

[SQUEAKING] [RUSTLING]

[CLICKING]

- HAZHIR** Today, we are focused on growth of a professional field and modeling that. So I see fewer models submitted so far. So we'll see how many will show up. So now we have 2, 3, 4, 5, 6. We have seven right now. So we could go through these. But before we get started, maybe just a little bit of, what were the common challenges you were facing, things that you could have gotten help for, or when you were thinking about it, were challenging. Anything that comes to your mind, feel free to share. So anybody wants to start us on that?
- AUDIENCE:** I have done the conceptualization with handling quality, the needs of quality, and how the job's being done. What would the quality of job be in that? You have the mix of people? And in that regard, I also had the problem of allocation of the tasks, yes. I was thinking that-- because, for example, we have 10 experts, 10 novice, but we have five tasks.
- HAZHIR** Yeah.
- RAHMANDAD:**
- AUDIENCE:** So how do you overcome?
- HAZHIR** Those are very important questions, and they actually may even point to important policy lever points because the allocation is not determined fully. It depends on the underlying matching technology that is being used in the space. I'm calling it technology, not that, necessarily, it is a technology, but whatever is the process, yeah. Other observations?
- AUDIENCE:** Just on that, I couldn't really figure out if it was like-- if there was a different-- I ended up not doing this, but I couldn't really figure out if there was a different demand for professionals versus rookies or if there was a way to sort of make that part of it.
- HAZHIR** So is demand homogeneous? Yeah, so that's an interesting observation. So you could actually think about demand to have different dimensions of size, of complexity, of margin. And if the quality of work has been going down, for example, your size of not only the number of projects, but size per project or the margin per project may also shrink, so that's an interesting idea. It wasn't in the problem definition, but that's a good call, Jake, that it could be a feature you could incorporate.
- AUDIENCE:** There are two questions that I never really resolved. One is how much to explicitly account for alternatives. So someone chooses not to go with the new field, they're choosing an alternative. And that has implications for the recognition accrued to the alternative. So accounting for that, I chose not to go with thinking about the quality of the alternatives. It became too much. I'm not even sure I needed recognition.
- So that piece, and there was one other. Oh, thinking about the elements of-- the determinants of service quality, and in particular, how to respond to excess demand and the implications of that on learning. If it's an overburdened system, rookies probably aren't learning as much as they could. I chose not to model all of that, but it was in the back of my head.

AUDIENCE: I was wondering a little bit about the utility. And if it was financial benefits, this would-- what's behind the utility for the service? Because that is such a big driver for the whole thing. It could be such a strong reinforcing. If there's financial benefits for somebody to use this service, it's going to increase the demand so much.

So I was thinking how to-- and then it became so complicated because it can be-- because it's an open area. So it's like, OK, it's hard not to model a certain-- specific field when you think about such things, as what need is this service fulfilling for people? And how much do they benefit from that?

HAZHIR Yep. So the quality or utility impact on future demand is a pretty big part of this model. Very good. Anybody else
RAHMANDAD: wants to share what they might have found challenging or interesting, formulation issues?

AUDIENCE: I want to have novices going through training, taking some labor out of experts too. But then I tried to do that, but then the allocation became too much. I was barely handling the allocation of time of experts and novices as it was. And right now, my trainees can decide to work, or train, or will not have anything to do. But experts are not involved in training novices. And then that seems logical, but I couldn't do it.

HAZHIR Yeah, so kind of on-the-job training versus explicit expert allocation. Yeah, and this is most important and non-
RAHMANDAD: trivial, as you say. Allocation problems are generally hard, so having good formulations for those. Oh, we have two Alban's today. [CHUCKLES]

Any other thoughts?

AUDIENCE: Another thing that I didn't end up tackling-- cause I thought it was trickier-- was allocation of when both rookies versus pros try to leave the market because there isn't enough demand, generally, to make it appealing.

HAZHIR Yep, that's also pretty important. And when you leave the market, it's kind of-- if you are a rookie, you may go
RAHMANDAD: completely and you may never come back. When you're a pro, the chances are you go into a different mode of operation. But if there is demand coming back, you may come back to the field as well. So that's actually an interesting additional wrinkle you could consider.

I think these are pretty good thoughts. All of them are important problems. So let's now dive in and see how you have been handling those in your models. And what are some of the solutions you have for dealing with these? And so let's open all of them for-- so I think we have the models open. So let's do a quick walkthrough in terms of the structures that you have used. And then we can do the deep dives.

So this one is Jake's model. And we have here the rookies, veterans, and their capacity. So, Jake, can you tell me what you have in mind by capacity here? Is it about their skills? Or is it about their-- what's the idea?

AUDIENCE: I didn't do as much in the way of skill. I think you could, in theory, do a sort of utility of each, a rookie and a vet. But this is literally just the amount of work that an employee can do in the--

HAZHIR Ah, I see, I see, I see. So why do you need stocks for that? I'm just trying to understand. Why is it just the number
RAHMANDAD: of rookies multiplied hours per week or something?

AUDIENCE: It is, but I modeled it this way.

HAZHIR We can come back to it. I just was trying to understand what the idea is. We can come back to it. So then you

RAHMANDAD: have the stock and flow for demand. This is potential demand, current active demand. That is unmet current active demand. That is met. It has kind of a start. So, basically, these are projects that are happening, projects that are kind of in the queue, and projects that could materialize, but are not yet active. And you have cycling through. So maybe, rather than projects, think of them as clients.

And then you have tracking of the quality of work through success versus failed work. We should come back to that and see how exactly it is formulated. And then you have reputation, and I assume reputation then has an impact on recruiting new potential actors. I don't see people leaving the field. So in this sense, once you go from potential demand to the right-hand side-- well, unless this market expansion is also potentially market shrinking, that is.

AUDIENCE: Yeah, I think it can go two ways.

HAZHIR It can go two ways. So then you can have both sides. Makes sense. Let's look at the next one. So this is Jason's

RAHMANDAD: model. And we have recognition. You have active projects. You have another addressable market, where the small market that then turn into active projects. This is kind of similar to Jake's three big categories. Although, there might be some differences.

You are trying to model something about the alternatives and how they are getting recognition. So you're not keeping it as a fixed construct outside. But maybe in competition, you may get more market share or less market share and that may have an impact. Then you have rookie experience the structure. This seems to be coming out of Sterman's standard formulations there with some effect of experience.

AUDIENCE: Yeah, this is just a non-conserved copula.

HAZHIR Yes.

RAHMANDAD:

AUDIENCE: Which is also from Sterman.

HAZHIR Yeah, but you're using the co-flow of total experience to match the experienced employees or the rookies?

RAHMANDAD:

AUDIENCE: Only experienced.

HAZHIR I see. Yeah, got it.

RAHMANDAD:

AUDIENCE: Yeah.

HAZHIR So you actually are creating different grades of experience. So this is actually an important thing to have in mind.

RAHMANDAD: So in typical models of skills, you either break down the population into different levels of skills, so it is more of an aging chain, like the experience versus rookies structure here. Or you could have a co-flow structure that says, you have a population of workers and they are building skills. And that is the co-flow that goes with the population.

Now, it is technically fine to also combine the two here, just as Jason is doing here. But it is not as common, and because kind of, they're doing the same thing. So it might be a little bit of an overkill to do both of them together. But, technically, there is nothing wrong with that. So that's OK. And here it basically creates different shades of experienced employees, so to speak. So that's what might be happening here.

AUDIENCE: One thing-- we can come back to it-- that I like was thinking about is I have utilization kind of adjusting the experience accrual. The idea was, if there isn't a ton of demand, you're not learning as much. Your experience is valuable.

HAZHIR Yeah.

RAHMANDAD:

AUDIENCE: And then it saturates. I'm not sure of that.

HAZHIR So we should come back to it because those are important formulations and could become tricky. It's not
RAHMANDAD: obvious. So I definitely want to look at it. Yeah, definitely. So this is Gerardo's model with customers that are in the potential, interested, current, and disappointed groups. So this structure makes sense with the kind of caveat that not everybody is going to be disappointed first. So you may have current-based customers. Some of them go back into interested or something. That's possible.

Then you have projects that are defined based on the active customer base. Then you have your practitioners. And with the rookie experience structure, that makes sense. Then we have the reputation of the field, which comes from some measure of current quality that's coming from our rookies, and total work, and so on. That's pretty clear. Thank you. Next one, this is Hassan's. So we have novices. And Hassan is kind of putting a stock for how many people are even possible to be potentially joining the field if I'm--

AUDIENCE: To be available, what are the ones who have joined, but are not working as of yet?

HAZHIR Oh, OK. So right now, you are actually capturing the allocation of projects to people using stocks. That's an
RAHMANDAD: interesting--

AUDIENCE: There's benefit.

HAZHIR --way of doing it. So it is fairly operational. But also, it creates this time constant challenge. That is, there are
RAHMANDAD: dynamics of working on projects that are in the order of weeks and months. And then there are dynamics of the field that are in the orders of years. And you then need to capture both of them consistently. It's quite doable. It just adds a lot of complexity that may not serve you that much.

That is, the short-term dynamic, the faster dynamics of allocation, you could assume they are almost happening instantly. Based on the current demand and current available-- current total supply, you just get a fraction that are allocated and you're done with that. You don't necessarily need to capture the movement between projects for this bigger picture question of how a field evolves over time.

So that's a little bit of these tastings. But one of the-- I would suggest going with simpler alternative here, but the logic is fine if we can come back to it. And then you have potential demand, odd address demand that turns into ongoing projects, and then turns into recently developed projects that field-- that kind of informs the recognition of the field. And then you have the reputation as a separate factor that comes from experts versus non-experts. And you have some opportunity, that you should come back and see how exactly it works.

Next one is Sercin's So this starts with clients on the top with potential, those who know about the field, those who are being served by novices or by experts. So you're kind of dividing them at the time of getting the project assigned, whether they get served by novices or by the experts. So it's a little bit close to what Hassan was doing in looking at the explicit allocation right at the point-- at the project level.

And then you have the same idea here for the novices and experts serving the client, so very similar comment to Hassan's model. And then we have perceived potential clients per practitioner that may have an effect on getting people into the field. It's good. We should look at some of these later.

This one is Alban's. So we have not awarded potential clients, awarded potential clients, active clients. And active clients are co-flowed with projects and completed projects. It's a little bit tricky to get this co-flow to work correctly, so we have to come back to it and see how it works. Then we have the reputation, experts and novices. You have the demand feedback on growth of the field. This is great. Let's go to the next one. Ross's model has?

AUDIENCE: Certificate.

HAZHIR Hmm?

RAHMANDAD:

AUDIENCE: Certificate.

HAZHIR Certificate. Yes, it's an interesting idea. Let's see how it is operationalized later. So fulfilled demand, potential

RAHMANDAD: demand, current demand. So, Ross, by fulfilled demand, you mean demand that has been completed, but it is in the memory of the people? So what is project depreciation?

AUDIENCE: I guess it's time the project becomes obsolete and people become inactive [INAUDIBLE].

HAZHIR I see. So you're basically thinking of a constant pool of potential demand. And after a while, they come back and-

RAHMANDAD: - yep, got it. Then you have reputation, quality of the demand that has been fulfilled, novices and experts, recognition and reputation. So these are coming from the size of the project and the quality of projects. Cool.

Good. So I think, actually, we have a little bit more heterogeneity today in terms of the structures that are used. So this is kind of very nice to go into some of them in more depth and see what we can learn from each. So maybe we can start with Ross's today. So here, we have-- let's start from the kind of choice of the customers.

So, basically, this formulation of customers, this is a conserved set of stocks and flows. So you have a net total population who may ever be interested in this field. They are just cycling through different stages of being potential demand, interested in demand, or being served right now. So demand is kind of the projects that are being served, I assume. Those projects get completed. And these people, after a while, again, would need some projects.

