SEI Podcasts

Conversations in Artificial Intelligence, Cybersecurity, and Software Engineering

Capability-based Planning for Early-Stage Software Development

featuring Anandi Hira and Bill Nichols as Interviewed by Suzanne Miller

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Suzanne Miller: Welcome to the SEI Podcast Series. My name is Suzanne Miller, and I am a principal researcher in the SEI Software Solutions Division. Today, I am joined by two of my colleagues in that division, Ananda Hira, a data scientist, and Bill Nichols, who leads our work in software engineering measurement and analysis. Bill has been a frequent guest on our podcast series. Anandi is new to us. In this podcast, we are going to take a look at capability-based planning, its benefits, drawbacks, and how to implement it. I want to welcome Anandi for her first podcast, and Bill, welcome back.

Anandi Hira: Thank you.

Bill Nichols: Thank you.

Suzanne: Anandi, since you are new to the podcast, can you please tell us a little bit about yourself? What brought you to the SEI, and what is the coolest part of your job here?

Anandi: Yes, definitely. I did a PhD under [Dr. Barry Boehm](#), who was the founder or the first implementer of software cost estimation models - the [COCOMO](#) II model. After I got my PhD, I went and worked with [Tecolote Research](#) for two years, and I had continued to do software cost research there. Then I joined the SEI about a year and a half ago now. I was on LinkedIn. I saw a post by one of the managers at that time. He had put a job posting up. I knew him because I had done research with him while I was at USC doing my grad school work. I just messaged him and said, *Hey, do you think I could work from home for this position?* He went and asked his boss, and he came back and said, *Yes, go ahead and apply*. And here I am, He had tried to recruit me informally before, but I didn't really want to move out of LA, so this worked really well. I think that is one of the things that is coolest about my job, in my opinion, is that I get to work from home here in LA. Secondly, I really like the people that I work with. They are incredibly talented, smart. They are very supportive in all my endeavors and what I try to do, so that is really fun. Most importantly, I really do enjoy what I do. Understanding the software development data and finding ways to estimate software, I just find it all really interesting.

Suzanne: All right. Bill, we are going to link to some of your previous podcasts [[here](#)] and [[here](#)] in our transcript, so people will know where to find other things from you. For those in our audience who haven't seen your earlier work, can you tell us just a little bit about yourself and what you do here at the SEI?

Bill: Sure. My background is in physics. That is really where I learned to program. We did tons of data analysis. We measured our volume in reel-to-reel tapes, to date myself a little bit. I then worked for the nuclear Navy for about 15 years doing engineering software for nuclear analysis. That is where I learned how to work with process planning and large software efforts. I used that when I came to the SEI to work with other teams and teach them how to use disciplined methods, how to use estimation and planning to bring the projects in on time. A couple of things I get a charge out of is working at the SEI, you really find out that everyone has an opinion. [H.L. Mencken](#) once quipped*, That for every one problem, there is a solution that is neat, plausible, and wrong*. My mission is to bring measurement to the table so you can identify what is actually right or wrong, try to figure out why, and what is the delta between the facts and the fantasy in software engineering. Being able to research or write about that is one of the things I find really fun.

Suzanne: You have been a good prophet. We try not to make it a wasteland for you. But, yes, I am very familiar with, *How would we measure that?* One of

Bill's frequent questions, which is a great question to ask. To begin this discussion, can one of you define what we mean when we talk about capability-based planning. How do we define a capability in the type of work that we do? Because I am imagining it would be different if you go to different domains. Bill, do you want to start us off with that one?

Bill: Well, I would defer to Anandi. She spent a lot of time doing the research and pulling this together. I think this is an opportunity to really tell people what you found.

Anandi: Thanks, Bill. I did a literature review, a kind of informal literature review, just in case we have research scientists that are listening in here. What I found is capability-based planning is a framework used primarily by the U.S. government, as well as a few other countries, but is also being used by the commercial business sector. What they are doing in this framework is understanding what type of capabilities they currently have and what kinds of capabilities they really need to be successful. When I was doing this literature review, I found—and I am going to go into the definition of capabilities first—I found that there were four types of ways capabilities were defined. This would apply to both the U.S. government, or any government sector, and the commercial business sector.

