The Great Mental Models

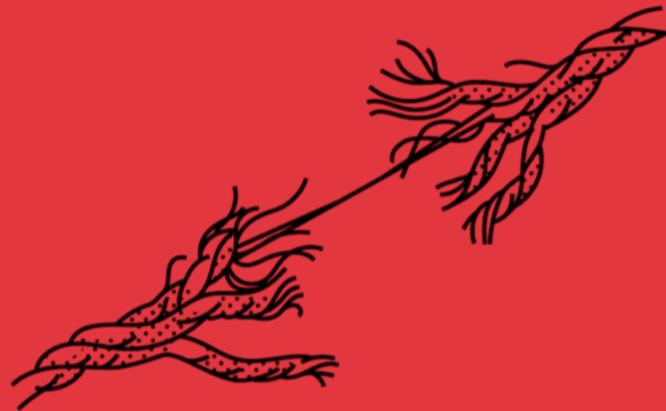Vol.3

Systems and Mathematics

𝑓s Farnam Street

Systems

Critical Mass

–
Going critical

A system becomes "critical" when it is on the verge of changing from one state to another. The final unit of input before the change has a dispropotionate impact. It is the proverbial straw to break the camel's back. Before a critical mass is reached, the camel can support the amount of weight it's required to carry. Then the weight passes a threshold where any additional amount is disastrous, and the final straw tips the camel into another state. Once a system passes a certain threshold and enters a critical state, it only takes a tiny nudge to change it.

When a system changes from one state to another, we say it has achieved critical mass, also known as reaching the tipping point. In social systems, critical mass tends to mean when enough people have adopted something, such as a belief or product, that its growth can sustain itself. In his 1978 book Micromotives and Macrobehavior, game theorist Thomas Schelling wrote, "The generic name for behaviors of this sort is critical mass. Social scientists have adopted the term from nuclear engineering, where it is common currency in connection with atomic bombs."

The amount of energy required for a system to achieve critical mass is variable. Different systems have different properties and thus require varying amounts of inputs to tip from one state to another.

Heated water is at critical mass when it is hot enough to change from liquid to gas. There is a massive difference between 211 and 212 degrees Fahrenheit. One is the boiling point; the other is not. In business, critical mass is the point where a business makes enough money to no longer need outside investment or the point where the financial growth of a company becomes self-perpetuating. In epidemiology, critical mass can refer to the point where enough people are vaccinated in a population to prevent an infectious disease from spreading to vulnerable people who cannot be immunized.

Using critical mass as a model helps us understand the effort required to achieve sustained change. Systems have certain inflection points where they change from one state to another. It doesn't help us to focus solely on the tipping point and ignore the work required to bring a system there. Because the inputs that tip a system into a new state tend not to have a linear effect—the final unit of input that leads to the change in state has an outsized marginal impact—we are disproportionately impressed by them. We are also disproportionately affected by them. But the straw only breaks the camel's back when there is already a lot of weight on it. Putting one piece of straw on a camel isn't always going to have the same effect.

The critical mass lens also helps us identify the parts of a system we can target to advance change. In social systems, for example, we don't need to spend equal effort changing everyone's mind. We can instead focus our efforts on changing the minds of opinion leaders to more quickly progress change.

Systems in a critical state tend to be precarious, but they don't stay that way for long because they're so easily tipped. Getting insight into what could be the straw is valuable, as is recognizing when a system is poised on the edge of instability. A pencil balanced on its end may appear at equilibrium as it remains upright. But it could topple at the slightest disruption, so it is not stable.

The work required for change

We like to tell stories about the tipping points. We look at the landmark cases or individual actions that sparked a cascade of change in the past and wonder how we can recreate them to push our current system into a new state. Using the mental model of critical mass, however, reminds us that it is equally important to pay attention to the effort involved in the build-up.

In September 1893, New Zealand became the first self-governing country to give most adult women the right to vote in parliamentary elections. American women would not earn this right for another twenty-seven years and British women for twenty-five. An important thing to understand about women's suffrage in New Zealand is that it was far from a sudden change, even if it may have appeared as such from afar. Through the efforts of many people over many years, there was a slow shifting of the Overton Window to the point where women being able to vote became reasonable in the minds of enough people to shift the voting system into a new state.