So what is the unit you're using here? Is it kind of in the-- it's in the project units. The project is-- it's OK. I think project is fine. I would think of them more as clients, but it probably is fine to just think of each client to have one or n projects at any time, at any point in time. Just kind of the concept of a client that is looking for, basically, a professional, a client that is being served by a professional, and a client that doesn't currently have a job because it takes time to have another project.

That is a little bit easier to imagine than, for example, a project that has been fulfilled and then will return into demand. So it's just relabeling the unit and the variable names. Perhaps no impact in the underlying math of the model, but it's a little bit cleaner that way. But also, let's remember that once it is a fixed pool, you don't have much opportunity for expanding the field.

Now, there is some opportunity because, here, the project field awareness controls what is happening with the projects coming in. So it's basically the project potential demand multiplied by some fractional rate that gets materialized from all of the people who are-- who have something that can be served by this type of capability. A fraction will join, and that has a base fraction multiplied by some field attractiveness or impact of attractiveness and growth.

Now, that baseline fractional order rate of 5% per month-- and the unit, you could just write it as 1 over months. You don't need DMNL over months. That's perfectly fine, but it's just easier. That kind of tells me you need to be careful with field attractiveness. If you're thinking of baseline to be maximum, and then field attractiveness being between 0 and 1 rate, then it works fine because then there is no chance that this number becomes too large. And that's probably how you have formulated it, not having gone through it.

But when I'm looking at it, I'm saying, I like this baseline fractional order, then, to be maximum fractional order rate, so that I know by looking at the variable names that field attractiveness this is formulated to be maxed out at 1 or something like that. Just taste. There's nothing mathematical here. We'll come back to the field attractiveness.

Then the demand that is materialized needs to be completed. And that completion rate comes from a maximum completion rate and an average project completion rate. So it is demand divided by time to complete or maximum project completion rate. So I assume this maximum project completion rate is coming from the capacity to complete projects.

And this is a little bit-- again, variable name-wise, I would use minimum time to complete or something along those lines to highlight that this is just for extreme conditions, not the typical time to complete the project because, if it is the typical time to complete the project, it should come from the pathway that accounts for the labor availability because that is the normal binding process.

So for this flow, I want it to be binding 90% of the time by availability of labor consultants. That's what determines the rate. But just to be robust, I don't want it to be completing projects with infinite speed and/or with the speed that is infeasible given the demand. So that makes a cleaner formulation, which means this would be minimum time to complete projects in the way I think about it. But now you have put it at 12 months, which is not actually the minimum time. It is closer to what the typical time might be. So can you tell how you were thinking about it?

AUDIENCE: Yeah, I guess I didn't think about what you just explained. That's a good point.

HAZHIR That's fine. So that's kind of whether you are using this time as the bounding constraint for extreme conditions or
RAHMANDAD: as the main driver. These are two different use cases. So if you want to use it as main driver, that would create the desired completion rate. Then desired completion rate can be compared, for example, with the resources available, with the consultants available. And that can give an actual practical completion rate that is bounded by both sides.

So that would be the way to do it rather than doing the minimum here. That's the alternative way to think about it. It works, probably works just fine. I'm not too worried about it not working in terms of breaking some extreme condition criteria, but it would have other consequences. We'll get back to this maximum. Projecting, then you have a higher order delay for projects, yes, a third order delay. This is just how long it takes for people to come up with a new project that they want to have.

Now, keep in mind that, here, you have a 20-month delay, minimum, for people to actually realize the next project or bring up the next project because of that 5% baseline fractional order rate. So that's OK, but keep in mind that you have two delays here. One is that time-to-depreciate delay. That is 36 months. And then you have another 20 months delay. So in average, you have 56 months of delay between two projects from the time you actually finish one project until you're bringing in another project.

In your back of the envelope, any calculation you're doing, you should have both of them in place. Again, nothing problematic there, just to think about the implications of the structure you have put here. So that's the core for the project side. Now, let's look at the novices and experts. So we have people entering the field. It depends on awareness. It depends on fulfillment ratio. It depends on maximum novice entering rate.

So let's actually get a feel for how this is happening. So maximum novel-- novice entering rate is actually in person per month. So this is telling something about capacity of cold field for attracting new people, the maximum capacity. Then you have this attractiveness that feeds into people coming into the field. And then demand fulfillment ratio is the ratio of fulfilled demand to maximum demand. And maximum demand is coming from-- oh, some ad hoc number. So I would be worried about having an ad hoc number as the maximum demand.

AUDIENCE: Some initial. I guess the total demand is.

HAZHIR Ah, OK. This is basically capturing the total number of all of the--

RAHMANDAD:

AUDIENCE: Yeah, that's the initial value for the potential.

HAZHIR Got it. So, basically, you start with maximum demand in this stock. And because this is conserved, then you put

RAHMANDAD: everything else at 0 at the beginning. This is the total number in all of these stocks. So the demand fulfillment ratio is a term that gives me the feeling that 1 means we are serving anybody who wants to be served. That's the feeling I get from the term.

The way you have formulated here, it can never get close to 1. It just can't because the other two stocks will always have a big chunk of folks who are cycling through. Even if you have project completion rates that are happening as fast as technically possible, it's like zero time. You still would have 36 versus 20 ratio of how many people are in the fulfilled demand versus potential demand. So this demand fulfillment ratio-- let's see if my computer comes back.

Yes, so this demand fulfillment ratio can never exceed 36 divided by 56 or some ratio like that. So that puts some kind of an ad hoc normalization or maximum level for this demand fulfillment ratio that makes tracking of what will happen next a little bit harder for me. So, again, something that is not wrong, but does not-- the name of the variable doesn't correspond to what I read from it when I'm looking at it. But that's aside. So 1 minus this demand fulfillment ratio is giving a signal of--

AUDIENCE: I was trying to have some excess demand, some proxy for [INAUDIBLE].

HAZHIR Some excess demand. Can you explain?

RAHMANDAD:

AUDIENCE: Something like, if there is excess demand, then novices enter.

HAZHIR I see. So you're saying novices are entering based on excess demand, or based on some signal that demand is

RAHMANDAD: not being served as well as it could have been?

AUDIENCE: Yeah, that's what I'm trying to do. But [INAUDIBLE].

HAZHIR It may not be doing exactly what you want because the reason this demand fulfillment ratio might be small could

RAHMANDAD: be that the reputation of the field is pretty terrible, and people are not coming to the field to be served. Or it could be because there is a lot of demand, but you don't have enough supply. And, therefore, a lot of people are stuck in the demand stock.

So you can have an inflated demand stock, which is a signal for these people to-- for the novices to join the field. Or you may have an infinite kind of inflated potential demand stock, which is a signal not to come to this field in some ways because this is not a reputable field. So both of those are coded the same way here. And, therefore, this would not do what you want to do because it's not clear which of these--

AUDIENCE: But would it fill the attractiveness, take care of this?

HAZHIR So field attractiveness, where does it take care of it? So it comes into here as a separate factor. So the way I

RAHMANDAD: would think about it is, what is visible to a novice in this case? What are the signals that they may see? So the signals they may see is that this is a booming consulting space. What does booming means? That there is a queue of people who want projects to be completed and-- so if I join, there will be projects for me. That's probably the simple, easy, fairly straightforward signal.

You can do that by just looking at the delivery delay compared to kind of desired delivery delay, or something along those lines. So as long as you capture how fast projects are getting completed compared to how fast, typically, clients want them to be completed, that will give you the signal for whether this is an attractive space to join for that.

AUDIENCE: Backlog.

HAZHIR Yeah, some version of a backlog. And you already have the backlog. So demand is actually a backlog. This is
RAHMANDAD: being served. But delivery delay compared to the desired delivery delay is the core idea.

AUDIENCE: Does it make sense to compare the backlog of the supply, kind of the capacity?

HAZHIR Compare the backlog to capacity. So backlog to capacity is the delivery delay.

RAHMANDAD:

AUDIENCE: Oh, yeah, right,

HAZHIR That's by definition exactly.

RAHMANDAD:

AUDIENCE: Thank you. But is it capacity of--

HAZHIR So think about capacity as projects per month.

RAHMANDAD:

AUDIENCE: Yeah.

HAZHIR Think about backlog as projects. So project divided by project per month is, in months, the delivery delay,
RAHMANDAD: average delivery delay. Then you have the desired delivery delay. And the balance of those two would be one way to get this signal for novices entering.

AUDIENCE: So is this kind of analogous to the pressure to expand capacity in market?

HAZHIR Yes, it would be analogous to pressure to expand capacity. Yes, I think-- and this is actually a decent signal. In
RAHMANDAD: these cases, you don't have very clean signal whether this is a good field other than that, OK, consultants in this space are pretty busy. There are a lot of jobs for them, or now there is not much job in this space.

AUDIENCE: I have a question. Shouldn't it also be tied to reputation? Because, well, what if reputation is low and then you are looking at the very short period?

HAZHIR Absolutely. So that's a very good kind of second input into the novice. So is this a busy field that has good
RAHMANDAD: reputation versus a busy field that doesn't have a good reputation? Makes a difference because that is informative about the longer term trends. Yes, it might be busy, but it is a fad. And everybody who kind of has had experience with this says, don't go there. So then you can add that factor. Absolutely, Maria, that does come in as a nice addition. So the field attractiveness, if it is capturing something about quality, is a good input into this.

Again, I'm also need to look at the formulations for field attractiveness to see whether that is already capturing the right non-linearity there, or you need some additional transformation here, but that-- because you're using it in two different places, just as a multiplier. So you have it as a multiplier into entering, and you have field attractiveness as a multiplier into projects ordered.

And these are two different use cases of an underlying concept. One is impacting the novice's decision to enter a field. The other is impacting project owners to start new projects. So the functions for decisions of these two groups are different. You don't have degrees of freedom to separate these two when you just have both of them multiplied.

So I would probably pick one of them, anchor to that so that my project attractiveness, or field attractiveness, is anchored, for example, to project owners. That is, its ups and downs are consistent with what a project owner's weight on attractiveness is. So that I don't need a free parameter for the project owner. But when I come to novices, I will add a new parameter to regulate the strength of the impact of this perception on novice behavior because the two are using different functions.

These are different decisions, so you can't just randomly use the same thing. Is that clear? This is kind of potentially important general idea. And, folks, if you're online, have an idea, please just jump in, or have a question because I'm not seeing your screen in front of me. So if you raise your hand, I may not see it. So please just jump in.

So people enter. They are novice. There is a training process. The training process can be bounded by two factors. So you have the minimum of the novice, training per expert. So you divide all of that by time to training. So this is an interesting formulation. I think it is fine. There is nothing wrong here.

So you have two different pathways. One is that novices take some time to be trained. So it is novice divided by time to training. That's one constraint. If you don't have people, you can train them. The other constraint is the expert ability or expert capacity for training novices. And you get that by experts multiplied by a fraction of experts that are dedicated to training.

That is, what fraction of each expert might be dedicated to training? That's kind of sets a maximum. And training per expert, that is trainee per expert. That is just translating, how many trainee equivalents are going for each expert? I don't know if you need the trainee per expert. Yeah, probably you need it.

AUDIENCE: This is weird because, in the book, I think you have units of experts, which has always bothered me. And Russ is doing a correction to give you units of trainees, which makes more sense.

HAZHIR Yes, so I think you can have it because, ultimately, this trainee per expert is multiplied by fraction of experts
RAHMANDAD: dedicated to training.

AUDIENCE: Yeah.

HAZHIR These two parameters are fully collinear with each other. I don't think they are used anywhere else, so which
RAHMANDAD: means you have, really, one degree of freedom. This is like SIR model with contact rate and infection rate. You can have them. Conceptually, there is--

AUDIENCE: It gives clarity.

