performance/behavior.

DR: Yes, not with that exact terminology but planning vs. proposed alternatives. Hopefully students don't get hung up on this.

3. Forward Looking (35 minutes)

e. What role should systems analysis play in professional practice?

f. What systems analysis skills and techniques should universities teach to prepare new practitioners to successfully join the profession?

JK: Teach optimization (IP/LP/DP), simulation modeling concepts, random variables and statistics, stochastic hydrology and time series analysis, heuristic optimization, uncertainty analysis, riverware simulation model. Focus on critical thinking and problem framing, and the computational tools (Matlab/R).

LB: All those are important skills as students transition into practice. Aside from all of the technical skills -- coding is important, it's becoming a lost art, need to write your own code and be flexible, be able to anticipate things you might not normally expect. Glad to hear Joe mention critical thinking. We were all new engineers at one point, but it seems that some students have more intuition than others for looking at results and figuring out why it happened, what's the next question to ask. Incorporating political realities of water supply planning frameworks, not just an engineering problem. Things on paper don't always make sense in the real world. Academics and practitioners should work together more and have applied research projects, workshops. Having graduate student "interns" helps to bridge this gap.

DF: Will not hire someone because they know how to use a hammer or a saw. They should have a vision for what a house looks like, and they know the steps that go into building it. And, they can describe to someone who doesn't want a house why they should want a house. He's confident that systems analysis graduates know how to use the tools coming out of college. But wants to make sure they have a fundamental understanding of the context for using those tools.

CD: Agree. Stay away from people who only know the tools, and think the answer from the tools is "the answer". Seldom is that actually true. The critical thinking piece is paramount. Many factors come into the decision making process that you need to be open to. Another important issue is technical writing, to describe in reports what your recommendation is. GIS capabilities are also important. Can't deliver a product without it. People want the sexy visual presentation. The H&H part is also important (hydrology and hydraulics). Stats is important. Can't rely on 1 undergraduate stats course to help students do monte carlo, handling aleatory and epistemic uncertainty in modeling, and an understanding of what "risk" actually means. Defines risk as a three-prong thing: probability of certain flow/stage, probability that system will perform as designed, and the consequence of the system failing to perform as designed. Risk is more than just the event itself, but all the things that lead to it and the consequences.

(Audience Questions)
Audience comments start with a dash. Panel members are initialed.

- Process analysis: is this analogous to systems analysis, or is it part of it? For example hydrologic/hydraulic process.

CD: Process analysis is an integral part of the evaluation of the existing system. Want to explore all of the physical processes that lead to a particular consequence. This includes natural and man-made process, tied together in a systems evaluation.

- Echo CD/DF comments about communication. Committee at U Maryland to study civil engineering education, what is needed from graduates? Everyone said communication skills, writing, speaking, being able to share the context of what integer programming (for example) is, means, and what value it conveys to the client.

- Someone else from the private sector echoes this. Must work independently, and be able to foresee the next steps of the analysis.

- Do you see a value of research projects, masters degrees etc?

DF: They don't hire people who haven't done research projects. Master's students are the entry level hires at his firm.

CD: At HEC, direct association with UC Davis and Sac State. Benefit of having those students go work for them for temporary program, but they hire many of them afterwards. Big difference from start to finish of students' masters' degree, which includes their work experience at HEC. Can identify the ones that get along well with others. Can see the benefit of a master's degree.

- USBR Sacramento: we struggle with new graduates (1) not understanding the importance of what they're analyzing before they analyze it, and (2) being able to collaborate with people outside of engineering. Can't work in system operations without doing this. When they have these skills, it makes all the difference in the world.

DR: How should universities go about teaching these critical analysis skills? This doesn't usually show up on the syllabi. How should it fit in?

CD: We've sent new hires to professional writing classes, because not doing this will be a detriment. Not worth continuing to review things that are poorly written. Universities should encourage a professional writing class.

JK: This is a challenging question. Relates to process analysis vs. systems analysis. We're getting into a curriculum planning discussion. One professor can't control this, the decisions about (for example) requiring a professional writing class would be outside the control of one professor. But for the process part, students will take hydrology/climate classes. Then in the systems classes, encourage analytical skills. Try in graduate courses to have writing as part of the class. Quiz as a prompt. Students typically don't like the writing assignments, but they improve. Also try to get students to make/write responses to different audiences, both scientific and not.

LB: Lots of common needs, but everyone has strengths and weaknesses. Example, when looking at interns to help with IWRP, not looking for highest GPA, instead looking for someone with drive/desire to do these types of projects. Want someone good (on paper), but self-motivated who can see the big picture. Some of these skills will come in on-the-job training, when engaging with subject matter experts, some of it will come organically as they grow professionally.

DF: Do not envy professors. Every term you're faced with a constrained optimization problem: how much stuff can you fit into this class? Practitioners could recommend topics that could fill up 5 years. So, you have to make decisions. But something that seems missing right now, seems like we've lost the idea of case studies in courses, because they take too much time. But a lot of these skills we've learned through case studies. JWRPM is not case studies (because negative results can't be published). You learn a lot when this happens, and there's a great value to students for hearing about this. Either failing to use the right tool, or frame the problem the right way -- but people need to be honest in their case studies. Can't really "teach" someone critical thinking.

