

Operational and financial flows

Class handout

[As class starts, Radu passes out a handout with the following case and asks the students to read it out loud as a group, each taking turns to read. Radu gives students some time to ponder and discuss among themselves in smaller groups.]

Case: Operating a clinic in a revenue pinch

St. Anselm Dialysis Centre is a specialized outpatient clinic serving patients with chronic kidney disease. Most patients visit the centre multiple times per week for dialysis treatments, often on a fixed schedule that structures the rhythm of their daily lives. The clinic operates six days a week and closes overnight, a schedule shaped as much by staffing realities as by patient needs.

Each patient visit follows a standard routine. Patients check in at the front desk, are assigned to a dialysis chair, undergo treatment, take time to recover, and then leave. Treatments last several hours, during which patients remain largely immobile, often reading, sleeping, or talking quietly with staff or one another.

St. Anselm's operating revenues come from two sources: (i) a fixed reimbursement for each completed dialysis treatment and (ii) additional reimbursement based on the number of hours a patient occupies a dialysis chair. For many years, these revenues were supplemented by a large private donor who provided stable annual support to help cover operating expenses and periodic capital improvements. Recently, this donor informed the clinic that they would be ending their long-standing tradition of support, choosing instead to invest their resources in establishing a new kidney exchange network.

The loss of this funding has created a significant budget shortfall. Demand for dialysis services remains strong, staffing levels are largely fixed in the short run, and there are no plans to increase the number of dialysis seats in the clinic.

Question for consideration:

Given the loss of donor funding, what (if anything) can St. Anselm do operationally to make up for this gap in its revenues?

Class discussion

RADU: Before we start, does anyone have a picture in their head of this place? A dialysis centre?

BINESI: I do, a little. My aunt went three times a week for years. I used to visit her in there on occasion. We would attempt the crossword together and never finish it. I believe it was four hours a session. It was essentially the main out-of-home activity in her life.

RADU: Wow, such a big part of your family's life. [*Turns to the group.*] So, what should we do here at St. Anselm?

[*Awkward silence extends for 5 or so seconds until Haoyu speaks.*]

HAOYU: Okay, let me just say what everyone is thinking but don't want to say because it sounds too obvious. We need to treat more patients.

RADU: How would that increase revenue?

HAOYU: You see, I knew you would ask me exactly this kind of follow-up question! I think it's obvious, but you still act as if you are confused.

[*The class laughs, so does Radu.*]

RADU: And? Why will having more patients increase revenue?

HAOYU: Well, revenue doesn't go up if you don't serve more patients, right?

RADU: It certainly might seem so. Let me ask Camila about this. [*To Camila*] In economics class, did you learn a formula for revenue?

CAMILA: [*Mildly startled.*] Yes, we do. We learn revenue equals price times quantity.

RADU: [*Radu writes this on the board*]

$$\text{Rev} = pq$$

And what is "quantity" here at this dialysis clinic?

CAMILA: Well, actually that is something I was hesitating a bit on. Since there are two sources of revenue should there be two quantities?

RADU: Two? [*Stands looking slightly puzzled.*]

FARAH: Yes, two. One quantity is the number of patients who come through, and the other quantity is how long they stay.

RADU: Very good, I like this. Can we think a little more about the "two types" here? Let me adjust our formula to reflect this insight:

$$\text{Rev} = p_1q_1 + p_2q_2$$

where "1" here represents the fixed reimbursement for patients that "come through", as you said, and "2" represents the additional reimbursement for how long they stay. But it makes me wonder, what should the units of p_1 and p_2 be?

MING: [*Groans.*] Another "unit" chase? Will these ever stop?

RADU: Why would we stop? This is a basic skill to understand formulas. It's like saying one day you will stop chewing food because you have done it so many times. So tell me, what are the units here Ming?

MING: [*Fake chews for a few seconds while sarcastically smiling before speaking.*] I'll pass.

[*A brief silence.*]

FARAH: I'll bite. Since q_1 is the number of patients, then p_1 should have the unit "dollars per patient". [*Radu writes on the board.*]

$$\text{Rev} = \underbrace{p_1}_{\substack{\text{dollars} \\ \text{patient}}} \underbrace{q_1}_{\text{patient}} + p_2q_2$$

As for p_2 , is it dollars per hour?