HAZHIR It gives clarity, but it is not doing anything for you mathematically. There's nothing wrong here. Yes, there is kind
RAHMANDAD: of a little bit of a taste issue, that you have this minimum of the stock things, stock things. And then you divide the total thing by this time to training. And people get confused with this formulation.

When I opened, it I said, well, what is happening? It's the minimum of novice and something. And the reason is that I normally think of two different processes. One is that novices get trained because they are kind of spending time on the job. That happens regardless of getting training. So that is novice divided by time to training. That is coming from novices. That's one path.

And then the other path, I would say, OK, each expert, if they spend full time training people, they will be able to train half a novice per month to become an expert or something, some number, if that is the full time. So that is my trainee per expert. Then I'll multiply that by the fraction of time that experts are going to invest in training, and that becomes a second channel. And that will take care of the training rate for me.

AUDIENCE: Like a separate flow?

HAZHIR Exactly. Just not separate flow, but separate pathway for the flow. Now, then there is the question of how to
RAHMANDAD: aggregate these two. There is the natural training coming from my experience of working. Then there is this expert-driven training that is the extra boost that I get in my training.

One way is to look at the minimum and say, these two are overlapping. So if the experts are spending time, they don't boost it unless they spend enough that goes beyond what I'm getting from my-- getting my hands dirty on a day-to-day basis. The other formulation says, no, actually they are completely independent and, therefore, they are additive. You can add them together. But if you're adding them to the other, then you need to be careful not to drain the novices too fast if you don't have any novices.

So then the part that comes from the experts should get some upper bound that is bounded by minimum time to training, which is different from the times to training. So that would be perhaps a more complex, but also more realistic formulation that allows you to separate these two explicitly. Right now, you're kind of putting all of them together. This will work, but a little bit harder to explain.

The other problem-- not problem, but what I, kind of looking at this, would say, OK, this is not dependent on how much work these people have. So if you have very busy schedule or no busyness of a schedule, this is not capturing it in terms of impact on training or impact on the expert time spent on training. That's kind of-- both of them are kind of missing.

AUDIENCE: I feel like I had just entered the math.

HAZHIR So that's good. So we can look at that. So the expert fraction dedicated to training is impacting the maximum
RAHMANDAD: project completion rate. So let's look into it. It's a little bit intimidating. For now, let's put aside a certificate. I assume it is not a big deal yet. So you have the maximum novel product-- novice productivity by novices, maximum expert productivity, 1 minus fraction dedicated to training maximal. So this is the total capacity.

AUDIENCE: But I guess it doesn't affect them until you hit the maximum.

HAZHIR It doesn't have an effect on what?

RAHMANDAD:

AUDIENCE: The fraction that I take out does not have an effect on the project completion, unless the project completion hits the next one.

HAZHIR So that certificate is about project completion?

RAHMANDAD:

AUDIENCE: That's just a policy.

HAZHIR Oh, yeah, so the part that's kind of not, in my view, fully yet consistent with what you are trying to do is that, if
RAHMANDAD: you have few novices, then experts are not spending any time on training. So the maximum x -- so 1 minus fraction of expert dedicated to training should not be 1 minus that fraction. It should be 1 minus a very small thing, or 0. That is not endogenously captured here. Does that make sense?

AUDIENCE: Yeah.

HAZHIR So it does need to be tracking, what fraction of experts are actually being dedicated to training because of the
RAHMANDAD: need for training, because of existence of these novices? So there is a little bit of a demand and supply. So you are just focusing on the supply side, but what was the demand for training that got material-- that got served by experts?

And then based on that, what is the realized fraction, dedicated training? That realized fraction is now what is reducing the expert availability for training. I don't remember how exactly Sterman's text handles this because he has an example that goes through this, but I don't know right now.

AUDIENCE: It's not endogenously handled, maybe in a challenge that I haven't done.

HAZHIR Yeah, I think there might be a challenge that goes through that. But this is a non-trivial problem because you
RAHMANDAD: need to create explicit demand and supply and then calculate how much they are being served. Now, this maximum project completion rate is then compared to this desired project completion rate that we had here, that kind of drains the projects.

And then you have the quality of fulfilled demand coming from novice fraction, effect on quality. So if you have novices, a bigger fraction of workers to be novices, then your quality goes down. And this is important, to have the same quality memory loss as this project depreciation. And the way you are enforcing it is using the same time constants, time to depreciate, and the same delay order.

So that is fine. Mathematically, it gives you the same result, but the better way to do it is actually to use the project depreciation to drain this directly because then, if you change the time to depreciate, that's already in both places. But if you change the order of delay, for example, here, you don't need to come and change it here as well.

AUDIENCE: All right, I thought the project depreciation's a project.

HAZHIR That's OK. You have a transformation of the units. So you need a unit change.

RAHMANDAD:

AUDIENCE: I guess the novice fraction changes? So a project coming in, let's say, does not have the same [INAUDIBLE]. So I can't--

HAZHIR Let me think. So you're tracking the quality as a--

RAHMANDAD:

AUDIENCE: As [INAUDIBLE].

HAZHIR As another co-flow, basically. It works still. The way you have to do it is to calculate the average quality. So the
RAHMANDAD: average quality would be the total quality divided by the total number of projects that are fulfilled. And then you multiply that back into the outflow. So this is really just a co-flow.

AUDIENCE: Why is it important in this closed setup that Russ has that quality, the memory of quality, co-flow with demand?

HAZHIR So this is actually a definitional issue. So, actually, here, fulfilled demand, the way Ross is defining it is basically
RAHMANDAD: the period over which these projects that were completed have an impact in the memory of the people in the field. So this is exactly the purpose of having this stock because you have-- as we discussed at the beginning, there is another stock, potential demand.

These are also people who are not being served and are waiting to get their project into-- to get a new project going. But the difference between these two stocks is that the first one, fulfill demand, the memory matters in terms of the reputation of the field. The second one, the memory is gone. So I think, in that sense, it is doing a meaningful thing here.

AUDIENCE: That makes sense.

HAZHIR Good. I think we touched on key issues here. Anything that you wanted? Oh, reputation. So reputation and
RAHMANDAD: recognition, we have fulfilled demand with quality of fulfilled demand, giving the average quality of fulfilled demand. So this is kind of that average quality we talked about. And there is a quality gap that-- so, basically, this is kind of a smooth function, except that it is asymmetric for the reasons that we have discussed. Makes sense to have asymmetric view.

And it is kind of adjusting quality to-- reputation towards quality, asymmetric. That's largely fine. I think it should do its-- and recognition is saying something about this demand fulfillment ratio, which we talked about as being a little bit hard, complex concept, not fully capturing what you necessarily want. But, ultimately, this is anchored towards a number around-- in between 0 and 1. And this sensitivity, what does it do? It kind of is-- yeah, it's a power exponent.

So a higher fulfillment ratio means there is more projects around that are in the memory of people. Now, those more projects around-- and then there is a memory loss that goes with time to depreciate that you're using. But you need to be careful here. Here, you're using a first order delay. And down here, you're using a higher order delay. So that's why you need to pick one of them and then use that to drive all of the outflows. Otherwise, the parallelism breaks down.

So here, the recognition memory loss should come from project depreciation with whatever unit adjustment you may need. Although, it's also somewhat asymmetric here as well. So I'm not fully following what exactly is happening here. So you are adjusting the recognition towards indicated recognition with this time constant. But also, you're eroding the recognition. So in a steady state, this stock will always be below the indicated recognition. Is that what you wanted to do?

AUDIENCE: Let's think of a more extreme case, I guess. If there's no any more project, people are going to start forgetting the recognition is going to go down.

HAZHIR Can you speak up?

RAHMANDAD:

AUDIENCE: Oh, if there's no project anymore, then people are going to forget it over time. The recognition is going to go down?

HAZHIR Yes, but then if there is no project, your demand fulfillment ratio becomes close to zero. So your indicated
RAHMANDAD: recognition goes very low.

AUDIENCE: I guess that's the confusion because, fulfilled demand, all sorts of depreciation. So I guess I didn't need that, recognition memory loss.

HAZHIR Yeah, so this is creating-- this is messy because you had two different types of formulations here. One is a goal--
RAHMANDAD: kind of going towards an indicated value. This is just a smooth function, pretty standard. That creates an anchor there. Then you have this recognition lasting, which is just an outflow. It's just getting things-- basically, there was nothing else. This will go to 0. So that creates another anchor. And this stock is kind of lost between these two.

And the reason for why it is lost between the two is not clear. So that's why I don't necessarily like that approach. Now, let's say it was moving towards the indicated recognition. So now, what the field attractiveness does, what is it? You're multiplying the two. These are kind of apples and oranges. So one is saying, how many projects have been happening in some way, that fulfillment ratio thingy? It's basically about the scale of the impact. This one is about how good those things are.

Now, putting aside all the challenges with both of the formulations, multiplying how good something is with how big something is doesn't necessarily give you a good single metric. So if the reputation is bad, let's say, knowing that-- a lot of people knowing about it should actually make it go down compared to come up. Whereas, if the reputation is good, a lot of people knowing about it should speed up the adoption.

So in a way, the valence of adoption should come from the reputation, whether it is going up or coming down. The speed of adoption, the adjustment time, could come from this recognition from this size. So they should have two different types of impacts rather than lumping them together to this single attractiveness. Does that make sense? Great. So we spent quite a bit on this, but I think it was a good conversation because a lot of these equations come out.

AUDIENCE: Just really curious, if there's some time, can you remind me how you did quality, how you formulated quality?

HAZHIR So the quality is coming from the ratio of novice versus experts here. There are kind of issues to tackle here
RAHMANDAD: because it is not just the novice versus expert fraction that matters. It is also about how much of the time of experts is spent on training novices versus how much of the time is on doing the projects. So the time on doing the project by novice versus the time on doing the project by experts is what is kind of really driving it, not just the two numbers. But as a first order approximation, this is fine.

AUDIENCE: I just wanted to see.

HAZHIR Yeah, OK. Let's switch to-- let's see. What's this one? This is Jason's. Let's get about-- get started with the
RAHMANDAD: projects. So you have?

AUDIENCE: So when you're regeneration?

HAZHIR Yeah, so you have people coming into the system with a fixed rate. This is kind of people who have new projects
RAHMANDAD: that might be relevant. And you're thinking of these as people. So these are as clients, basically. So we have new clients coming in from new use cases in the world. Some of them learn about it. Then with a delay, they decide to kind of go and get their project tackled by this field.

AUDIENCE: Or someone else.

HAZHIR Or someone else. So there is kind of a finding solution. There is a fraction, that they become clients. That makes
RAHMANDAD: sense. Then these projects are started and finished. And so we can look at those. And then project delivery impacts recognition. There is a delay. There is a kind of a fading of recognition. So this is similar idea, though this one is about the scale of how people know about it.

Then you have, also, the recognition of the alternatives. So that's fine. And then the backbone makes sense to me. Once projects are done, they're done. So in a way, this is a little bit of a different conceptualization, even though it's not that far from what Ross had. But this one is saying, there are kind of flow of projects coming into the system. They get allocated between these two types. And then we don't care about them later, once they're out. They just have a recognition reputation for a while.

Here, another addressable market. Time to become aware depends on awareness penetration. So let's look at this time. So it has an effect of unaware fraction on time to become. And then what is unaware fraction? Fraction of population that is unaware, search time. So the bigger the fraction of population that is unaware, the slower is the time to become aware. Is that the idea?

AUDIENCE: The bigger the fraction is,

HAZHIR Yeah, so you're dividing-- so it's 1 over the fraction of the population that is unaware. So the larger that fraction,
RAHMANDAD: the smaller this.

AUDIENCE: Yes, that's right.

HAZHIR And, therefore, the smaller this is, the smaller it's time to become a verb, which means the faster that people
RAHMANDAD: become aware.

AUDIENCE: That's right.