The first definition type or grouping type is the high-level objectives or needs. These are usually operational needs or how it would be used. Something that is really emphasized is it is not necessarily what we would think about as features and functions, but you want to look at a higher level than that even. In software, if I were to say, *I need to build a database that can do queries*. I am getting down into the features and functions. Instead, I want to think about what is it that I actually need that database for, even before I get into the defining of the features. So, *I need to be able to store information on my personnel, so that I can quickly access them when needed*, for example.

The second type of definition that I have seen is operational outcomes. Note that this is different from needs or objectives, but you are looking at the actual outcome of the work that you do or the project that you work on. If you are saying something like, *We need to be able to make a certain amount of money,* like for the business commercial industry, or *We need to be able to be agile and adaptable to changes*. *We need to be able to be prepared for any kind of adverse behavior or reaction that we might get*.

The third one is activities and processes. I thought this was really interesting. It is not something I initially thought of when I hear the word *capability*. But I

think it helps remind organizations that sometimes they just have to look at how they are behaving in terms of their activities and processes, that they need to be evaluated and could be improved so that they can meet their success criteria or objectives.

The last group of definitions I found that is a little bit of a different focus is the ability to produce or achieve an outcome or an objective. Instead of just looking at what we want, now you are also looking at, do you have the ability to do so?

Suzanne: That means that there are going to be some different ways you go about planning. If I am trying to plan for a process capability, that is probably going to be a little different than planning for an operational outcome, but both of them are going to share some aspects of capability-based planning. Why don't we talk about sort of what some of the applications are for this? In the Department of Defense [DoD] in particular, you mentioned that the categories go across multiple domains. For the Department of Defense, what are some of the applications of using this type of planning?

Anandi: I would say, as a first step, capability-based planning replaces what was traditionally used, which was threat-based planning. In the threat-based framework, you were reacting to a specific, expected threat. You knew we would have a type of war, like a specific type of war, and we would need specific equipment for that or weapons for that. In today's world now, especially with how you have cyber-attacks and different ways that people might want to attack a country or a nation, it is more about being comprehensive and being able to look at the big picture and be prepared for anything. And so, like you said, *Yes, you would have different planning if you were going to look at your process of specific things*. Capability-based planning is really looking first identifying *what is it that we do need to look at*. Then as you go into it, like if you say, *OK, we need to review your processes and make changes to those, that is where we think the most improvement is needed*. Then you would start to get into the action steps if you will, and moving down into a lower-level detail of what you do towards that. Capability-based planning would help you decide what part you want to work on. Again, going back to defense, the goal really is to define a military defense mechanism, if you will, that is able to react to anything, things that you could or could not predict happening. You might not expect a war, and you want to be somewhat prepared for it. You have to realize maybe someone will do a cyber-rattack instead. To have the infrastructure in place to be able to react to that and be successful against whatever may come.

Bill: To build on that, one of the things that you can think about is what you need, what are the capacities that you need to operate in this new dynamic environment? The DoD, for example, right now is trying to become more agile to deliver software more frequently. That means you have to have things like a skilled educated workforce. That capability becomes fundamental. If you want to be able to deliver quickly, you have to be able to get that into the field. So that is going to affect things like your processes, or how you do cybersecurity so that you can get it released. From a cybersecurity standpoint, you have to be aware of, what are we going to do if there is some kind of cyber attack? How are we going to respond? What are the things we have to be able to do to make that response? We have to recognize it. We have to be able to get the right people on there to identify what was the vulnerability. We have to be able to do things like get the patches out promptly. We can't let that kind of exposure be out there necessarily. There are all sorts of ways that the capability comes in, and it really plays into the Agile mindset.

Suzanne: One of the things, when I was reading through the [white paper](), I thought, is what we are really talking about here is resilience, right? We are acknowledging that our environment is very dynamic, whether it is technology-based, people-based, or threat-based. We are trying to shift to where we are dealing with all the dimensions of the environment, not just the threat. We are looking at capabilities from a multiple-dimensions-kind-of viewpoint, as you just pointed out, Bill, so that we are not forgetting anything—well, to the extent that we can—especially early when we are starting to plan things. Is that fair?