[There is a brief pause with everyone thinking.]

CAMILA: No, no, no. We are getting trapped again. It is one of those “area” prices.

RADU: *[Slowly.]* Yes, very good. I am with you on this. So what are you thinking for the unit of p_2 ?

CAMILA: Dollars per patient-hour?

RADU: Makes perfect sense to me. And so you are saying the units in the formula looks something like this: *[Turns to draw on the board.]*

$$\text{Rev} = \underbrace{p_1}_{\substack{\text{dollars} \\ \text{patient}}} \underbrace{q_1}_{\text{patient}} + \underbrace{p_2}_{\substack{\text{dollar} \\ \text{patient} \cdot \text{hour}}} \underbrace{q_2}_{\text{patient} \cdot \text{hour}}$$

We are thinking of this q_2 as an area in some inventory buildup diagram.

[Pauses, staring at the board for a while.]

This all makes sense, I guess. But a formula with an area in it is not what I expected. *[Looks down at his notes.]* I am still not fully happy somehow.

CAMILA: Why are you not happy? This is the revenue function, and we are trying to improve revenue.

RADU: Right, but the question asked for how we could improve revenue “operationally”. I kind of want a formula that has our favorite operational measures— R , I , and T . Are they in hiding somewhere in this revenue formula? Binesi, what am I not seeing here?

BINESI: I may be even more lost than you.

RADU: I am relieved to hear that; we are together on this. Who can help Binesi and I?

[Some awkward silence and then Ming speaks up.]

MING: Wait, what exactly are you looking for Radu? I may be more confused about that than anything else.

RADU: I guess I wanted to see how revenue, which is a financial flow, is related to the operational metrics we have been harping on, R , I , and T . Wouldn’t that be satisfying? We know how changing our operations impacts R , I , and T , so if we could write revenue in these terms, maybe this could help us get a sense of what intervention we should make to boost revenue.

MING: So like, we want to relate the revenue question to an operations question? And to do that, we want to convert the revenue formula into a formula involving our Little’s Law characters: R , I , and T ?

RADU: You said it better than I. Can anyone help with this?

[There is a period of 10 seconds or so of students and Radu pondering.]

FARAH: Ah yes! I think I see it. Divide both sides by the total time of the day! Inventory and throughput show up in the formula.

RADU: Wait, what? Can you write this on the board?

FARAH: Yes, happy to! [*Gets up and walks to the board, taking some chalk.*] So, when we divide by the total time the clinic open we get:

$$\frac{\text{Rev}}{\tau} = \underbrace{p_1}_{\substack{\text{dollars} \\ \text{patient}}} \frac{q_1}{\tau} + \underbrace{p_2}_{\substack{\text{dollar} \\ \text{patient} \cdot \text{hour}}} \frac{q_2}{\tau}$$

Recalling that you once wrote τ as total time before. But q_1/τ is nothing other than the average throughput R and q_2/τ is nothing other than the average inventory I . Recall, to get average inventory, we divide the total “area”—here q_2 —divided by the total time τ . And so,

$$\frac{\text{Rev}}{\tau} = p_1 R + p_2 I$$

RADU: Wait, wait ...I see how you get R because the formula for that is the number of jobs divided by the time, or $R = N/\tau$ as we wrote it before. But how did you get this inventory I again?

FARAH: We just did that with the tax returns! The average inventory I is the area under the inventory buildup graph divided by the elapsed time! This q_2 is precisely the area under the inventory build-up graph.

BINESI: [*Blurts out*] Yes, yes. I see it. It makes sense. Just like the tax returns.

RADU: [*Still pondering for a few second before speaking.*] Oh, I also now see it. We did this basically already last class. But how should we interpret this Rev/τ character on the left-hand side?

FARAH: That is the rate at which revenue is generated.