HAZHIR So what's the logic there?
RAHMANDAD:

AUDIENCE: Logic is, it's harder to-- if you have a large fraction of people who are unaware, in that situation, the people right at the margin are going to find it pretty quickly. But as that fraction decreases, those people were harder to find, or harder to connect or recognize the solution. So it takes them longer. It's like it's going to improve--

HAZHIR There is a logic there about low-hanging fruits, but I don't see it as a first order need here. And the reason I don't
RAHMANDAD: see it as a first order need is that you already have that feedback directly in this link from another addressable to becoming aware. If you don't have another addressable, nothing will happen here. So you have a first order effect that just says, if there are not many unaware people, you wouldn't have newer projects. So changing the time constant means the fractional rate of becoming aware is higher when fewer-- when more people don't know about it.

AUDIENCE: Yes.

HAZHIR That is a little bit of an iffy proposition. I'm not buying that just because you say that. I need some evidence to
RAHMANDAD: buy that proposition. But it's not going to do a lot here. Although, it actually can do quite a bit because, right now, with this sensitivity of 1, you're basically making the time constant to be 1 over the unaware addressable fraction. So it is unaware divided by total population. So when you then divide the time by time constant, the equation here becomes unaware to the power of 2 divided by this minimum time divided by total population. I don't know.

AUDIENCE: Total population is a constant, yes?

HAZHIR Very good point. That's the next thing, that the total population is right now a constant. But total population,
RAHMANDAD: what is it actually?

AUDIENCE: You're right.

HAZHIR It's like--
RAHMANDAD:

AUDIENCE: It's not doing anything.

HAZHIR I don't know what it is trying to do. No, the point is that, if you're talking about all of the people who are in one of
RAHMANDAD: these three states, or maybe perhaps even in the recognition state, you should track that explicitly by adding those people. If you mean something else, then you need to be explicit why that something else is important here. It's not very clean here for the way it is working.

But then we have a time to find solutions. And then they choose which fraction becomes interested in your field versus the alternative field. And that comes from the quality. So there is a relative quality. You have a reference quality, and you have a perceived quality. So I assume reference quality is for the competitive field you're compared to.

AUDIENCE: You [INAUDIBLE]. I thought about it as, what is the quality when experience is at its reference level?

HAZHIR So that's very important difference. So I don't want to interpret it in a different way.
RAHMANDAD:

AUDIENCE: So I--

HAZHIR Because right now, the decision that is happening here-- fraction who become clients-- is determining, what
RAHMANDAD: fraction go to the alternatives? And what fractions come to us, correct?

AUDIENCE: Yes.

HAZHIR So if that is the definition, then this should be driven by the relative quality of us versus the alternative. So if
RAHMANDAD: your reference alternative is defined as them, then it works. If it is defined as r maximum quality or something along those lines, you are double-- using the same variable for two different reasons. And that's going to be problematic.

AUDIENCE: That makes sense I didn't think that.

HAZHIR Good. Then with that in mind, we have relative quality coming from your perceived quality. Your perceived
RAHMANDAD: quality has a symmetry in its adjustment. It comes from indicated quality. That comes from your relative experience. And it has its own parameters. So we have to see where the relative experience is generated. And this recognition, it was driving what--

AUDIENCE: So the recognition is driving the allocation from-- I thought about it as driving the fraction you choose. Oh, that's the awareness of penetration. I'm sorry. So the recognition, if you look at becoming aware--

HAZHIR Oh, OK. It is coming partly from your recognition versus the other's recognition.
RAHMANDAD:

AUDIENCE: So it takes longer.

HAZHIR But let's see, what does this--
RAHMANDAD:

AUDIENCE: It's just a fraction, so what share of recognition belongs to our field versus the other field?

HAZHIR Oh, yes. That is now a weird formulation here. So if we have a lot of recognition for the other field, this
RAHMANDAD: formulation shots off becoming aware. And when it shots off becoming aware, no field, neither ours nor theirs, will get any solutions, will get any customers. So that just doesn't make sense.

AUDIENCE: Yeah.

HAZHIR Then we have projects. Sorry, we were up here. So perceived quality is coming from indicated quality, from
RAHMANDAD: relative experience. Relative experience is coming from total experience versus reference experience. Reference experience is just a fixed number. That's kind of a little bit of a red flag for me, but we should come back to it and see if it makes sense. So let's see, what is total experience? So total experience is the stock of experience that is a core flow for the experienced employees.

AUDIENCE: Yep.

HAZHIR So that is stock of experience. So here, OK, let's actually look at this formulation more closely. So we have
RAHMANDAD: rookies join. There is a time to join, time to leave. There is an indicated rookie. Indicated rookie comes from feasible annual rookie per-- annual projects per rookie. That comes from rookie productivity, work hours.

This is kind of calculating how many rookies-- how many projects each rookie can serve per year. And you look at the gap between the service capacity from expert capacity and rookie capacity versus the demand for desired fulfillment rate. So that does make sense. So you have just current projects, desired fulfillment time. That gives you a service gap, comparing these.

AUDIENCE: And you can only bring in rookies.

HAZHIR So when that gap is positive, you get an indicated rookie that is positive. If it is negative, you get a negative
RAHMANDAD: rookie. Although, you have blocked it from being negative. So, therefore, indicated rookie cannot become negative.

AUDIENCE: That's true.

HAZHIR But it could.

RAHMANDAD:

AUDIENCE: Yeah, no.

HAZHIR Maybe even it should.

RAHMANDAD:

AUDIENCE: Yeah.

HAZHIR Because you are using this flow as a two-way channel, you don't want to remove the signal that, ah, there is not
RAHMANDAD: really much work to be done in this field. And based on that, there is not much of a service gap to think about. Now, service gap here is accounting for how much total capacity for service we have versus how much total demand we have. And that creates-- So that shouldn't be creating your indicated rookie. That what it should be creating is the indicated extra rookies you want to have or, yeah, extra rookies.

AUDIENCE: Very incremental, yeah.

HAZHIR That is, this should not be compared with rookie employees down here. Ooh, my God.

RAHMANDAD:

AUDIENCE: It's not that bad.

HAZHIR Indicated rookies are bigger than rookie employees. Then it is indicated rookies minus rookie employees. So this
RAHMANDAD: is just the time constant. You could use the if-then-else in the denominator for the time constant you use. But you have assimilation time, so I'm not sure. But for now, either way, you are comparing indicated rookies with rookie employees.

AUDIENCE: Yeah.

HAZHIR So if my indicated rookie was a hundred, what does it mean? It means I'm a hundred rookies short of the existing
RAHMANDAD: demand. So I needed to have a hundred rookie more compared to what I currently have to be able to serve the demand.

AUDIENCE: Yeah.

HAZHIR The way you are doing it here, you're taking all of the existing rookies-- you may have a thousand rookies-- and
RAHMANDAD: you're indicated as a hundred. So this gives you minus 900. So it says, let me fire these rookies that I have because I just need a hundred. No, you don't need a hundred. You need a thousand and 100. So that's what I'm saying. It is kind of a first order problem that is missing here.

So rookies are now adopt, join. They assimilate with an assimilation time. So this is the simplest formulation. It doesn't care whether they are working or not, doesn't care whether there are experts to help them or not. And then they become experienced. The experienced folks would leave with a time constant as well, just as-- well, rookies would not leave unless they are removed because of this gap.

And if the gap was correctly formulated and could go negative, then it could work fine. Right now, it is not really doing what you want it to do. It doesn't get feedback right now from availability of projects and so on. So that's something to keep in mind. Then we have this co-flow of experience. So as you assimilate, you add more experience with--

AUDIENCE: That this was kind of ad hoc, but the thought was, if there isn't a project or work availability, the quality-- the amount of experience accrued goes down.

HAZHIR So this is actually important. You are doing two different things inside this flow, experience accrual from
RAHMANDAD: assimilation.

AUDIENCE: Yes.

HAZHIR One is you just get new people assimilated. They come in. Each person who comes has some level of experience.

RAHMANDAD: As a rookie that has just become-- gets the level of experience, that is usually kind of a fixed number.

AUDIENCE: I think it is working out to be a fixed number here.

HAZHIR Then I don't need four or five different things going into it. And it's probably not a fixed number because you

RAHMANDAD: have utilization.

AUDIENCE: Without that utilization, it's because I'm multiplying--

HAZHIR But you also have assimilation time.

RAHMANDAD:

AUDIENCE: Minus the rate, so it could--

HAZHIR So, conceptually, it is assimilation rate multiplied by experience per assimilating rookie.

RAHMANDAD:

AUDIENCE: Yes.

HAZHIR Something like that. That's fine. You get that. Now, maybe you're calculating it this way. So you're saying, rookie

RAHMANDAD: effective work hours per unit of time multiplied by assimilation time is the total hours of experience that rookies come with it. So, as such, that is fine. Only, you don't need the utilization. Then once they go in, you are saying, if they are being utilized, they gain more experience. And if they are not being utilized, they don't gain more experience. Maybe that is what you had in mind.

And that is a separate inflow. It is about inflow of people who are experienced, inflow of experience from just working, which you are capturing here from experience of working because experienced employees multiplied by effective work hours multiplied by utilization. That's good. You already have that. You don't need the utilization again in this beginning flow. And then you have experience loss, which is a standard. So that's good. So this total experience is what we had up here.

AUDIENCE: Yeah, that drives quality.

HAZHIR Yes. Now, that total experience is being compared to this ad hoc reference thing. You just got from there some
RAHMANDAD: number and put it here.

AUDIENCE: Yeah.

HAZHIR Don't do that. It's not going to work. It will create headache for you. It might be orders of magnitude off. It needs
RAHMANDAD: to be anchored to something about, what is the experience if everybody, for example, was a rookie or something, that--

AUDIENCE: I think a lot of what I'm realizing is because I hadn't-- I didn't have a clear story on the demand side about separating the demand and what the downstream implications of that were, it all got very muddled.

HAZHIR Yeah, so I think we covered key issues here. We could go into a couple more formulations, but I'm interested to
RAHMANDAD: see one more model. So let's look at another model. Anybody wants to volunteer their model for next round?

AUDIENCE: [INAUDIBLE]

HAZHIR Jake is shaking his head. [LAUGHS]

RAHMANDAD:

AUDIENCE: [INAUDIBLE]

HAZHIR Alban. Let's go to Alban's model. So let's look at the not awarded potential clients. They become awarded
RAHMANDAD: potential-- aware, sorry, not award. Aware. Awarded, awarded awarded is the word. It's OK. And then they can become active clients or not. And you have a total aware population versus indicated total aware population. So this is potentially a two-way flow. If they indicated it's below, an indicated fraction of population that is aware comes from the completed projects and their effects.

So if you have a lot of completed projects, that increases this effect. So that increases the fraction. So big picture, you make more of artifacts projects, you increase the fraction of population that may be aware of this methodology, this tool. And, therefore, that increases the population that becomes aware. Now, that's all good with the caveat that people forget about things. New generations come. So I would have an outflow from these completed projects. This is remembered completed projects and that. Hassan?

AUDIENCE: In that chain, I had something similar to that chain up there. If the indicated total aware population goes down, and we have a lot of active products, can't this stock in the middle get negative? And I have trouble--

HAZHIR Very good point. So that's absolutely right. And that is why you actually need another layer of protection, which

RAHMANDAD: is a flow from aware population, potential clients, back to becoming aware. And this part is fine because this is already kind of the maximum. So that the outflow moving backwards cannot exceed aware potential population divided by this awareness time constant. So that should set a maximum, minimum rate for backflow.

AUDIENCE: Does that make sense, that it's like a sharp corner?

HAZHIR It is OK as a first order approximation. You're right. It would create a sharp corner, but it is not too bad. So this is

RAHMANDAD: actually-- in the assignment 4 of the basic SD class, we have this same issue. And we add that formulation. But that was a good catch. That is important.

AUDIENCE: Oh, I had the same.