Bill: I think what we saw from Anandi's literature report, it depends on which one of those definitions of capability you happen to be focused on for the problem at hand. What you described is a very common problem in the world today, but you could also have something much more focused on, say, specific operational need. It is important to be able to distinguish what it is you are trying to do because the capabilities can mean different things to different people at different times.

Suzanne: Fair enough. From that, let's talk about what are those parameters that help you understand what kind of capability-based planning you should be looking at and what the situation is, how you want to deal with it. What sort of parameters can you use to help guide people into how they can apply capability-based planning.

Anandi: The first step is to recognize that you can apply capability-based

planning across organizations. Especially, like for governments, you are looking not just at a specific military service or a specific organization, but across all of them. You want to look at your capabilities at that level. You could also do this at a lower level. You could look at it organizationally if you needed to as well. The first step is to really identify which of these wide-view perspectives is necessary for you to first look at and decide, *This is the level that we need to start the planning at and deciding what we need to do*. The next thing that can help in this is identifying scenarios, use cases, and case studies. That is to start to look at the details a little bit more like, *What if this scenario happened?* Now you can start to analyze what capabilities you have and identify the gaps by saying, *OK, well, this is how we would react. This is something we wouldn't be able to react to because we just don't have that capability in place*. Whether you are looking at cross-organization or just (within) organizationally, either way, the use of use cases and scenarios is very helpful in helping determine—and it could even help determine what level you do need to be looking at. What are the kinds of problems you are trying to prepare yourself for? As you can imagine, since we are doing the planning and the scenarios at such a wide view, you would have to have collaborations in place. You are going to be working across a lot of structures, a lot of organizations, a lot of accountability structures as well. A lot of these decisions and scenarios you are thinking about, especially for governments and defense, are cross-jurisdictional or even cross-nations. And so you are involving a lot of stakeholders, and you want to and need to involve them early. Along with your stakeholders that would be part of the thinking and decision-making process of the capabilities you need and don't have, you also have to remember that all of the capabilities you think or identify as either having or as gaps—they all need to work as systems of systems. Because you are probably going to need to take capabilities across different organizations and use them together to create or use as one capability. You are going to need to also include systems engineers at that early stage along with your other stakeholders. Something else that you would need, like another parameter to implementing capability-based planning, is, of course—I already talked about this—your scenarios and use cases. With respect to those, there are two aspects to that. You want them to be as broad as possible so that you are accounting for any possibilities within your solution space or your problem space, if you will. But even with the scenarios you come up with, you need to be as specific as possible, not getting too detailed, but specific enough to be able to realize what capabilities you do have, which capabilities you don't have, or that you think you would need in the future. These scenarios also help, as we talked about, we would have stakeholders, so being able to communicate about our capabilities and our needs with them. It would be a context for that

discussion that you would have with them, so that we are all on the same page in understanding, *Oh, yes. I am understanding the context that that capability would be needed, and, yes, we don't have it*, for example.

Now, that would also bring up the point about priority. I am sure in an ideal world, you would have everything, but in the real world, we can't have everything. We have financial constraints or logistic constraints. So you have to have a way of identifying your priorities. Also helping make those kinds of decisions, say the last really required parameter, is being able to estimate, because a lot of times, we do have financial constraints. One of the ways that we have to constrain our solution space is how much money we can put towards it. You also want to be able to look at comparing different solutions, possible solutions, to fill in your capability gaps, but then also looking at, well, what would that potentially cost, so that we can see which solution set is not only the most efficient but also effective because you want the best of both worlds. You want to make the best tradeoff possible.

Suzanne: OK. There are parameters we need to look at. When I was listening to you and when I was reading, I was hearing that a lot of the things we are talking about are in the early stages of a project. This is particularly useful because that is when we don't have all the detailed information. I know we have all been on proposals where they want phases of estimates sort of down to the nit-noids, even though you haven't even built the project yet. What I am hearing you say is there are a set of things we want to look at in those early stages, but we are not trying to get down to the feature level when we are at the very beginning, but we are trying to get the landscape. That is one of the things we get with capability-based planning is a better view of that landscape. Does that characterize it well?