HAOYU: That helps me with something I was thinking from the beginning. Process flows are all about movement, literally “flow”. The revenue formula $\text{Rev} = pq$ never felt right to me because it was not “moving”. Revenue is like a pile of dollars. We want to see how the dollars move. The donors offered a pile of money. We need to get the money flowing from our operations.

RADU: Very astutely put Haoyu. So let’s see how our new formula helps: [*Takes the chalk from Farah and writes in his own handwriting on the board.*]

$$\text{Revenue rate} = p_1 R + p_2 I$$

calling the Rev/τ character, the revenue rate. So, can we increase the revenue rate if we increase R ?

MING: That is what Haoyu suggested at the very beginning of the case before you distracted us in deriving this formula.

RADU: I did distract us, didn’t I? My apologies. But I guess we have this formula now, [*Points to the board.*] which seems like progress.

MING: Why is it any better than the words?

RADU: I guess we need to see if it is. Can this formula help us?

CAMILA: Not really, I don’t see how it can give us any insight into how to increase R . The case said that demand is strong and the staffing level is fixed. Isn’t R as large as possible?

RADU: Good point, good point. I think you are saying we cannot squeeze much out of this first term. [*Points to $p_1 R$ in the formula on the board.*] What about increasing I to grow this second term? [*Points to the $p_2 I$ term.*] That seems to also increase revenue in our formula.

MING: We can't do that either, the case said that they are not going to increase the number of dialysis seats. So how can I go up?

FARAH: I have an idea, by Little's Law, $I = RT$ so the formula is actually Revenue-rate = $p_1 R + p_2 RT$. So can't we just increase T ?

RADU: Wait, wait, wait. [*Takes a breath and writes this new formula on board and then pauses for a moment thinking.*]

$$\begin{aligned}\text{Revenue rate} &= p_1 R + p_2 I \\ &= p_1 R + p_2 RT\end{aligned}$$

Farah helped us see a T in the formula, so we can increase this. Is this right?

CAMILA: No, no, I don't think so. The formula make it look like we can increase T to increase the second source of revenue. But we need to remember from Little's Law that $I = RT$ and, as Ming just said, I is fixed. So if we increase T then R must go down.

RADU: Wait, what?

CAMILA: [*Gets up to get the chalk from Radu.*] So we know, $I = RT$ from Little's Law. But if I is fixed, then R and T must remain in a kind of fixed proportion. Like this:

$$\underbrace{I}_{\text{fixed}} = \underbrace{R}_{\downarrow} \underbrace{T}_{\uparrow}$$

FARAH: [*Not being able to help herself from interrupting*] And if T increasing causes I to decrease, this means the revenue rate actually goes down! Inventory is fixed and R decreases so the first term in the revenue rate formula decreases while the second term stays constant. How did I did not see this before?

RADU: [*Takes the chalk again and slowly thinks through what Farah said while writing.*]

$$\uparrow T \Rightarrow \underbrace{\text{Revenue rate}}_{\downarrow} = p_1 \underbrace{R}_{\downarrow} + p_2 \underbrace{I}_{\text{fixed}}$$

It is very easy not to see this. We needed this revenue rate formula and Little's Law to piece this together. At least I did.

MING: So what about decreasing T then? We keep I fixed, so a decrease in T can be offset by an *increase* in R . Little's Law works to our favor this way.

BINESI: No. That's backwards isn't it? Spend *less* time with each patient makes you *more* money?

RADU: Yes, let's slow down the logic here. Suppose you have 10 chairs, all full. If each patient sits for 4 hours, how many finish in a 12-hour day?

MING: 10 chairs, three turns each. That gives 30 patients.

RADU: And if a patient sat for 3 hours instead?

MING: Four turns per chair. So 40 patients per day. [*Pauses.*] So ten more reimbursements coming out of the same chairs.

BINESI: [*Slowly.*] And the chairs were full the whole time either way. So the by-the-hour money never changed. We only added the per-patient money. [*Sits back.*] I hate that that's true. You just shortened my aunt's treatment by an hour to book ten more people.