HAZHIR Yeah, so now, total aware is pretty clear what it is. Now, people become aware after some time. So now we have

RAHMANDAD: another question, whether these people become active clients. They are using the-- and these are in clients. So this is in clients. And then clients can have projects. So this is demand per client. So conceptualization is a little bit different here. So these are longer term people. These are people who are proponents of the field. They are using it with some rate, that service demand per client is the rate by which they are generating service.

And I kind of like this. It's kind of, in some ways, more useful way of breaking down people because it is not the same as projects. There is more inertia in people and their mentality than in projects. Projects are activating and going away. Then we have the quality reputation that impacts whether these people who are aware are willing to use it or not.

So that indication comes from the total aware population and quality reputation. And quality reputation, based on this formulation, should be designed so that a quality reputation of 1 basically means every aware population, every aware person, wants to be an active client. And a quality reputation of 1-- 0 means none of them want to be. So that's kind of just to have the meaning of quality to be matched here.

The formulation here is just similar to the other one, indicated minus active divided by time constant. If indicated is zero, active is a number that is larger. It becomes a one-way flow the other way. This is robust. This wouldn't have a problem that we talked. So that's good. Yeah, now, we have the demand coming from these active clients. They initiate projects. These projects take some time.

So there is a potential completion. There is a max completion, very standard formulation. That potential completion comes from expert versus novel completion rate that come together to create a total completion rate. The expert completion rate is coming from the productivity. Then you have feedback, effect of schedule pressure, et cetera, on the right-hand side. It's OK. It might be an overkill to have that. I'm OK with not even having that, so to have, basically, a fixed productivity. But there's nothing wrong with it. It's nice to have something extra here.

Similarly, you have it for novices. They have a fractional productivity that gives their total productivity. And then, again, some feedback from schedule pressure. Now, you have two desired completion rates for novice versus experts. So you are creating these more complex schedule pressures.

AUDIENCE: So the assumption is that we first allocate tasks to the expert? And then they can adjust their work hours, but to the max extent. And then whatever is that, you have to push novice to do more.

HAZHIR Got it. Got it. That's good. That's fine. I think that's actually a cleaner formulation than assuming kind of equal
RAHMANDAD: allocation. I might have opted for something that allows us to move between the two extremes, so that a better matching algorithm allows you to do one versus the other. But this is a good starting point and the formulation we haven't captured before.

So, basically, active projects create a desired completion rate that, minus what the experts are completing, gives the desired completion rate for N. And E completion rate is coming from here. E completion rate, yes. All of that makes a lot of sense. Let's look at the learning rates now. So there is joining of novices, average monthly new joiners of the field, and effective demand on joining. Yeah, so this is basically setting a maximum. Is it average or maximum?

AUDIENCE: Average.

HAZHIR So this effect, can you go above 1 and below 1? We'll see. Relative demand is coming from perceived demand.

RAHMANDAD: That's fine. And then average demand of alternative fields, so what's that? It's kind of comparing this field to some other alternative field to give a relative demand. So this part, I'm not quite following why you are formulating this way. Can you tell a little bit more, Alban?

AUDIENCE: Yeah, so I'm thinking people deciding to join a few are being fulfilled. And assuming that their signal is only demand, so they compared this field versus another field in terms of the attraction.

HAZHIR Yeah, but the problem with that is that people don't look at the demand alone. They should be looking at
RAHMANDAD: demand versus supply to see, what is the room for joining, or not joining, or kind of expansion? And that usually comes from a signal of delivery delay, or reputation, or something else. So this one is kind of driving the whole joining process with two external parameters.

One is this average monthly joining, and the other is this average demand of alternative field. Both of them are this external anchor, as I can't fully see how it impacts all of the dynamics. But they are disjointed from the rest of the story in some sense. So I like this to be kind of focused on serving the demand. Kind of, Jason's formulation started to get to that, but then it made some wrong adjustments.

But the idea that, yes, there is this much demand. There is this much supply. There is a mismatch. That mismatch motivates people to join because they see there is room for growth here. There is kind of business coming in, something along those lines. And then you don't need to have this external parameter. It can be all fairly endogenized into the adjustment of the field.

Then you have these people quitting. Some of it is coming from the fact that they don't have enough demand. That's all good. I haven't looked into it, but the idea is correct. Then you have the learning time that is coming from just some maximum and minimum. And then there is this adjustment based on practical experience.

So you are calculating how much the novices are actually actively working. So if they are not actively working, it becomes the maximum learning time. And if they are actively working there, it becomes the minimum learning time. That's nice. I like that. It's kind of a clean way of capturing the fact that, if novices are not given projects, it takes more time for them to grow.

Now, you don't have the impact of experience, folks, training novices, perhaps. So in a well-coordinated field, when there is not much demand, experts can actually help more with training of the novices. So the training time may actually shrink, perhaps. So we could come up with alternatives there. But this is a good starting point.

And then you have the effective demand for quitting of the experts as well. That's all fine. I think the rest comes together cleanly. Then let's look at the reputation. So quality reputation comes from the expert versus novel completion rates, so E completion plus N completion multiplied by this quality fraction divided by E completion plus N completion. So, yeah, that that's fine for indicated quality.

Now, what I want to highlight here is that, right now, this is a little bit more subtle. So the way indicated quality is formulated right now is very tightly connected to your stock and flow of novice versus experienced. Does that make sense? So it's really about this relative quality and what fraction of people are in these two stocks.

What fraction of people are in these two stocks really, at the end of it, comes back to these time constants for quitting and for assimilation of the two, guys. That's kind of what determines the core under it. So when these two come together, they indicated quality has an anchor based on those time constants and based on this quality fraction. That anchor may not map exactly into the anchor you want for quality reputation impacting the indicated A .

That is, the built-in implicit anchor that you have from the workforce sector doesn't necessarily give you the minimum and maximum of this quality reputation that you need for indicated A . Remember what indicated A was. Indicated A is about people deciding, this is an attractive service. This is a good quality service that they want to use. So to give you an extreme example, if the indicated quality only changes between 0.5 and 0.6, that's the range of feasible things that may happen with these parameters. Then your indicated A will only change between 0.5 and 0.6. It doesn't have much flexibility beyond that.

AUDIENCE: But it is not only the stock of the expert novice because this is a completion rate. And then if you don't have demand, none of us will push to do no work. So the completion rate by novice is zero.

HAZHIR Yes.

RAHMANDAD:

AUDIENCE: So they can go a wide range, not just incremental stuff.

HAZHIR That's fair. So I think it can go to 1 when you don't have projects for novices. It cannot go to 0. The lower bound
RAHMANDAD: might not be very high. So if you have a lot of demand, it is still-- then it is bounded by that parameter. So the range is probably on the top. It goes to 1, of course. On the bottom, I don't know. But there is this inherent anchor question there.

Now, you do have a little bit of control over it with this quality fraction of N . If you think of it as a free parameter to play with, that could shift the lower bound a little bit. But you don't want that because now it is playing two different roles. It's a little bit tricky. So, anyway, it's an invitation to have just one more free parameter to make this adjustment of quality reputation to indicated A . Something there might benefit from another degree of freedom.

But, otherwise, this looks pretty good. I think kind of-- so that factor and this anchoring here are the two that I would highlight. And if we run this before we-- oh, now, you have a field that is growing. Now, if these folks are pretty lousy, you still get them to be growing. And part of it is that the completed projects continues to push the not awarded-- not aware potential clients.

So this will always be this total desire-indicated fraction aware will go up. Although, it is already going to 1 very quickly. So then there are these parametric assumptions. Is it reasonable to assume, in five years, everybody would want to know about it and so on? But it's interesting. If this indicated total aware population is 1, that, very quickly, why don't we see more movement? Because not aware is actually pretty high. And this time constant is only six months.

So something-- there is a big gap here. That's not clear to me, what is happening here. So I think it's a good time to take a break, but lots of good formulations and interesting challenges. I think this was a more challenging project. And I think you guys, each of you have some good formulations that capture one part of it.

We haven't yet had one that brings all of them fully together, but this is good. So let's take 10 minutes of a break. When we come back, we can focus more on your project proposals, get any questions there answered, get some of your feedback for your friends. And if you had more time, we can go through another couple more formulations as well.

Let's come back together, get us started with your discussion of problems, problem definitions of your friends. So I'm going to those. So we had it. Was it with comments from classmates? Good. So we have a few here already. That's great. So I think several of you have provided feedback for different people. Sercin and Jason have been lucky to have lots of feedback, somehow by chance.

AUDIENCE: Wait, oh, that is weird. And I haven't done one yet.

HAZHIR So you're the free rider today.

RAHMANDAD:

[LAUGHTER]

Why don't we just go in this order and get reactions? So I think this is Hannah. She had a feedback on Cathy's project. So, first of all, because nobody knows what each person's project was about, I am happy to open these, but-- and these are on the first versions of the project. So Cathy's project was about literacy and book sales.

So her starting point was something that looks like a puzzle, that we have had declining literacy, but book sales seem to be increasing. And then she's coming up with hypothesis for what might be explaining that. So, Hannah, kind of what was your reaction as you went through this? And did you comment on the first version or on the later version? I haven't--

AUDIENCE: This is the first version.

HAZHIR Good. So that was the plan, just because I wanted everybody to go through a more raw problem definition that

RAHMANDAD: helps see the challenges in defining the problem more clearly. So rather than reading through this, maybe you share, Hannah, what was your reactions? And what did you find potentially interesting, challenging? How would you think about making the problem more clear?

AUDIENCE: Mm, my first impression was that the problem was very interesting. It was something I never heard of before, and the graphs were very helpful. There was graphs towards the end. And I think, for me, the only thing that I was a little bit-- I thought could use a little bit more improvement was just making the problem itself a bit more specific.

It seemed very broad. I think because there was a lot of really great background information, but the problem itself towards the end seemed like it was very broad. It was just like on goods, generally. And maybe it could have been just focused more on the books that you mentioned in the beginning. Yeah, but I think, overall, it was very interesting. I think Cathy explained the dynamics pretty well in the background information.

HAZHIR Good.

RAHMANDAD:

AUDIENCE: Thank you. Yeah, I think in the revised version--

HAZHIR Yeah, could you speak up?

RAHMANDAD:

AUDIENCE: Oh, yeah, sorry. In the revised version, I think you gave a similar comment of, don't generalize to everything, but just focus on books. And so, yeah--

HAZHIR So can you now summarize, what is your updated kind of project definition based on the feedback that you have
RAHMANDAD: received?

AUDIENCE: Yeah, so based on the feedback, I think, so the puzzle is kind of increasing book sales and decreasing reading rates among adults. And I was looking around for book sales data, and I actually think there's better data for library circulation. Although, I haven't found that anybody's compiled it. So I might have to do some little-- take a couple of states or something and do some quick analysis for that.

And my hypothesis for what's driving these kind of divergent trends in sales versus reading, as surveyed, is that people have decoupled the value that you get out of reading a book from the value that you get, kind of signaling that you are among pop culture circles who have the book and who are talking about the book, and how these-- mostly on social media, like the conversation about the books on social media includes kind of full summaries and all the plot points. So you don't even really need to sit down and read the book to have something to add to the conversation any longer.

And then I think last time we spoke about it, it was pointed out that that's kind of one hypothesis for how these trends could be generated. And then another hypothesis for which I found support online and looking into it is that there are heterogeneous groups of readers, and that the differences between people who are reading a lot more and people who are reading a lot less are actually growing.

So, whereas, maybe the average of group A and group B would be eight and 12. Now it's like three and 20 or something like that. And so these divergent trends could also potentially explain the difference between consumption and sales. And so I'm going to model-- I'm going to try to build a model with both of those and see whether both of those mechanisms can generate the pattern. And I think maybe it's some combination of both as well.

