<u>The Hidden Mathematics Shaping Health and Care Leadership</u>

Why good leaders need better mental models, not more data
Dr Jason Broch, November 2025

Most people join health and care because they want to improve lives—not because they want to wrestle with equations. Yet the longer I work in this world, the more I realise that many of our toughest challenges aren't clinical or even organisational. They are mathematical—not in the sense of complex formulas, but in the quiet, often invisible logic that governs how systems behave.

This mathematical logic shapes waiting times, staff capacity, emergency flow, budgets, prevention strategies, and organisational relationships. But because it isn't taught formally, leaders often find themselves fighting the system's behaviour rather than understanding it. Much of the frustration in modern health leadership—whether in the NHS or in Canada, Australia, Singapore, or the US—comes from trying to change outcomes without appreciating the underlying rules.

What follows isn't a maths lesson. It's an attempt to reveal the patterns that sit behind healthcare complexity: the subtle currents beneath the surface. When you understand these patterns, problems make more sense—and solutions become clearer.

The system is behaving exactly as designed—even when we don't like the design

One of the most common leadership frustrations is the sense that problems "shouldn't be happening"—A&E overcrowding, delayed discharges, long waiting lists, community teams overwhelmed with demand or Non-elective admissions despite better ways to care. Whilst health systems aren't living organisms with intent, they consist of structures that behave in complex dynamic ways, according to inputs, bottlenecks, incentives, and connections. The outcomes seen (desired or not) are mathematically inevitable based on these constraints and complexity.
Take emergency department crowding. We often talk about "pressure," "surges," or "performance," but the system behaves according to flows. EDs receive patients faster than they can be treated or transferred. Beds upstream are full, diagnostics are delayed, and discharge pathways can't absorb the outflow. This is a flow imbalance, not a failure of effort.

Systems thinking teaches us that ***<u>local pressure is rarely local</u>***.

A queue in the ED may be an echo of problems in primary care access, social care capacity, or delayed diagnostics. Leaders who adopt this mindset start looking differently at the problem. Instead of trying to "fix the ED," they look upstream and downstream: where is the real blockage? Where is the leverage point? Jumping to admission avoidance initiatives, may have little effect if there are other contributing

issues. Indeed, looking for impact of some services may result in an assumption that they are not helpful, all because the assumptions involved in modelling potential impact may not take into account the underlying complexity. Examples could include pro-active community personalised interventions with an expectation that the impact could measured at a population level. System mathematic shows why this is unlikely to be a successful mechanism of measurement or cost reduction.

Mathematical thinking begins with understanding that the system's behaviour is not mysterious—it's structured.

Why waiting lists grow (and why they're so hard to shrink)

Every country now faces waiting list challenges. It doesn't matter whether the system is tax-funded, insurance-based, or a hybrid: elective care demand seems to be rising faster than capacity. Yet we often treat waiting time as a political or managerial problem rather than a mathematical one.

At its core, a waiting list is a stock, and referrals and treatments are flows. If more patients arrive each month than can be treated, the list grows. Not because of poor leadership, but because of arithmetic.

This is why waiting lists are stubborn. Even a substantial increase in activity doesn't shrink the list if the inflow rises at the same time. Leaders often announce "recovery plans" without checking whether the additional capacity is enough to reverse the flows. It's common to add weekend lists or temporary clinics only to discover that the impact on backlog is limited.

The key question is simple: Are we consistently discharging more patients from the list than are arriving? If not, the list will expand—no matter how hard people work. Likewise what else is driving in-flow. Beneath the stocks and flow calculations here, is the economics of supply and demand as well as its impact on human behaviour. Increased capacity could lead to increased referrals, as referrers will see less barriers. If waiting lists are long, then other type of treatment may be chosen. Without thinking holistically about the complexity, a waiting list initiative could drive up both activity and demand.

Understanding this helps leaders make smarter decisions. Instead of short bursts of activity, they focus on sustainable changes to inflow (prevention, alternative pathways) and long-term increases in treatment outflow. Stocks and flows give us a clearer, calmer view of what's going on.

Healthcare flow collapses at high utilisation

Healthcare organisations often strive for assumed maximum efficiency by ‘sweating their assets’ —full beds, fully booked clinics, perfectly utilised imaging slots. But queueing theory tells a different story.

In systems with variability—and healthcare is full of variability—high utilisation is the enemy of flow. Once occupancy rises above about 85–90%, queues grow exponentially. A tiny increase in arrivals leads to very large delays. Increasingly this is recognised, but it serves as an example where mathematical reality may be at odds with our human intuition. It is hard for leaders to ignore intuition, especially when something may seem logical and the evidence-based approach may even look foolish to others,

Think about an inpatient ward. If the bed base is almost full, discharges need to be perfectly timed for incoming admissions. They never are. When just a few patients stay longer, incoming patients queue—in ED or in ambulances. It’s not incompetence; it’s mathematics.