RADU: I follow all of this reasoning, but this is really counter-intuitive to me. We are saying that a *decrease* in T increases the revenue rate! That seems totally counter to this formula we wrote earlier: [*Points to the lower formula for the Revenue Rate written on the board, involving T*]

$$\begin{aligned}\text{Revenue rate} &= p_1 R + p_2 I \\ &= p_1 R + p_2 RT\end{aligned}$$

MING: Yes, this formula is really misleading. It's better we look at this. [*Goes up to the board and redraws some arrows.*]

$$\begin{array}{c} \boxed{\begin{array}{c} I = R \quad T \\ \underbrace{\quad}^{\text{fixed}} \quad \uparrow \quad \downarrow \end{array}} \\ \\ \boxed{\downarrow T \Rightarrow \underbrace{\text{Revenue rate}}_{\uparrow} = p_1 \underbrace{R}_{\uparrow} + p_2 \underbrace{I}_{\text{fixed}}}\end{array}$$

RADU: That is indeed something. [*Pauses.*] Are we getting tricked by all of these fancy formulas somehow?

HAOYU: No, no, it's right. Just like a restaurant! We want to turn the customers over quickly. Shorten T ! Quicker service time, more customers, more revenue.

[*Everyone seems satisfied with this except for Binesi.*]

BINESI: No, this is still wrong. What we have here is not a restaurant. It is not fair to the patients to have shorter times. Doesn't this mean they need to take less time to recover or get less dialysis treatment? I think for the well-being of the patients we cannot make T any smaller.

RADU: You may be right here Binesi, isn't T somehow set by the treatment protocols? We may be stuck with T as it is, no? Increasing it reduces revenue, while decreasing it could harm patients. But with T roughly fixed and I as high as it can be, then Little's Law says that R is essentially as high as it can go.

MING: So we are saying that nothing can increase the revenue rate? Our answer is that there is nothing we can do operationally to improve revenue? That is quite unsatisfying.

RADU: It is? I am quite satisfied with our understanding ...

MING: [*Cuts off Radu*] You would say that, Radu, "kumbaya" and we all learned something. [*Sarcastically.*] Congrats. I, for one, am not giving up so easily. Let's keep working to find revenue somewhere.

RADU: You're the boss apparently.

[*Everyone laughs.*]

[*Ming's determination emboldens everyone in the class to keep thinking. Farah is scribbling things and Camila is looking at the ceiling in thought.*]

CAMILA: Maybe we should increase prices? Is that an operational change?

RADU: Possibly it is, depends on your perspective, possibly. But is price something we can actually change?

MING: Changing price is not an easy fix in my experience. There is regulation and competition. Prices for things like dialysis are all pretty standardized.

[Another long pause.]

CAMILA: I feel we cannot change the operational metrics without changing something drastic about the design of the operation, like adding more dialysis seats or maybe getting “faster” dialysis machines.

RADU: Yes, it seems we need something radical.

[Another long pause.]

MING: I am seeing it all clearly now. The case said their staff is busy and seats are full, and they are not getting any more staff or seats. That tells you there is nothing to be done. And the radical fixes are all boring. The idea that adding more dialysis seats *can* increase revenue is a tautology. Everyone knows that. I don’t see why we needed any of our fancy formulas to come to this conclusion. It’s all obvious.

RADU: I like your confidence, but I am not so sure it’s obvious. Didn’t your understanding of process flows and our formulas help you be certain of your reasoning here?

MING: Maybe a little. I could have taken that learning for granted some, given how much we have talked about these ideas in recent days. I might admit it’s a little hard to tell the difference between obvious common sense and the things I have learned in this class.

RADU: I will take that as a compliment. But I believe we have learned something. This is really evident when we saw that increasing T will actually *decrease* the revenue rate when I is fixed via Little’s Law. This is far from obvious.

I’m sure that on certain topics, you have strong intuition about what is right or wrong. These intuitions can be great guidance for us. But we also need to be aware that they can also be wrong or mislead sometimes. Intuition itself doesn’t always give us a lot of confidence. Even more, it can be hard to convince others to believe your ideas simply because you ‘feel’ something is correct. Using Little’s law and math to reason, we have something more convincing than just pure intuition.

MING: So our situation is like informed futility. We have a very clear explanation for why we cannot do anything in this case.