HAZHIR Very good. So that was a nice summary. So, basically, this is kind of-- so it starts with a nice clean puzzle, kind of surprising. Assuming that the data is OK, now we don't really have or haven't seen the data on sales of the books, so to be 100% sure on that. But literacy, at least, it is a couple of graphs in terms of average number of books read in the last year, for example, has been going down.

Percentage of people who read any books in the last year, it's kind of stable, a little bit going down. So there is evidence on the reading side. Now, assuming that the book sales hasn't gone down or perhaps even increased, then we have an interesting puzzle.

AUDIENCE: Which I think is a relatively safe assumption. One thing you might have heard about is that Barnes and Nobles were slated to close, and now they're opening stores instead. And Barnes and Noble, which is a huge book retailer here, has said that all of their trends have reversed and they have really positive outlooks thanks to the social media trends.

HAZHIR Yeah, that's very interesting. So, anyway, good starting problem. The first version of the proposal was a little bit kind of unclear, what was the exact hypothesis? You had this idea of social media creating some kind of a demand for books that is not real demand. That is, people are not reading the books. They're just buying books. So that's, ultimately, one hypothesis that is now clear.

We added in the conversation the kind of possibility of bifurcation, of having subpopulations that are reading a lot more, and then there's-- and I think making those hypotheses, turning them into quantitative model alternatives, is a nice one. It's kind of in the right scope. So great. Go with it, and we'll see how things come together. Next one, let's-- so you should share your overview, and then Gerardo can share his feedback.

AUDIENCE: So the overview of my problem is on diabetes care, that the prevalence of diabetes has been increasing in the past few decades. But the problem is that the control of this condition is very low in many countries. So treatment adherence for people that have diabetes is very important, but this treatment adherence is also unsatisfactory in many countries.

And its treatment adherence depends on two factors, patients' adherence, like changing their lifestyle or being aware of their condition to taking the medication. And the other factor is the health system that has an important role to improve the accessibility of patients. So in this model, I try to have some reinforcing loop that treatment adherence influence on the control of patients. If this control increases, it reduces the incidence of complications.

So diabetes is a disease that, if it is not controlled, it leads to some complicated conditions, such as cardiovascular diseases or other conditions that pose more financial difficulties to patients. So this is the overall problem. So I have received some feedback from Hashir and another feedback from Gerardo that is really interesting.

For this model, I try to conceptualize or structure the progress of patients from the healthy population, that they are at risk. So patients, like people over age of 30, they are at risk of diabetes. And they might go to the next level of prediabetes. So prediabetes can be controlled, and then people can go back to their healthy population. And then we have the diabetic patients and control population, or uncontrolled, or population with complications.

And then I'm going to have maybe the other-- next step of this model is to subscribe the population with different ages because the age is important for people that are at different urban areas or rural areas. This kind of stuff also affect the patients' situation to this progress of their disease. And then I'm going to have the test, the different interventions, like if we have the increased awareness, how it influence on this progress of this disease, or some other possible interventions that are more effective.

HAZHIR So, Gerardo, do you want to share some of your feedback, what kind of-- at least on the first version of the draft
RAHMANDAD: that you read through? And I think Sepida highlighted a few more kind of solutions as well or updates as well, but, yep.

AUDIENCE: [INAUDIBLE] but [INAUDIBLE] really being said. So, basically, I just say, my feedback is to improve how the model will be built. And so apart from the description in the [INAUDIBLE], step-by-step workflow. And so with this, just a feedback, one, for example, is to try to-- or my mind came up on these perception of importance, for example, of screening in the population.

So it's sort of a feedback loop related to awareness of disease and awareness of how the private screening could be important to this problem. And so it could be really important feedback loop. And another one is related to the-- and e-health device that kind of improve the other-- the problem. So I just-- inside a feedback loop to--

HAZHIR Thank you.

RAHMANDAD:

AUDIENCE: [INAUDIBLE] that, to me, would be-- that's an interesting problem for her.

HAZHIR Yeah, so this is kind of a pretty clean problem in terms of well-defined space. It's kind of, diabetes is well known.

RAHMANDAD: And for tackling-- but it is also a complex problem. There's a lot of research in this space, so you're not the first one tackling it. That is good in terms of learning from it. But also, that is complex for adding, what is now new that you would be adding?

I think, as we discussed in my feedback as well, starting with a solid backbone of stock and flows, for a lot of these health scare problems with patient flows, this is a very good starting point. So it's one of those situations that I'm not too worried about seeing feedback loops explicitly at the beginning of the project. I want a solid stock and flow that kind of cuts the patients in the right groups, establishes the baseline without any longer term feedback.

There are kind of small feedbacks in every stock, how it is managed and how people flow across different states. But if you get that together nicely, you have a very solid starting point for any additional new mechanism that you want to capture. So that was kind of my main feedback, and I think there were a couple others. I think Maria's project has a similar flavor to it. That solid stock and flow, make that your primary goal. If you got a chance to add a feedback, great, but don't force yourself.

Given the limited time you have, you might just be able to get a good stock and flow structure working for that. But I think nice background, but also, good cutting of the space that you just described, people who are fine, people who are at risk, prediabetic, then diabetic with different levels of complication or not and diagnosed or not. And that kind of sets the larger state for the later work. Let's look at Jason's project. So, Jason, kind of big picture, quick overview. Then we get a little bit of feedback from Jake and others.

AUDIENCE: Well, this really has changed quite a bit.

HAZHIR Good.

RAHMANDAD:

AUDIENCE: So this first iteration is more of a perspective agenda-type question, but it's not well-bounded or concrete. And so what is it about? Basically, it's about capacity planning and how airlines are able to evaluate the quality of long-term decisions when they make shorter term downstream decisions that are changing the performance, and also altering the demand landscape itself. So this statement-- I don't remember what I said here.

HAZHIR So I would like to investigate the impact of planning process on organizational learning. Each stage of the process
RAHMANDAD: has its own planning horizon and informational cues, downstream decisions. So that was kind of the starting point. Of course, now, this has evolved. But let's get a feedback on that, kind of. So Jake, you have shared some nice notes here. So can you just summarize what you saw here that could be improved?

AUDIENCE: Yeah, so it sounds like maybe it's deviated a little bit from sort of looking at organizational learning as the exact end goal. But I guess I was curious what the actual planning levers that you were going to be looking at to see the impact on overall learning, like how you know if your planning process is actually helping, or the adjustments to your planning process is actually helping or hurting your overall deviations from matching demand.

And then I think that spelling out some of the types of shocks that you need to be able to respond-- to have the model respond to, like COVID, and like 9/11 sort of specifically, why planning in those areas is a modelable problem, even though it seems like it's just like, everything goes to 0, but spelling out some of those levers and what the expected behaviors to shocks would be.

HAZHIR Yeah, thank you. So let's hear from others who had, also, feedback for Jason. So MA.

RAHMANDAD:

AUDIENCE: That's me.

HAZHIR OK, Maria. Go ahead.

RAHMANDAD:

AUDIENCE: I was just trying to be helpful in terms of thinking about how he could operationalize the learning and what would be the signal for-- I wasn't sure if you would want to measure performance or what would be then the signal for learning. And yeah, I'm just trying to [INAUDIBLE] start thinking about that.

HAZHIR That's great. And I think kind of a specificity and clarity here is kind of the key feedback that I also had earlier for
RAHMANDAD: Jason, kind of how you get to a more concrete problem efficient. And, Ross, I think?

AUDIENCE: Yeah.

HAZHIR You had-- yep.

RAHMANDAD:

AUDIENCE: I guess it's pretty similar feedback about being more concrete about what you're actually modeling.

AUDIENCE: Right.

AUDIENCE: I guess the purpose of the model is to demonstrate where the learning opportunity is missed because you're making sort of corrections.

AUDIENCE: My kind of-- so it's evolved since now, but one of the ways its evolved is specifying learning about what-- and for the new iteration, it's learning about demand environment. There's other things you could learn, like for example, how-- there's learning parameters that you could try to learn about that govern how quickly each airline learns about the demand environment. That could be another question. I think-- what was your question? Sorry

AUDIENCE: Oh, so is it to demonstrate--

AUDIENCE: What's the goal?

AUDIENCE: Yeah.

AUDIENCE: Yeah, in the new version, the goal is to kind of investigate the consequences of-- basically, show that there's path dependence and you can have a good market environment, a good demand environment. And when you couple forecasting, which both-- which two competitors are engaged in forecasting in that environment, it can really shift kind of the realized demand and the performance outcomes. Just based on the pairing of those forecast sensitivities, it can change in the same type of demand environment.

AUDIENCE: So you still have the different timescales, different time frames.

AUDIENCE: The time scale issue of planning went away in this version, yeah. There is temporal complexity that I think will be important because you're kind of making a forecast, comparing forecasts, and then doing two things. You're adjusting your prices, and you're adjusting your forecast of remaining demand. Yeah, there's two people doing pricing.

HAZHIR So I take kind of big picture, everybody had that feedback of, OK, this is not very clear what the exact problem is.

RAHMANDAD: And, sometimes, these theoretical words, like organizational learning, temporal complexity, they're nice for selling the paper, ultimately, to the academic audiences. But it's not helpful as a starting point because it doesn't tie you to a very concrete problem to model and question to model.

We have talked about these different ways of defining problems, whether you're trying to explain a reference mode, you're trying to look at a policy or a few policy levers, or you are picking a mechanism that you have observed as kind of a structure of the system and trying to explore the implications. Do you now have a better feel which of these three may best fit what you're doing?

AUDIENCE: Third category.

HAZHIR So, basically, what are the mechanisms that you are focusing on to explore their implications?

RAHMANDAD:

AUDIENCE: Yeah, the main mechanism is this process of revenue management, where you have a flight taking off in a year from now. And every day you take bookings, you have to adjust kind of your-- so it's the mechanism of dynamic forecasting and revenue management coupled with competition. And I want to see, when you put those two things together, how do they interact? What's the kind of-- yeah, I'm interested in that parameter space when you have different kind of adjustment or nerve sensitivity.

HAZHIR And you have, basically, some hypothesis. And the hypothesis is, basically, a connection between a structure and

RAHMANDAD: a behavior that you think may be happening. And your hypothesis is that, when you have competition and these kind of continuous adjustment of pricing and--

AUDIENCE: It's pricing.

HAZHIR It's largely pricing in this case. Then you may get some inefficiencies in the system.

RAHMANDAD:

AUDIENCE: Yeah.

HAZHIR And that's your hypothesis as well. So it's a little bit of the first approach as well. That is, you actually came into

RAHMANDAD: this by the feeling internally that there are some inefficiencies in the planning among the airlines that, in the bigger picture, combines pricing and longer term capacity planning. Then you narrowed it down into, OK, let me understand the pricing side under competition to see whether I can see inefficiencies, problems, that may just come from the standard pricing process, and then perhaps connect it to the capacity planning.

AUDIENCE: Because there's two kind of time horizons, and it's too hard to think about them interacting with each other unless you've figured out how one works by itself. And then you can, perhaps, have a clear story about that second kind of longer term capacity planning discussion. And then you could couple them together and see what happens.

HAZHIR Yeah, so I think this was a good example of going through a more challenging problem definition that started

RAHMANDAD: with a feeling that things are not really doing that well in the airline industry in some planning space. So Jason has experience in that space and brought that concern, but it wasn't a very well-defined problem. Then he brought it into the question of, OK, there is this shorter term and longer term time horizons of planning.

And I think something is not working perfectly there. And then from there into, OK, let me understand this shorter term horizon with competition because I think competition matters here. So now we shifted from a reference mode type E, but not a clean reference mode into more of a mechanism that you need to model, with the idea that maybe it contributes to a problematic reference mode. And maybe the result would be that it doesn't. It's perfectly fine.

AUDIENCE: That part of it is I'm used to-- part of my challenge with this exercise is like, do I need to know in advance that it's going to yield a problem or give a specific behavior? If you did know that, then why model it?