This logic explains:

- ambulance handover delays when bed occupancy is high
- operational chaos when a single clinic is cancelled
- CT/MRI backlogs when scanners run at or above 90% utilisation
- deteriorating flow after well-intentioned “efficiency drives”

Understanding queueing theory should shift leadership attention away from blame and towards creating system conditions that improve flow: modest slack, resilient processes, realistic scheduling, and investment in the right part of the pathway. *Not trying to fix a narrow point of failure, when the maths tells us we need to widen to a system perspective.*

Uncertainty is not the enemy - poor interpretation of uncertainty is

Leaders often face pressure to give certainty: firm numbers, exact forecasts, definitive improvement trajectories. But healthcare is inherently probabilistic. The question is not “What will happen?” but “How likely is each scenario?” This is because it is driven, not only by complex, dynamic population health risk, but also the nuances of individual behaviours, risk appetite and sometimes perverse incentives.

Understanding risk can help navigate:

- winter pressures
- demand surges
- screening performance
- diagnostic accuracy
- financial risk
- Predictions

Variation often gets misinterpreted as "real change" when it is simply statistical noise. Probability helps leaders avoid overreacting to random swings in data or erroneous conclusions.
Good leaders don't promise certainty. They offer clarity about risk, confidence, and uncertainty.

Seeing variation for what it is, reduces anxiety and improves action

One of the dangers in health management is the treatment of every data fluctuation as meaningful. A spike in ambulance handovers, a dip in clinic utilisation, a rise in complaints—it can all feel like a signal.

But most of the time, data is just…variable.
Distinguishing common cause variation (normal, expected noise) from special cause variation (a shift requiring intervention) helps leaders:

- protect staff from unfair blame
- avoid overcorrecting
- reduce unnecessary meetings
- maintain stability rather than chase randomness
- detect true system change earlier

This is why tools like Statistical Process Control (SPC)—used widely in quality improvement—are so powerful. They help leadership teams stay calm in the face of noise and focused when something real is happening. It also helps to demonstrate the highly predictable patterns that exists in complex dynamic systems. Above, we pointed out the potential futility of trying to track personalised interventions impact at population-level, however another mathematical peculiarity is the relative predictability of some activity patterns at system level.

Incentives can explain organisational behaviour despite shared values

Health and care leaders often work within networks of organisations that share values but not incentives. Payment systems, regulatory frameworks, performance targets, and budget structures all influence how organisations act.

Game theory helps explain why:

- organisations sometimes act defensively despite system goals
- pooled budgets can stall *without explicit risk-sharing rules*
- providers in competitive markets may struggle to collaborate

- *prevention underperforms when incentives are short-term*
- pathway redesigns fail when benefits land in the wrong part of the system

It isn't because leaders don't care. It's because incentives can have a powerful effect on behaviour. Incentives are not always financial and understanding the wider influences on the way people act is essential. ***Game theory nudges us toward designing systems where collaboration is the rational choice, not just the moral one.***

Optimisation: leadership in the real world of trade-offs

Every leadership decision involves constraints—money, staff, space, time. Optimisation doesn't mean perfection; it means choosing the best possible option when everything can't be done.

Healthcare optimisation questions look like:
Given our workforce limits, what mix of services produces the best outcomes?
Which elective specialties should get marginal theatre time to maximise overall productivity?
How do we balance urgent demand with long-term prevention?
How do we redesign pathways to improve outcomes without increasing cost?

These are optimisation problems, and they benefit from clear framing. When leaders see them through this lens, trade-offs become explicit rather than implicit. Decisions become more transparent and defensible.

Understanding networks helps us strengthen the system's fabric

Formal structures like ICSs, LAs, Mental Health organisations and hospitals only tell part of the story. The real health system is a network of referrals, professional relationships, informal influence, shared norms, and information flows.

Network thinking helps leaders understand:

- how certain clinicians act as flow "hubs"
- why some innovations spread and others die
- how workforce shortages propagate between services
- where the system is fragile or over-dependent
- how miscommunication can become systemic risk

When we focus only on organisational governance, we miss the network behaviour that actually shapes system performance. This is far more powerful than contracts that may be offered by purchasers. It is naive to think that effective change can be brought about by a commissioner through a change in contract or spec, without understanding the influence of the informal networks with and across organisations.

Human behaviour doesn’t follow mathematical rules—so we need behavioural insight as well

Even the best-designed pathways fail without human alignment.
Behavioural mathematics helps explain why:

- staff resist well-intended change
- patients miss appointments despite reminders
- clinicians reject digital tools that technically “work”
- leaders misjudge likelihoods under pressure
- teams default to the familiar, even when ineffective

Factors like loss aversion, cognitive load, anchoring, and status quo bias influence everything from medication adherence to organisational transformation. Successful leaders understand the mathematical structure of the system and the psychological reality of the people within it.

A toolkit of mathematical concepts is essential for navigating a more complex world

None of these concepts require algebra or advanced calculation. They require awareness of the mental models—an understanding that under the surface of healthcare lie patterns and rules that quietly shape outcomes.
When leaders become fluent in these patterns, they move from firefighting to foresight:

- from blaming individuals to reshaping systems
- from reacting to trends to interpreting variation
- from demanding certainty to managing risk
- from capacity concerns to flow redesign
- from heroic effort to sustainable structure

The mathematics of health and care is not about numbers—it’s about truth. It reveals why the system behaves as it does, and it gives leaders a clearer lens through which to make decisions.

If you recognise these patterns in your work, or if they resonate with your experience of leading in health and care, I’d welcome your thoughts. The more we talk openly about the underlying logic of our system, the more intelligently and humanely we can shape its future.