RADU: Exactly, is that a problem? Knowing exactly how you are in trouble is a first step in getting out of trouble, isn’t it?

CAMILA: And maybe our analysis can drive a change in plans to get more dialysis seats. This all might be convincing in the next board meeting. Sometimes to take a big step, you need to eliminate the feasibility of all small steps.

HAOYU: Wait, wait, I have a simpler solution. Just find another donor!

RADU: Wouldn’t that be nice! But let me echo Ming’s earlier sentiment on this point. In a world of infinite free money from donors, formulas indeed may not be needed.

[Everyone laughs.]

Let’s continue our discussion next time.

Email

Dear students, today's class went nothing like I originally planned. I had notes prepared that I ended up discarding entirely partway through. I want to reflect on why, because I think the detour was worth taking.

Why I threw out my notes. Haoyu said something during class that I keep reverberating with me. He said that the formula $\text{Rev} = pq$ never felt right to him because it wasn't "moving." Revenue is a pile of dollars. Process flows are about movement. We want to see how the dollars flow, not just how many accumulate.

This is a better motivation for the revenue rate formula than anything I had prepared. My original plan was to just give you the revenue rate formula, a formula I had adopted from a previous set of slides I was given from another professor years ago. What we did instead was arrive at it by basic principles, asking what shape a revenue formula needs to have in order to connect to the operational metrics we already know. That is the right question, and I am grateful we found our way to it.

The broader point is that operations management and financial analysis are usually taught as separate languages. Managers who speak one often struggle to translate into the other. What we did today, deriving a revenue rate formula in terms of R , I , and T , is a small example of what that translation looks like.

Two kinds of revenue streams. Let me use this email to make explicit something that was implicit in our discussion. The revenue formula we derived:

$$\text{Revenue rate} = p_1 R + p_2 I$$

has two operationally distinct terms.

The first term, $p_1 R$, is what I will call a *throughput-driven* revenue stream. You earn this revenue each time a job completes—each time a patient finishes treatment, each time a customer checks out, each time a ticket is sold. What matters is how many units flow through the system per unit of time. Examples are everywhere: the fixed co-pay for a doctor's visit, the admission ticket to a concert, the transaction fee on a sale.

The second term, $p_2 I$, is what I will call an *inventory-driven* revenue stream. You earn this revenue as a function of how many jobs are in the system at any given moment, and for how long. What matters is not how many flow through, but how many are present and for how long they stay. Examples here are equally common: renting a car (you pay by the day, for the days you have it), staying in a hotel (you pay for each night you occupy the room), subscribing to a streaming service (you pay monthly, regardless of how many shows you watch). In each case, the revenue depends not on throughput but on inventory—on how many units are in the system and for how long.

Many businesses have both. The dialysis clinic is one example. A video game publisher is another: you pay once to download the game (throughput-driven), and then a monthly fee to access online multiplayer (inventory-driven). Once you start looking, you will see the two-term structure everywhere.

The constraint Little's Law imposes. The most striking moment in today's class, to me, was when Camila pointed out that you cannot simply increase T to earn more inventory-driven revenue, because with I fixed, Little's Law forces R down by exactly the same proportion. The two terms in the revenue rate formula are not independent levers. They are connected by the constraint $I = RT$.

This is worth stating as clearly as possible. Suppose the clinic tried to increase revenue by keeping patients longer—increasing T . If the number of chairs (and therefore the maximum inventory I) is fixed, then longer treatment times mean fewer patients cycle through in a given period, so R falls. The gain in the second term ($p_2 I$, which is unchanged since I is fixed) is overcome by the loss in the first term ($p_1 R$, which falls because R falls). The revenue rate cannot increase this way.

Formally, with I fixed:

$$\text{Revenue rate} = p_1 R + p_2 I = p_1 \cdot \frac{I}{T} + p_2 I = I \left(\frac{p_1}{T} + p_2 \right).$$

Since I is fixed, the revenue rate is a *decreasing* function of T . Shorter treatment times—not longer ones—*increase* revenue, provided we hold I fixed. This is the “restaurant insight” Haoyu articulated: faster table turns mean more revenue.