HAZHIR Exactly. So the answer to that is always no. You don't need to know that it will create a problematic behavior.

RAHMANDAD: Otherwise, why would I build the model in the first place?

AUDIENCE: So then what is a problem statement? The problem statement is one of these three categories, where you're observing that there's some conflict or tension, potential conflict or tension.

HAZHIR Yeah, and in a sense, it doesn't need to be any of them exclusively. It is kind of a mental conversation between
RAHMANDAD: these different ways of anchoring what you're doing in the modeling. So one way is to think of it, I'm trying to explain this mode of behavior. But in this case, you don't have a very clean mode of behavior that you can explain with certainty because you don't have actual evidence of significant inefficiencies, that you can come and show me and convince me that there is some positive-- Cathy's problem does have a more clear kind of behavior over--

AUDIENCE: Just don't make sense [INAUDIBLE].

HAZHIR Just, in the first order, they don't make sense. So now everybody is hooked. But in your case, you see, I have this
RAHMANDAD: nagging feeling that there is something. And then the mechanism behind it, let me talk about mechanism. So now it is bringing you to the space of mechanisms.

And you can anchor it now to the space of mechanisms and defining the problem around that. And that's perfectly fine. But you can see these different problem definition approaches are emerging out of these problem definitions that you guys have been working on. And that's exactly what we want to have. So Sercin's problem definition is-- actually, he's not here today, but--

AUDIENCE: [INAUDIBLE]

HAZHIR Oh, yeah, OK. So aggregate business behavior under uncertainty, endogenous sentiments, macroeconomic--
RAHMANDAD:

AUDIENCE: Fluctuations.

HAZHIR Fluctuations. This is actually a pretty broad problem. So this is kind of focused on an academic audience. And I
RAHMANDAD: think we have a few feedback items. So we have-- who wants to go first? Jake, do you want to share your feedback? And then Maria, and then Ross?

AUDIENCE: Sure. So I think I found it interesting. I got a little bit confused kind of in the distinction he's making between risk and uncertainty versus this idea of uncertainty and sentiment that's being modeled. And, particularly, I guess it's being applied in the context of operations and sort of buffer planning, I guess, is the idea or what I took away from it. And it mentions as well that you're going to be working in both banks and household-like reactions to everything, as well as the firms. And it just feels generally very broad to me.

HAZHIR Yeah.
RAHMANDAD:

AUDIENCE: But so I guess I'm unsure where the crux is. Is it monitoring operations within-- operations buffer planning with sentiment? Is that the idea?

HAZHIR That's a good question. And I think, kind of, it is something that Sercin needs to answer because, basically, he
RAHMANDAD: starts with a very fundamental question of, there is uncertainty, there is risk, and there is buffering against those that households and businesses do. And how that buffering against risk may happen dynamically is kind of the problem space.

But it is less clear exactly how you narrow that down because that becomes, potentially, modeling the whole economy. And that's way too complex a problem to tackle, even too ill-defined a problem to tackle in the first place. Modeling the economy is not enough. It's just too general. You need a problem within that. Yep. Maria, do you want to share any thoughts you had?

AUDIENCE: Sorry, I forgot to unmute myself. So kind of similar to what you said, I thought it was very broad still and written for an academic audience, so kind of very far from becoming a modeling problem at this stage. So I started from the basics, let's say. So what would be the intended use of the model?

Would it be to explain the reference mode, assess policy interventions, or find the implications of mechanisms? Yeah, is it for theory building or sensitivity exploration? Yeah, something about the model boundary as well could have been useful, things like that. Yeah, kind of going to the basics, I would say.

HAZHIR Yeah, now, so I think kind of in the second part, towards the end, it tries to become more specific, which is very
RAHMANDAD: helpful. So Sercin is highlighting that you have agents. Each agent is represented with a balance sheet. They have fund and goods that are flowing between different agents that follow the accounting principles.

So it kind of gives a big picture view. In fact, the agents are divided into households. So they may buy goods, which means you give money to somebody and get goods from them. You have firms that are selling goods, basically, and producing goods. You have banks that lend money to people. But if you try to build all of these agents, this is really a full economy model. There are models like this that people build. I'm not saying you can't do it, but it is pretty ambitious.

Sources of inertia, it's capital stock for firms, inventories of the firms. So if you're accounting for inventories in these dynamics, that's yet another layer of complexity. It's kind of, you're going into more detail for businesses. Liabilities, cash is stock, and then you have sentiment, which is a whole different space. And then reference modes, income, sentiments, potential oscillations, sensitivity of parameters of the real sector with respect to sentiments and so on. Ross, do you want to add something?

AUDIENCE: Yeah, I guess it's similar in the sense that simplification, maybe you can use household demand instead of household-- or interest rate instead of banks, and simplify from capital [INAUDIBLE] to assets and liabilities. Another question was like, sentiment sounds like something irrational, in that it is a function of market signals, like growth and volatility. I was curious how, in general, someone would model something irrational.

HAZHIR Yeah, so this is-- now, Sercin is an economist, and so he has experience working on these problems. So if
RAHMANDAD: somebody without experience would have come and proposed this, I would say, no, don't even get us started. But this is kind of what-- he has spent enough time to know the lay of the land. And there is kind of good modeling that is a starting point he can draw upon.

But still, without a more clear problem definition of what you want to do with this model, it is a little bit harder to say, what is in? And what is out? So is it a prediction tool at the end of the day? Is it a new theory development tool at the end of the day? That you would say, OK, nobody has looked at these alternative ways of projection into the future of opportunities to invest or opportunities to consume.

And this alternative way of future projections makes a big difference into how we understand the economy. So that's kind of going to this expectations or sentiment question. Then you need to narrow down, what exactly is the sentiment of space, expectation space, that has not been explored, that you are bringing in a new formulation there?

It might be-- so that's the type of question that I've been asking, but there is also work that does basics of this machinery. So you can actually draw upon it. There is agent-based modeling that has done this. There's kind of history in system dynamics of doing this. There are these models of macroeconomic behavior with firms and households in those models, potentially adding banks.

It's can become very complex, very quickly. So I'm worried about that. But, otherwise, the definition of stocks flows ideas are a solid space to explore. So let's see what else we have here. So we have feedback from Hannah for Oriana. So let's take a quick look at Oriana's problem. So this is the first version, and Oriana has updated hers as well. So do you want to give a quick overview of what you were interested in?

AUDIENCE:

So I'll only go over proposal one because that was already pretty convoluted. And then if I pare it down even further to clothing brands, I was thinking about the ways that the secondhand market interacts with the primary market when it comes to that because, depending on what the brand is, let's say, take, for example, Hermes versus Supreme.

For Supreme, the secondhand market, it being sold out actually increases the prestige and hype around the brand versus if you, say, look at something like Hermes, being on the secondhand market and falling into the wrong kind of consumer actually destroys brand prestige. And that's its own problem.

But the feedback from both Kajir and Hannah was that these are way too broad and I need to focus on just one thing. So in the updated proposal, I'm focusing specifically on Supreme. And so it's like, Supreme doesn't actually offer any of physical, better product. The t-shirt you buy at Supreme is just like a Hanes t-shirt with the Supreme logo on it. So they're not actually competing on quality.

So what they are competing on is like prestige, like clout and cultural relevance. But an interesting issue that comes from that, which is the people that made Supreme culturally relevant, are skaters. Skaters aren't trying to spend \$700 on a t-shirt. But the reason Supreme has the prestige it does and it sells out so quickly because, on the secondhand market, people will buy Supreme and resell it for \$700.

And so there the problem becomes, Supreme is losing out on money. If retail is \$100 and it's getting resold for \$700, that's \$600 of profit that they've lost. But without the secondhand market, they lose a bunch of that prestige that allows them to sell out in the first place, which is also mixed with, they still maybe need to keep their cultural relevance because, without the skaters and the people who actually made the brand cool in the first place, being able to wear the brand, then you just get filled with all these, I guess, quote, unquote, posers wearing Supreme.

And then it becomes very uncool. And then they, for example, no longer sell out in minutes. This was like a brief period of, let's say, four to five years. And so looking at the ways that the secondhand market and the wealth disparity interacts with both profits and cultural relevance for a brand like Supreme that really is only fighting on prestige and cultural relevance and no actual indicators of quality, unlike other luxury firms.

HAZHIR Yeah, go ahead.

RAHMANDAD:

AUDIENCE: I was thinking about how this might be analogous to some parts of ticket scalping and how, if you're buying the resold stuff and-- you wouldn't want to brag like, oh, yeah, I bought this on the secondhand market and paid \$700 for the Hanes t-shirt. And if you're buying a scalped ticket, similarly, you're not bragging about buying the more expensive version of the ticket or supporting the people who are just buying to resell it. And I wonder, yeah, if you have any thoughts on the people who are just getting in the queue to buy it up really fast, just so that they can sell it at the increased markup and how that--

AUDIENCE: How does selling out impact a--

AUDIENCE: Yeah, but then people's perception of, oh, why did they sell out? It would shift from, oh, because it's very popular and everybody who bought this wants to wear it to, oh, this is kind of like a washed out or saturated brand, and it's just all of these resellers buying it up and then selling it at a super high margin.

AUDIENCE: Yeah, I feel like they're similar in the sense of, it's kind of that idea of, oh, it's all these posers or people who don't really like the music getting it. But I think maybe it's slightly different because what I'm thinking with artists, let's say a musician, is like, at the end of the day, anyone can listen to the music. So you're still going to have fans coming just from enjoying the albums that they're putting out versus, with Supreme, if no one's wearing the clothes, the skaters can't access the clothes, which is actually the draw, let's say, to Supreme.

So if you completely cut off their relationship to the clothes, I think there is an actual collapse of the prestige of the brand versus, if Taylor Swift concerts were pretty much only like super wealthy millionaires and billionaires who could see the show, and then there's 10 people in the nosebleeds, I think she can still retain a lot of her audience, purely because the actual music she's selling and the reason she's popular will continue to remain available for everyone.

AUDIENCE: Yeah, that makes sense, like multi-channel versus--

HAZHIR Yeah.

RAHMANDAD:

AUDIENCE: Yeah.

HAZHIR Other thoughts? You wanted to say something, Jason.

RAHMANDAD:

AUDIENCE: You reminded me in that there's lots of questions in here. And I think it could benefit from taking a slice or perhaps moving slightly adjacent to the original thing that is interesting to you, which is this question about the properties of the products and the connection. You're asking this question about prestige and kind of losing contact with the original population the thing is designed for, which is what's motivating you. But maybe there's a smaller, more concrete question you can ask. What that is--

One place to explore would be like a question about market failures. Or not market failure, but, basically, you could ask the question, it seems inefficient that there's this huge secondary market. Why isn't the primary market able to capture all of that revenue? And in what ways do they rely on the secondary market to sustain the primary? So just very focused on the relationship between primary and secondary market.

AUDIENCE: As in like cutting out, let's say, for Supreme, the skater group entirely? Or what do you mean?

AUDIENCE: Maybe this is just me. This is what I thought about it. In the ticket sale space, if the retail price is \$100 for a ticket, but then on Ticketmaster or the secondary platform, people are willing to pay \$800 or-- you can sell them for a lot more. You would think the primary vendor would just sell them for that higher price, and that would be the end of the story. Why do these secondary markets kind of exist? Why are they a necessary consequence?

AUDIENCE: I guess in the fashion case, it's actually really important what specific type of brand we're talking about. So for Supreme, I think the reason why there's some Goldilocks zone between the resale and the retail is Supreme needs to figure out how to actually allow the skater group to still buy their brand.

So skaters, we'll say, are a lot less-- or a lot more price elastic. And so if Supreme starts selling their stuff at \$400 or \$500, they've now entered just the luxury brand pricing with Fendi and whoever else. And they can't compete with those brands on price because that's just not the branding they are. So they have to keep it lower and--

AUDIENCE: Which is [INAUDIBLE] the secondary.