Anandi: Yes, definitely. You would use capability-based planning in the early stages. At this point, we are not even looking at a specific program or project even. You are just trying to figure out what it is that you need. That would then start to define, *All right, this is a project that we would need to take on to be able to fill this capability gap*.

Suzanne: This is a planning technique that in contrast with some of the other things we have done with DoD customers before we are getting into specific programs, this is really at the mission engineering or the program executive office sort of portfolio level. It is something we can apply at those levels to help them with estimating the kinds of variety of capabilities that would need to be installed through different programs beneath them. Is that right, Bill?

Bill: That sounds pretty good. I would take it up even a level higher and say that you are thinking about what are your needs. Not how you are going to do it beyond the features and the design or the architecture, but you are not even at the requirements level yet. You're really focused on what do you need. What do you need to do? What do you need to have? What kind of workforce capabilities do I need to acquire? You're at a very high level.

Suzanne: OK. I didn't get that as much from my reading as I got from the conversation, so, this is really good. One of the drawbacks would be if you're down in the nit-noids, this is not the technique for you. But are there any other drawbacks that we should be aware of if you wanted to adapt that capability-based planning for your higher-level sort of user and stakeholder needs gathering so that you can put together a portfolio or put together a plan that is going to allow you to generate the kinds of requirements that would be needed to actually implement something?

Bill: I would start with the uncertainty. I think Anandi has a few things to say about that. But you are going to have a very wide range of uncertainty when you start for a number of reasons. Do you want to elaborate on that?

Anandi: Yes. As I mentioned before when we are using scenarios, for example, to try to identify the possible problem space that we want to have capabilities for, you'd have two sources of uncertainty that come just from that. You have the breadth of scenarios. You're not really knowing exactly what could happen in the future, right? Like we can never really know as much as we try to prepare for it, analyze it, et cetera. Then even as you start to pick a particular scenario, the level of detail that goes into it, even the details for a scenario. So like if we know something is coming, for example, let's just say we know a war is coming, but you might not know exactly the parameters to that war, right? There's the details to that specific scenario that also brings in uncertainty. As you can imagine, there's a lot of uncertainty to work with. I mean, at least even me, just thinking about trying to manage all of that uncertainty, how do you even start? But something Bill had said to me once while I was talking about the results with him was, he said, "You know, but it is important to remember that it is not a bug. It is a feature of capability-based planning."

Suzanne: Fair enough, fair enough.

Anandi: Something else I'd also mention is, again, going back to coming within our fiscal constraints, and that is going to be a challenge as well because, as we said, this is something that we have been noticing programs

having trouble with is we are going into programs with just capability needs statements. That is one of the reasons I did this literature review was to understand what is the level of detail that we are expecting to know when it comes to doing estimates? Because, as I mentioned, that is my background, in software cost estimation. What is the level of detail that we even know? Everything we've said today is all about how high level it is and how much uncertainty there is. And the more—like the less detail you know, the harder it becomes to estimate that right because you can only compare to things that have been done. And once things have been done, you have very specific parameters that you use to identify analogous programs, like to use that and say, "Yes, that is how much effort we think it'll also take to do, you know, this piece here in our new project." That is going to be a huge challenge is trying to estimate in support of capability-based planning.

Bill: To the follow up on that, what's important to understand is the capabilities-based estimate isn't going to give you a number, it is going to give you a range. It is going to give you a range of possibilities, and that is where you start to decide, "You know, what do I think I could live with?" And that is what's going to guide the next level of requirements engineering and design, is trying to bring that into something that you can understand. But at the capabilities level, you have to make big decisions. Like if you're going to the moon, is this something that is even plausible with our budget?

Suzanne: Sure. The kinds of information that you gather by going multidimensional on this, by dealing with different stakeholders, by dealing with different scenarios, by dealing with different dimensions of uncertainty help those discussions because it gives you a richer space to talk about than just, I want to go to the moon. Yes?