- We can teach critical thinking, through case studies. Example of risk analysis class, students responding to wrong statistics in news articles. Example of infant mortality sampling error. Importance of Type I, Type II, and Type III errors (solving the wrong problem).

- Corps of Engineers: two cases, 40 years apart. First, how to optimize pump stations. Simulation, LP, multiobjective. At the time, David said, too far ahead of its time, didn't get used. 40 years later, LP to optimize reservoir optimization (HEC-PRM?), it was accepted. So the systems method is much more accepted in the field, and the risk of uncertainty is a much different question. It's a gradual process to get this accepted.

- Are we really "supporting" the decision maker, or are we the decision maker? Are we the consumer of the systems analysis? Maybe the profession could move farther faster if we thought of ourselves as consumers of these tools in addition to the developers of them.

DF: Reminds of book "existential pleasures of engineering". Which echoed this point, we should be more active in the decision making. Maybe that is why we don't have great examples where systems analysis led to a decision, because the engineers didn't play an active enough role. How should we change this?

- When I left graduate school, the things that made me employable were mostly not from courses. For example working in a lab, learning independently. Courses are important but need more opportunity to explore problems under students' own guidance.

- From the private sector, need to learn how to learn. Communication and writing skills. That's when they go back and try to find classes. So maybe we need to show the need for this earlier in students' college course planning.

JK: Grad school advising/conferences/papers are essentially writing training. Course planning is zero sum, don't want to skip a technical course in favor of a soft skills course. Those of us in the academic realm should be helping students with writing. Which is hard, especially when we can all improve our own writing.

- Not a lot of space for communication skills in a curriculum. Nationally we're moving toward less of those classes, even in high school and undergrad. How do we ensure that we don't lose this, as we're pushing for more STEM skills?

JK: No excuse for america falling behind in STEM. Math courses help with critical thinking.

DR: Quantitative results can be presented as a report, able to train in both. (Jery makes the same point -- if you can't explain to the client, a computer will replace you).

- Example of Rick McCuen making students write every class (and editing). Everyone hated his classes, but people agreed it was the most important class in their career. Should convey toward young staff how important this is.

- Student perspective: learn more in actual engineering classes on writing assignments than you would in a specific technical writing class. If not forced to write technically in college, couldn't do job skills now.

LB: Communication between engineers isn't always the same as with non-technical people. Need to boil down information from the analysis to just a few powerpoint slides for a utility board presentation to make your point. That's a unique skill.

g. How can the profession more effectively use systems analysis in the future?

CD: As you said, accumulating curricula nationwide, very few of them have communication and technical writing as a piece of that. Good to hear that people are including technical writing in their assignments. This must be happening, can't say that we're doing a good enough job on this.

DF: Challenge is to figure out what to leave out of a course (or a curriculum). So much demanded of you as a faculty members, how do you decide what to leave out? For example, you could leave out HEC-RAS and include technical writing instead, because specific tools can be taught later outside of university.

- Education doesn't stop after the degree. Students won't be good technical writers until they do it for a few years. Same thing for management. There isn't enough time in the university setting, but we try to expose them to what will be important in the future, so that they can focus on learning on the job afterwards.

JK: We also want students to get jobs, so you couldn't really take HEC-RAS out of the curriculum (for the example). Hard to control quality of the technical writing class, usually offered by another department. Constrained optimization analogy is a good one.

- Research/thesis is where people pick up the critical thinking skills, and defending it in front of an audience. This is what he values (rather than coursework-only masters degrees) in hiring.

(Final Comments)

JK: Should continue to keep open dialogue between academia and public/private sector. All ears for how to improve systems education.

LB: Collaboration opportunities are a way around some of these issues. Research for the sake of research has its place, but targeted and applied research is better to help students get these skill sets. Long-term internships help students see the value. Training good people and they come back as consultants. Opportunities for masters research in the collaborative realm as well. Lots of real-world challenging problems. Don't need to make them up in academia, just ask us (practitioners).

DF: Also talk about the value of professors going out and getting real-world experience as well. Go work with utilities, agencies, who have real problems that aren't simple. Cluster of problems, or just a mess. Great value comes from that too. Might not be able to publish a paper out of it, but it's very good for the students.

CD: Sharing projects with students at HEC to use in their master's projects has been valuable. Thesis-based master's is a huge advantage. Get as much practical experience as possible. There's a huge drive to create and deliver papers, but sometimes these aren't as well thought out as they could be. Maybe sometimes ethical things are discarded in the rush to publish. What you're putting on paper lives with you for years to come. Need to do a thorough analysis before you put your signature on a paper.

Panel Blurb

This panel of practitioners and academics will discuss current practices to teach environmental and water resources systems analysis and how to better educate the next generation of analysts and practitioners. Through a facilitated discussion, panelists will address questions such as: How is systems analysis currently being taught? What role should systems analysis play in professional practice? What encourages or limits the use of systems analysis in the water resources engineering profession? And what systems analysis skills and techniques should universities teach to prepare new practitioners to successfully join the profession? We will also welcome and solicit audience comments and questions in an effort to identify and recommended practices to better educate the next generation of environmental and water resources systems analysts and practitioners.