Certain unusual aspects of New Zealand's society and events in its history helped lay the groundwork for changes in the voting system even before the official suffrage movement began. Many of the people living in New Zealand had settled there in recent decades and desired to create a fairer society than the European one they had left behind. Seeing as the population was small (under 750,000 in 1893, including 40,000 Maori), fewer minds needed changing to create a critical mass. The movement received support from prominent male politicians early on, which aided in getting a foothold in Parliament.

Women receiving equal access to education in New Zealand was another key factor in the build-up of opinion change to critical mass. Due to the campaigning of educationalist Learmonth Dalrymple, girls received the same secondary education as boys, with the first school for girls opening in 1871. Dalrymple also successfully ensured women were able to attend university, where they made up half the student body by 1893. Greater education led to improved employment prospects outside of the home, beyond the customary option of domestic labor. More and more women entered the workforce once they had better education, gaining social influence in areas such as teaching, journalism, medicine, and the arts. When they faced worse working conditions than men, New Zealander women began to unionize.

In many ways, the New Zealander suffrage movement was entwined with the temperance movement, which sought to restrict or prohibit the consumption of alcohol. Throughout the nineteenth century, alcohol became a growing problem in many countries, leading to poverty, violence, crime, and harm to family life. For New Zealanders, it was particularly harmful among men working in the agricultural, maritime, and industrial industries. As in many other countries, it was reported that many men drank away their wages before even making it home at the weekend, leaving their wives and children bereft. Seeing as women tended to suffer the most as a result of widespread heavy drinking, they were influential in the movement.

Although the temperance movement never achieved the aim of total prohibition in New Zealand, it constructed a framework for women to politically organize. Alongside unionization, it gave women the confidence that they could have influence if they worked together in sufficient numbers with clear goals and a sense of focus. As Patricia Grimshaw writes in Women's Suffrage in New Zealand, "Women, on the practical side, learned the arts of organization, administration, and leadership which could be turned to use in later years in their own cause. Women, on the ideological side, entered a sphere in which a new outlook on their basic rights developed rapidly, spurring them to aim at the realization of their full rights as women."

All of this work culminated in the suffrage movement, led by Kate Sheppard, which built upon the social change that had been growing since the country's founding. In the early 1890s, Sheppard organized several petitions in favor of women being able to vote, which she presented to Parliament. Despite initial failures, the movement kept trying, gaining more and more support each year. By 1893, her petition amassed 32,000 signatures, a number all the more impressive considering the tiny population of the country at the time. After numerous attempts, the bill passed by a whisker. The changes in opinion had reached critical mass.

In turn, women earning the right to vote in New Zealand helped motivate and inspire similar movements elsewhere because it showed wider suffrage was possible. After World War II, women's political emancipation spread around the globe, a visible symbol of wider improvements. Once you pass a tipping point, the whole nature of a system changes. It develops new properties, and new things are possible. New Zealand was that tipping point for women's suffrage in many other countries.

When we look back at significant social changes, it's important to recognize the work involved in building a critical mass. Women getting the vote in New Zealand was the result of years of effort on many different fronts to build the capabilities needed to change opinions. As social norms regarding women voting started to change, the movement gained the critical mass necessary for petitions in Parliament to be the final straw that resulted in a new state.

We can learn from the mental model of critical mass that changing a system doesn't require changing everything about it. Changing a small percentage of its parts can shift the whole thing into a new state. Getting people to alter their beliefs doesn't mean convincing everyone; once you pass a threshold, the change perpetuates itself.

Organic cities

In nuclear physics, critical mass refers to the minimum amount of fissile material needed to start a self-sustaining reaction. You can pile up the uranium, and nothing will happen until a high enough density is reached. To focus on what prompted the change from inert to active in a nuclear reaction isn't all that interesting. It's just one more bit of uranium. The more interesting question is, how much is needed to kickstart the reaction to continue without further inputs? The lens of critical mass is thus a useful one to apply to other situations where we'd like to produce self-sustaining reactions, such as cities.