But Binesi immediately flagged the limit of that analogy. Patients are not diners. You cannot safely rush a dialysis treatment. And so the clinic finds itself constrained on all three operational levers at once: I is at capacity, T cannot be shortened for safety reasons, and therefore R is as high as it can go. This is what Ming called “informed futility.” Knowing precisely why you are stuck is not nothing—it tells you what kind of change would actually help (more chairs, faster machines) and protects you from wasting resources on changes that look helpful but aren’t.

In defense of a negative result. Ming left class dissatisfied, and I want to take her dissatisfaction seriously, because it points at something important. We did all that work, she felt, only to conclude that nothing can be done. Where is the payoff in that?

Here is the payoff. A result that tells you precisely *why* and *where* a system is stuck is not a failure of analysis. It is one of its most valuable products. Some of the most consequential findings in science and mathematics are of exactly this kind: you cannot build a perpetual motion machine, you cannot trisect an arbitrary angle with straightedge and compass alone. These are not dead ends. They tell an entire profession to stop spending effort in one direction and to look instead at the single assumption that would have to break for progress to be possible.

Our conclusion has the same shape. We did not merely throw up our hands; we showed that revenue cannot rise *unless the design of the operation changes*. Knowing the exact shape of the trap you are in is the first step out of it. Ming called this “informed futility.” I would drop the second word.

Costs have the same structure. I want to flag one further idea that we did not have time to develop in class, but that follows naturally from everything we have done.

Just as revenues can be throughput-driven or inventory-driven, so can costs. Some costs are incurred each time a job completes: the materials used in a manufacturing process, the transaction cost of a sale, the variable cost of a patient visit. These are throughput-driven costs. Others are incurred as a function of how many jobs are in the system and for how long: the cost of inventory storage, the depreciation of equipment that wears with use-time, the cost of capital tied up in work-in-process. These are inventory-driven costs.

This means that the same Little’s Law logic applies on the cost side. Reducing T may reduce inventory-driven costs (less time in the system means less inventory-carrying cost) while also reducing throughput-driven costs if faster throughput means fewer resources consumed per unit time. In many settings, the

operational interventions that increase revenue also reduce costs—which is why improving throughput efficiency is so often the right place to start. We will see more of this in cases ahead.

Where do p_1 and p_2 come from? We took the two prices as given and moved on. But who sets them, and how they are split between a per-treatment charge and a per-hour charge, is itself a design problem with real consequences. Dialysis is the textbook case, so let me use it.

For many years, Medicare paid dialysis clinics two separate ways at once: a fixed amount per treatment, *plus* extra payments for injectable drugs administered during that treatment, most notably an anemia drug called EPO. Because those drug payments were profitable, giving more of the drug meant earning more money, and over time these add-ons grew to roughly a third of what clinics collected. The trouble is that EPO carries real medical risk above certain doses. So the payment structure set the clinic’s financial interest against its patients’ medical interest: the thing that made the clinic more money (EPO) was, past a point, worse for the person receiving it. In 2011, Medicare bundled everything into a single per-treatment payment expressly to remove that incentive, and drug use fell substantially afterward [1].

Notice the direction of that reform. It moved dialysis *toward* the throughput term: pay a flat amount each time a patient is treated, and *away* from paying more for doing more to each patient. Under the old scheme, a clinic earned more by adding interventions to each patient; under the bundled scheme, the only way to earn more is to treat more patients, efficiently and safely. That is precisely the alignment Binesi worried was missing. Good medicine says: don’t overtreat, move patients through safely. The new payment says: your revenue rises when you move patients through. The two now point the same way, where before they fought. This was the whole purpose of the reform.

Let’s look again at St. Anselm’s own p_2 , the payment per chair-hour, which is exactly the kind of “the longer you keep them, the more you earn” lever that medical cost payers have spent more than a decade trying to defuse. This is the heart of the matter: the two prices are not neutral numbers but instructions in disguise, each one steering the clinic toward a different behavior. Lean on p_1 , the per-treatment price, and you are paying the clinic to bring more patients through and treat them efficiently. In other words, you are rewarding throughput. Lean on p_2 , the per-chair-hour price, and you are paying the clinic to keep each patient in the chair *longer*. Since every extra hour of occupancy earns more, it may stretch treatment past the point of medical need. A payer who wants safe, high-volume care therefore leans harder on p_1 and keeps p_2 small.