AUDIENCE: The cultural relevance can still stay there. And the secondhand market exists to create the hype for these other people. So, yeah, I think there's an interesting tension there, but I don't think you can separate that from the cultural relevance, unless I chose a different brand.

HAZHIR
RAHMANDAD: It's a pretty interesting, complex problem, I think, kind of because, as soon as you go into goods that are not just utility focused, and hype and prestige play a role, you have very weird, different economic implications. And that's kind of creates interesting problems. So in that sense, this problem definition more starts with a mechanism that is, OK, the mechanism is demand is not driven only by price or some underlying utility. It is actually driven more by prestige and so on.

And then within that, you can go in many different directions. So I think kind of focusing on one of those directions, which is what you are doing, makes sense. So let's think about secondhand market and its interaction with the firsthand market. That's kind of a nice focus area to just, OK, what would-- and then it has it a little bit of the policy lever question as well. What is the right pricing approach? And what is the right quantity approach?

These two are kind of hand-in-hand for a brand like Supreme that could benefit from secondhand market. But how far, how long, will it benefit? At what price point would it benefit from that secondhand market? And what are the longer term implications about novelty, about being able to get it to the hand of people who create the word of mouth?

So there is quite a bit that you can explore there. And I think kind of your updated problem definition is moving in that direction. So it's kind in a good space. Great. I think last one is Ross's problem. And Gerardo has some feedback on that. So, Ross, you're also looking at this space. So maybe you can give a very quick overview of what you're thinking of doing. And Gerardo can add.

AUDIENCE: Yeah, I'm mostly focused on the primary market and how the company's going to price its goods because the price itself comes with certain trade offs. If you increase the price, you increase the desirability for a luxury brand. At the same time, the accessibility goes down. There's that trade-off there.

And then there's also different segments of demand, people who are more price sensitive, which is a mass market, who would buy less per customer, but has a larger customer base, and then less price sensitive and more sensitive to quality. In the original version, I was also thinking about optimizing [INAUDIBLE] price to see how much profit they can get sustainably. But, yeah, in the end, I just decided to go with the fixed quality cost and competition, and just look at the price strategy.

HAZHIR Very nice. Gerardo, do you want to add anything to what your observations were?

RAHMANDAD:

AUDIENCE: Yeah, so the model really is quite well-described. The [INAUDIBLE] models are really nice. And, yeah, I just had some clarification [INAUDIBLE] about, clarification of the clients to clients that are described. So my comment is that one of the two can be more related to activity and quality. And then the other one is more on ratio between quality and price, something like that.

And another comment, yeah, the clarification also about brand prestige. And the other word, I don't remember, is just we're using [INAUDIBLE]. And the last one is on the competitive phase, where in the description, it's not clear what kind of mechanism, like more endogenous mechanisms [INAUDIBLE] that provide more detail about it [INAUDIBLE] but [INAUDIBLE].

HAZHIR You have--

RAHMANDAD:

AUDIENCE: I was wondering, in your model, what else is driving desirability beyond price? 2 and quality, which is reflected in the cost structure. It's supposed to be, but I guess [INAUDIBLE].

HAZHIR So if you fix the quality, then how does price impact, basically, demand? So how are you seeing it in the updated
RAHMANDAD: version?

AUDIENCE: Yeah, there's an inertia in the price itself, the people's expectation of whether prices go up or down. And then there's a competition price, I guess like the relative price [INAUDIBLE] prestige, which is going to decide the utility of the demand. And then how much is consumed is actually going to affect it too, the price. It's like the more you see people having it, it's less desirable. So I think there are certain mechanisms there.

AUDIENCE: What brand are you thinking?

HAZHIR Rolex.

RAHMANDAD:

AUDIENCE: Yeah, something like that.

AUDIENCE: But can you really say the more you see people wearing it, it's less desirable?

AUDIENCE: I feel like--

AUDIENCE: It's definitely true for some brands.

AUDIENCE: Yeah, what type of people, I think, is the more important.

AUDIENCE: So you have to model who's wearing it.

AUDIENCE: Yeah, like conspicuous consumption, like the thoroughbred market, that's where I got the motivation.

AUDIENCE: The what?

AUDIENCE: The thoroughbred.

AUDIENCE: Thoroughbred, yeah, conspicuous [INAUDIBLE].

AUDIENCE: Yeah, that's right [INAUDIBLE].

HAZHIR So I think this is pretty interesting space. I think there was a-- Ross's problem definition is very operational. And
RAHMANDAD: the first version, also, was pretty operational. And now he has updated it. So it's kind of a nice one. We'll see how things come together. And I think with the overlap with yours, you can compare notes as well and look at each other's models.

So thanks, everybody, for those who provided feedback for their friends. And the feedbacks are there in-- and we kind of discussed their outlines as well together. Maybe we have time to go through one more model before closing the class today. So anybody wants their model to be the Guinea pig? Hassan seems to be--

AUDIENCE: Yeah, [INAUDIBLE]. Different [INAUDIBLE].

HAZHIR Sure, let's do that. So is this Hassan's model? Yes. So as we kind of, at the beginning, talked about it, you have
RAHMANDAD: novices and experts working on projects moving into these stocks. So let's first go to the projects. You have potential projects. There is an exogenous number coming in. And this is in the form of projects. So new projects come for the field. It's exogenous.

AUDIENCE: Yeah, and then the reputation and recognition feed into the indicated demand.

HAZHIR Yes, so then the recent indicated demand is based on what is the potential multiplied replied by the sum of
RAHMANDAD: potential demand and--

AUDIENCE: So sum of all the demand. So I'm looking at the percentage of all demand that is interested in the field.

HAZHIR What was the recent demand? Sorry.

RAHMANDAD:

AUDIENCE: The recent demand is the sum of the other three stocks.

HAZHIR Oh, OK. So, basically, everything added up.

RAHMANDAD:

AUDIENCE: But multiply it by a couple of-- reputation and recognition are both between 0 and 1, so the percentages.

HAZHIR So, basically, all the possible-- all the demand that is in any of-- all the projects that are in any of these stocks
RAHMANDAD: multiplied by reputation and the other thing. The recognition gives you some indicated demand, that then your demand is moving towards that with this indicated minus recent.

AUDIENCE: We still have that risk of--

HAZHIR That has the problem of reverse may get too much. So that's part of the problem. The other part is-- so, usually,
RAHMANDAD: recent demand might be much bigger. So this becomes negative quite often. And that's the problem, yeah. And then if this indicator demand goes up, now you have more unaddressed demand for the field, which experts and novices start projects because it becomes addressing demand.

And then these are ongoing projects. And then you have novices and experts delivering projects. That becomes project delivery. And then this recent projects informs reputation. Or recognition, not reputation yet. And then this expert is starting projects and novices starting projects is this flow that looks at the unaddressed demand in the field.

AUDIENCE: With the experts if we have--

HAZHIR I see. So the unaddressed demand in the whole field is going to be unaddressed demand for experts.
RAHMANDAD:

AUDIENCE: That's it.

HAZHIR And then the part that they can fulfill, they will fulfill.
RAHMANDAD:

AUDIENCE: Yep.

HAZHIR And then what remains-- hmm?
RAHMANDAD:

AUDIENCE: The function there is that the function that is tangent to y equal to x and then goes-- saturates at y equal to 1.

HAZHIR Yeah.
RAHMANDAD:

AUDIENCE: And then the gap goes towards small business.

HAZHIR Yeah, and then the rest goes to the novices. That allows novices to get started. So, basically, you have a bunch of
RAHMANDAD: projects in this stock.

AUDIENCE: Yeah, whatever can be picked up by experts.

HAZHIR Yeah, so you are kind of missing a time constant to make this transition a little-- built into the project per person
RAHMANDAD: because this needs to be in the units of--

AUDIENCE: You have the time to initiate projects there, but, yeah.

HAZHIR Yeah, but the concept, really, if it is demand, it should be-- so this is the projects that are in the backlog. Then
RAHMANDAD: you want to turn it into demand for projects or kind of allocation. And, yes, the time constant can come somewhere down here, but it is better for it to be turned into demand right when you are trying to match it with experts. That's a little bit more taste in putting the equations, but makes it easier to read because unaddressed demand for experts feels like a bunch of projects are now allocated to experts. You want to flow off. I don't know.

AUDIENCE: I didn't like what I was doing there myself because I felt like it's a little too much binary choices and discrete choices [INAUDIBLE] between everything, sort of.

HAZHIR Yeah, but, anyway, you have the sufficiency availability of experts that creates a bottleneck here. And this
RAHMANDAD: formulation is also messy. Oh, God, yeah.

AUDIENCE: Yeah, that's--

HAZHIR Yeah, I know, but unaddressed demand for experts divided by time to initiate projects multiplied by this. So you
RAHMANDAD: have the--

AUDIENCE: [INAUDIBLE]

HAZHIR Yeah, utilization ratio. So take it out of the equation. You never put so many things together, especially with that
RAHMANDAD: complex thing. You can never track what is exactly happening. But that's the idea. And then once these guys-- it takes just some time for them to do it. The way it is working, this is basically the initiation of new projects.

So it goes into the ongoing projects. And then when they finish, this goes out. So that all is sensible, at least, at the first cut is sensible. Then you have these kind of quality measures, the reputation coming from whether the experts are delivering it or the novices. That creates a reputation that is just this prevalence of expert delivery.

So you could actually combine these two into a single parameter. You have asymmetric adjustment. So all of it is fine, but goes back to this field reputation now, coming back and feeding here directly into the indicated demand, exactly the same conversation we had with Alban's model, that this needs another degree of freedom to have the right effect. Otherwise, you don't have control over it. This is about expert versus novice availability. Then we have the joining of the field. You have exogenous joining from the novices that come into the picture. So that is a little bit--

AUDIENCE: I think the only thing that I did model endogenously is that--

HAZHIR Yeah, opportunities are impacting the flow of people to stay in or leave.
RAHMANDAD:

AUDIENCE: And the leaving happens for those who are not busy, essentially.

HAZHIR Yeah.
RAHMANDAD:

AUDIENCE: Which is a lot of the stuff--

HAZHIR Yeah, but so I think the leaving part is fine. But you probably also need some feedback for the entering. Fixed
RAHMANDAD: entering is a little bit too extreme. This is good. I think we are out of time. So, basically, great job on these. So starting next week, we are moving into your personal projects. If you haven't already, please put your problem definition in the final version of the problem definition, whatever is your final version. If you have edited it based on the feedback that you have received, please just put it there.

Nelson will be looking at those when he comes to the class. He needs a little bit of a background to be able to provide meaningful feedback in the class. That's number one. If you decided at the end that, OK, the personal project is too complex or you don't want to work on it, you're welcome to work on any of these problem assignments that we have had, and improve that, and submit that into the relevant folder and get feedback on that.

So that is a legitimate alternative if you don't feel good about your problem definitions, or you don't want to work on those for whatever reason. That's also perfectly fine. Any questions for plans for the coming weeks? So, basically, the plan is, each week, submit any update that you have. We have a conversation. We try to give feedback. And, hopefully, in a couple of weeks, we will have some interesting, clean models. Great. Thanks so much. Oh, go ahead, Maria.

AUDIENCE: [INAUDIBLE], sorry. Just a quick question. So for next week, we can also submit some income version of the model in Benson.

AUDIENCE: Submit an initial version of the project model in Benson for next week

HAZHIR Yes so submit and--

RAHMANDAD:

[LAUGHTER]

And she got disconnected.

AUDIENCE: [INAUDIBLE]

HAZHIR Yes, submit the initial version in Benson. And the whole system is gone. So that's it. Thank you. [LAUGHS]

RAHMANDAD:

[SIDE CONVERSATIONS]