Bill: Exactly. And you can start dealing with what are the tradeoffs likely to be?

Anandi: I am just going to mention, that would be yet another challenge that I've seen in literature also mentioned is because you have all these different stakeholders and you're trying to track all these different scenarios and uncertainties, possible solutions, so trying to come up with a common framework for everyone to work on in capability-based planning is also very difficult, and that has been a challenge. But yes. I mean, that is also part of the feature.

Suzanne: All right. We are sort of just getting started with looking at this kind of planning and how we can help DoD customers with this way of looking at

things. How are we looking at transitioning this? (Obviously, as an FFRDC that is a big part of our [job]. How are we getting these ideas out besides the podcast, obviously? And how can our audience learn more about this type of planning and how to implement it? What resources are already available? What are you planning to build in relationship to this?

Anandi: There is a lot of material that is out there, and Suz had mentioned a couple times while we were talking, a [white paper](#). Bill and I wrote a white paper together that summarized all the things that we talked about, all of the things I found in the literature that I found. The literature that I reviewed came from Glen Alleman. He has a heavy presence on LinkedIn. He also has a blog post that he calls, Herding Cats, I believe, if I remember correctly.

Suzanne: Great title.

Anandi: Yes, which reminds me, my PhD advisor, Dr. Barry Boehm, would say, *Cost estimation is like herding cats*. Anyway, he has a list, a great list of all of these references that talk about [capability-based planning](#) [CBP]. He was a program manager himself. So he is, you know, quite knowledgeable in that space. But I think there are a few other big names I would say in that space. There's Paul Davis, who, I almost want to say, started with this whole concept of capability-based planning in the Department of Defense sector, and so he has quite a few bits of work, too. But, yes, you'd be able to see these references. If you look at the references to the white paper and also if you look up Glen Alleman on LinkedIn.

Suzanne: OK, and that brings me to the question of, what's next? What are you doing to further this research or what other research do you two have on your plate that I can come back and talk to you in a few months?

Anandi: I mentioned earlier that one of the reasons I looked at capability-based planning and did this lit review was to really understand the problem space for estimation. That is really where I am focused on in terms of capability-based planning. I have some blog posts coming up soon, one of them at least, hopefully soon. To really explain to estimators that are in the defense sector, but even academic researchers, to really understand what the problem space is. Because one thing when I started working at Tecolote and here at SEI that really surprised me or that I didn't expect to learn, I guess, was the difference between the commercial world and government in terms of the estimation needs and how that affects what works and what wouldn't work. Because there are techniques that are being used in the commercial industry, for example, function points that doesn't really work in

this space. I am going to do a series of blog posts to kind of explain the problem space. I am also working on a research project called Capability-Based planning Software Cost Estimation. Which is abbreviated as CaBSCE, and that is to be able to estimate software costs within this capability-based planning space. The blog posts, this, other stuff that I'll be publishing will all kind of set this stage, if you will, for how CaBSCE will fit in and how it will help be able to do estimation in this problem space.

Suzanne: All right. We'll look forward to that. Bill, what's next for you? I know you have your finger in a lot of pies. What should we be looking forward to?

Bill: Well, I am looking specifically at a slightly later phase in the estimation game. That is understanding how things are going as you move into the implementation. Our goal is to be able to have a suite so that you can have this estimation for the initial project planning with things like a CaBSCE and then move into the development so that you can actually track more accurately over time, *what is the actual progress we are making? Are we on track? Are we not on track? When are we going to be done*? We had a lot of success in the ACE world, and we are moving ACE into transition, that is [Automated Continuous Estimation](). We are going to be going into a transition project to generalize and put that into production at actual DoD sites.

Suzanne: Excellent. All right. Well, that means we'll have some interesting conversations coming up, and I look forward to that. I want to thank both of you for joining us today and talking to our audiences about this. As I said, I look forward to talking with you in the future about as this progresses. And finally, a reminder to our audience that our podcasts are available pretty much any place you can access podcasts, including SoundCloud and Apple Podcasts. If you like what you see here today, please give us a like, and thank you again for joining us.

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