A payer who does the reverse is paying clinics to slow down. So the prices we treated as fixed constants are actually policy. Each choice of p_1 and p_2 encodes a theory of what you want the clinic to *do*.

Haoyu’s flowing dollars have a long pedigree. Let me close with the remark that reorganized my whole lesson plan. Haoyu said revenue felt wrong to him as a static pile; he wanted to see the dollars *move*. That instinct places him in a tradition roughly two and a half centuries deep. In 1758, François Quesnay—who was, of all things, a court physician to Louis XV—drew the *Tableau économique*, the first attempt to depict an entire economy as circulating flows of money and goods among its classes [3]. Being a physician, he built the picture by analogy to the circulation of blood through a body. I will let you savor that in a case about a clinic that circulates and cleans its patients’ blood for a living. Two hundred years later, at MIT, Jay Forrester founded the field of system dynamics with *Industrial Dynamics*, modeling firms not as balance-sheet snapshots but as systems of reservoirs that fill and drain—Haoyu’s bathtub, precisely [2]. When Haoyu insisted that dollars should flow rather than pile up, he was not being naive.

He was standing, without knowing it, in a very long and distinguished line.

References

- [1] Centers for Medicare and Medicaid Services. End-stage renal disease prospective payment system. Final Rule, 42 CFR Parts 410, 413, and 414; effective January 1, 2011, 2011. Bundled per-treatment payment replacing the composite rate plus separately billable drugs.
- [2] Jay W. Forrester. *Industrial Dynamics*. MIT Press, Cambridge, MA, 1961.
- [3] François Quesnay. *Tableau économique*. Versailles, 1758.

Extensions

[Posted as homework on the course's website for this class session.]

1. A car rental company earns revenue in two ways: a flat daily rate p_1 per rental transaction, and a per-day charge p_2 for each day the car is rented. Its fleet has 200 cars. On average, 160 cars are rented at any given time, and the average rental duration is 4 days.
 - (a) Write out the revenue rate formula for this company in terms of R , I , p_1 , and p_2 .
 - (b) A competitor offers only flat-rate rentals (no per-day charge) but has much higher flat rates. What operational characteristics would make the competitor's model more profitable? What would make it less profitable?
 - (c) A software platform for car rentals claims it can reduce the time cars sit idle between rentals from 6 hours to 2 hours. Using the revenue rate formula, explain the operational mechanism by which this improvement increases revenue.
2. A law firm bills clients in two ways: a fixed retainer fee per engagement and an hourly billing rate for time spent on the case. The firm has 12 lawyers. On average, each lawyer carries 4 active cases at any time, and the average case takes 3 months to resolve.
 - (a) Identify R , I , and T for this system. What is the throughput rate of the firm?
 - (b) A managing partner argues that taking on more complex, longer cases will increase revenue because they generate more billable hours. Using the revenue rate formula and Little's Law, evaluate this claim carefully. Under what conditions is the partner right, and under what conditions is she wrong?
3. Imagine you are presenting the revenue rate formula we derived in class to the board of St. Anselm. How would you introduce it? Would you even show the formula, or would you translate the conclusion into plain language and leave the formula out entirely? What do you lose if you do that?