Cities are complex systems where planners have often misidentified the elements required to create enough density to produce self-sustaining inter-actions. In cities, it's not the amount of infrastructure that produces interac-tions, it's how that infrastructure is laid out. A certain number of interactions are required for a city to function well and adapt to meet the needs of those living in it. What makes a city safe, interesting, prosperous, and creative isn't the buildings or streets. It's how the infrastructure fosters interactions and relationships between people.

Jane Jacobs wrote extensively in The Death and Life of Great American Cities about how to achieve self-sustaining interactions in cities and why they are important. She argued that when we isolate parts of cities, we miss the many interconnected functions that they perform. For example, "A city sidewalk by itself is nothing. It is an abstraction. It means something only in conjunction with the buildings and other uses that border it, or border other sidewalks very near it."

The system formed by a sidewalk and its users is what makes an area both safe and interesting. When the area around a sidewalk is subject to active mixed uses—homes, cafés, shops, and so on—there are always eyes upon it and people passing through. These people do not need to know each other or even to talk to each other. It is enough that they see each other, are aware they are watching and being watched, and observe each other's behavior. Jacobs writes, "The basic requisite for such surveillance is a substantial quantity of stores and other public places sprinkled along the sidewalks of a district; enterprises and public places that are used by evening and night must be among them especially."

It is the interplay of people that ensures a sidewalk is safe and places limits on antisocial behavior. People moderate how they act knowing someone is or might be watching. Any antisocial behavior that does break out is likely to be swiftly halted by the interventions of bystanders. An organic, unorganized

system of control enforced by social norms is more immediate and effective than the use of police, although the threat of them being called plays a role.

To understand why neighborhood safety breaks down in certain situations, we need to consider a sidewalk as needing a minimum number of interac-tions in order to function as part of a city system instead of just a piece of concrete. You'd feel safer at night walking along a street lined with bars open late than one with stores that close at 5:00 p.m. You'd feel safer walking along a main street passing the fronts of houses than an alleyway only visible from a couple of windows. You would feel safer on a crowded street than an empty one with a police officer present. You feel safer on a sidewalk that is part of a whole system of self-sustaining interactions. The more people that are using a sidewalk, at different times and for varied purposes, the better it functions as a safe space. This is true outside of cities, but other factors are likely to be relevant for safety in towns or rural areas.

It is this "intricacy of sidewalk use, bringing with it a constant succession of eyes" that also makes an area lively and interesting, and therefore a desirable destination. Activity attracts more activity. Many people using an area bring economic benefits, which further attract more businesses, especially more unusual and specialized ones, which in turn attract more people.

Visual activity is appealing to the eye. We like to watch things happening and other people going about their days, so crowds attract more crowds. People who watch attract more people who do by making an area safer, and people who do attract more people who watch by making an area interesting. It is a feedback loop that is dependent on a myriad of uses and interactions.

Our experience of a city also has to do with the relationships it fosters with other people. Again, interactions are paramount. Both social isolation and a lack of privacy are risks in cities. An individual may contend with both throughout the course of a day in a poorly designed city. Ideally we gravitate toward spaces where we can have controllable levels of interaction with

others. In Happy City, Charles Montgomery says, "The richest social environments are those in which we feel free to edge closer together or move apart as we wish. They scale not abruptly but gradually, from private realm to semi-private, to public; from boardroom to living room to porch to neighborhood to city."

One instance of an environment that allows individuals to regulate their level of interaction but also accommodates a wide variety of users is a plaza or square. Present at varying scales as a standard feature of the city, squares are mixed-use areas in which one could, among other things, meet a friend or date, enjoy a coffee at a sidewalk café, watch a street performer, exercise a dog or child, attend a protest, or strike up a conversation with a stranger. The surrounding bustle allows for both safety and interest. You feel safe meeting a date or talking to a stranger because there are enough people around to take note if something goes wrong. But you also feel comfortable having a private conversation with a friend or writing in a notebook because no one is likely to pay much attention to you in particular with so much going on.

Space alone does not create this environment. An overly large square can actively repel people as it feels overexposed and empty. A popular one must have enough activity and reasons to visit in a small enough space to create the density needed for spontaneous and ongoing interactions to occur.