4. At the end of class, Ming said the conclusion that the only real path to more revenue requires changing the design of the operation was obvious from the start. Was it for you? Write a short argument (a few paragraphs) for why the formulas added something that Ming's initial instinct did not. Then write the strongest possible counter-argument: that the formulas were unnecessary, and that a thoughtful non-expert could have reached the same conclusion just by reading the case carefully. Which argument do you find more convincing?
5. The email after class introduces a distinction between throughput-driven and inventory-driven revenue streams, and notes the same distinction applies to costs. Think of a business you know well—a previous employer, a family business, a startup you have read about. Categorize its main revenue streams and its main cost drivers as throughput-driven, inventory-driven, or mixed. Does the structure of revenues and costs match each other, or is there a mismatch? What would a mismatch between revenue type and cost type imply for the business's sensitivity to changes in R , I , and T ?
6. The class concluded that with I fixed at capacity and T fixed by protocol, R is maxed out and nothing can be done. Attack that conclusion. A dialysis chair is only earning when a patient is in it and being treated—not during check-in, turnover, cleaning, or the overnight and Sunday closures.
 - (a) Suppose 30 minutes of every patient's chair-time is turnover and setup rather than treatment. Estimate the revenue upside of cutting that to 10 minutes, using the revenue rate formula. Which term moves, and why?
 - (b) The clinic closes overnight and on Sundays “for staffing reasons.” Sketch the argument you would make to the board that this closure is the single largest pool of unearned revenue in the building—and then make the strongest argument *against* yourself.
7. Take the payer's side. St. Anselm is paid p_1 per completed treatment and p_2 per chair-hour. Notice that p_2 pays the clinic *more* the longer it keeps each patient—the clinic's incentive and the patient's welfare point in opposite directions.
 - (a) Show, using the revenue rate formula, exactly how a purely p_2 -based payment scheme would incentivize the clinic to behave, and why that is bad medicine.
 - (b) Now suppose you are the insurer and you want to redesign the two prices so that the clinic's revenue-maximizing behavior also happens to be good care. Propose values or a structure for (p_1, p_2) —including possibly making one of them zero or negative—and defend it.
 - (c) Every payment rule can be gamed. Describe how a clinic might exploit *your* scheme, and what you would monitor to catch it.
8. The chapter's punchline is that with I fixed, shortening T raises the revenue rate. Construct, in detail, a real business where the opposite holds—where a longer T genuinely raises the revenue rate—and explain precisely which assumption from the dialysis case you had to break to get there.
 - (a) Specify the business, its p_1 , its p_2 , and why I is *not* fixed at a hard capacity in your setting.
 - (b) Show with the formula why longer stays win.

Reflections

[Posted as a reflection exercise on the course's website for students to write about in a journal due at the end of semester.]

1. Are you someone who enjoys reasoning with mathematical formulas? Why or why not?
2. Camila argued that increasing T would help, and was wrong in a subtle way. Describe a time you were confidently wrong about something not because you lacked information, but because you were reasoning from a formula or framework that had a hidden assumption you hadn't noticed.
3. In a business setting, producing a formula can signal rigor but can also signal that you are more comfortable with abstraction than with judgment. Have you ever felt that showing your analytical work hurt rather than helped your credibility with an audience? What did you do about it?
4. Think of a senior person you have worked with or observed, e.g., a manager, a mentor, an executive, who had excellent operational instincts but no formal training in operations management. How did they convince? What, if anything, would they have gained from the kind of analysis done in this class?
5. We spent the class deriving a formula that led, in the end, to the conclusion that nothing could be done. Was that time wasted? Recall an effort of your own that produced only the clear knowledge that you were stuck. Did knowing *why* you were stuck change what you did next?
6. Haoyu kept blurting the "obvious" answer: treat more patients, find another donor. Are you more often the person who says the obvious thing plainly, or the person who suspects the obvious thing is a trap? What does each disposition cost you?
7. Ming resisted the whole exercise as dressing up an obvious conclusion in "fancy formulas," then admitted she'd taken the reasoning for granted. When someone shows you a rigorous version of something you felt you already knew, do you feel respected or condescended to? What determines which?
8. I (Radu) admitted in class that I adopted the revenue formula years ago from another professor's slides without ever deriving it myself, and only understood it once the class built it from scratch. Is there something you use fluently every day, e.g., a tool, a rule, a phrase, that you have never actually taken apart to see why it works? What would it take to make you finally do it?
9. In the email, we talked about the price structure of dialysis being a type of policy. This is different from how we usually understand price of normal items, say, a clothes, or a cellphone. Why is price in medical industry so special? Who should make the decision on these prices?