Strøget is a network of pedestrianized streets in Copenhagen created in the 1960s as part of an effort to switch the city's focus from cars to pedestrians and cyclists. Closing off the area to cars was a controversial move. People didn't believe Danes would simply want to mingle in a public space, considering the country's typically cold weather and lack of a preexisting café culture.

But today, Strøget is a lively area with an annual peak of 120,000 visitors braving the icy Danish winter on the last Sunday before Christmas.

Strøget works because it manages to combine many possible uses in one area, making it a busy and engaging place to visit. It facilitates the interactions needed for a city to function in a way that promotes needs like psychological safety and controllable social engagement. Pedestrians and cyclists pass through on their way to somewhere else. Shoppers visit both luxury boutiques and chain stores. Others visit the theater or church. Street performers attract audiences, as do peaceful demonstrations. People sit at pavement cafés or wander along eating inexpensive street food. Tourists visit museums and art galleries. People are willing to brave the cold because the area has so much to offer.

Architect Jan Gehl has since applied the principles of Strøget to other parts of Copenhagen and cities around the world. The city was able to promote a new sort of street culture by recognizing that a bustling public space is the product of a number of factors coming together at a certain density. Street culture is not specific to certain cultures; it is about having the right kind of spaces for it. These spaces recognize that a minimum of interactions must be maintained in order for them to function in a self-sustained way. The actual architecture should be invisible because the focus is on the people and on bringing out their best qualities.

The idea that infrastructure needs to promote and facilitate a certain number of interactions and not just look good explains why some attempts to design and build cities from scratch have been riddled with problems. If you focus on the infrastructure first and just build a list of requirements—like houses, stores, and streets—you increase the chance that your city won't function well. Rather, the infrastructure needs to be designed to facilitate a critical mass of interactions—something that planned cities often miss. Planned cities may try to design out those interactions because designers see them as a waste of time, or they may even want to discourage any type of organized action.

Planned cities often segregate different functions, like workplaces and homes, ignoring the benefits of mixed-use areas, which are the standard in natural cities. Visually this looks ordered and pleasing, but it doesn't promote the interactions cities require. It's useful for people to be able to access resources close to where they live. It cuts down on commuting and increases time people can spend on relationships.

Mixed-use areas combining residential and commercial elements create more interactions than those segregated for one function. Planned cities may segregate roads and sidewalks for pedestrians, viewing driving and walking as distinct activities. But this prevents people from being able to hail a taxi and combine the two functions.

Brasília, the federal capital of Brazil, was designed in the 1950s and '60s to replace Rio de Janeiro as the capital. Architect Oscar Niemeyer and urban planner Lucio Costa crafted a vision of a utopian city from scratch. In the visual sense, Brasília is a stunning World Heritage site. From the air, it has a beautiful bird-like form. As a place to live, it functions less well.

Areas of Brasília have specific uses: people live in one part, work in another, and shop in another. Without mixed-use areas or much catering to pedestrians, the city cannot form a street culture. Communities cannot cohere due to a lack of areas where people can mingle. Visual order—Brasília is laid out in a grid—does not translate into good function.

Everything in Brasília was built new and modern to similar specifications. Yet cities need buildings of varying age and quality to allow for people at different income levels. The architects and designers never planned for low-income housing, despite Brasília needing inexpensive labor as much as any other city. As a result, unofficial areas have sprung up around the city

that house its poorer residents. Only by deviating from the plan can it function at all.

So although Brasília contains the same parts as a typical city, those parts do not facilitate much interaction. It seems as if its designers believed that the arrangement of the infrastructure is irrelevant to city functioning. But how the infrastructure is laid out is critical because it facilitates the critical mass of interactions cities need to be able to adapt and grow to meet the needs of those living in them.

Conclusion

The mental model of critical mass gives us insight into the amount of material needed for a system to change states. We can categorize material as interactions, connections, or efforts. When enough material builds up, systems reach their tipping point. When we keep going, we get sustainable change. Using critical mass as a lens on situations where you want different outcomes helps you identify both the design elements you need to change and the work you need to put in.

Learn more and get your copy at

fs.blog/tgmm

fs