Out of Time! An Overview of Time Infrastructure

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Introduction: The Problem of Time

In the novel *One Hundred Years of Solitude* written by Gabriel García Márquez, Úrsula Iguarán, the longest to live amongst her generation, reflects on the fate of the Buendía family: "...time was not passing… it was turning in circles" (1970, p. 164). While a personal rumination, Úrsula's reflection on the family's curse brings forward a more complicated view of time: from her lived experience, it became multidimensional, embedded in something beyond individual control. The scope of this quote gestures beyond the individual and questions how time is shaped in social structures.

Time is a fundamental yet invisible network that weaves into nearly every aspect of life, from bureaucracy and finance to technical and social systems: time is infrastructure. However, the failure to recognize this has led to systemic vulnerabilities. As seen in the Year 2000 panic, where a software bug caused a global crisis, the 2010 Flash Crash, where milliseconds determined significant financial losses, or in immigration bureaucracies where delays leave individuals in indefinite limbo, the structure of time is not neutral. This matters because time infrastructure is not simply technical, it is also social. While measured time can facilitate efficiency and growth, lived time reveals how these systems remain weak. The failure to account for both dimensions can result in time-based inequalities, exposing fragilities and power imbalances.

To develop this argument, I define time as infrastructure, one that exists within a pluralistic context. I then examine how time infrastructure underpins speed in capitalist society, and how its failures reveal power imbalances within the experiential and technical components of time. Through technical, social, and philosophical perspectives, this paper highlights the urgency of rethinking time infrastructure not just as a background mechanism but as a sociotechnical network that shapes daily life and global structures.

What is *time infrastructure*? The Invisible Network of Time

First, I want to clarify what I mean by time infrastructure. Star (1999) defines infrastructure as an embedded and often invisible mechanism that becomes apparent only upon break-down. Infrastructure, once established, fades into the background, becoming naturalized in daily life: our mundane and expected standards, like pipes, wires, and sewers. Within this framework, time infrastructure refers to the technological, social, and institutional systems that regulate, measure, and coordinate time. Like other forms of infrastructure, it is largely invisible in everyday life, yet it creates a network that builds nearly all aspects of society, from global navigation and financial markets to healthcare and information systems.

Although timekeeping is now taken for granted, quantifying time has been a collective effort throughout history. Until the 18th century, while local mean time could be calculated, measuring time at sea, and therefore determining longitude, remained impossible. This made navigation and mapping very inaccurate, as not knowing the longitude, the missing companion to latitude, made specific locations incalculable. The issue was so critical that governments offered prizes to anyone who could solve this "time problem" (Sobel, 2007). In 1735, John Harrison's invention of the marine chronometer provided a solution, enabling precise longitude measurements at sea (Forbes, 1966) This breakthrough set technical infrastructure to facilitate reliable international trade and the creation of standardized time zones, further laying the foundation for globalization and today's GPS. By examining this history, I aim to outline that time is not just a singular linear measurement, but a foundational network shaped by social, political, and technological influences, embedded in all major sociotechnical systems.

Despite the central role of time infrastructure in shaping global coordination, economy, and ideology, its significance is still often overlooked until failure brings it into focus. The potential impact of neglecting time infrastructure became evident during the Year 2000 (Y2K) panic.

Widespread concern arose that computer engineers had not prepared systems ready to handle the new millennium, potentially preventing computers from transitioning to the year 2000. This made the bug a time issue, as it stemmed from how digital systems represented and processed time as a two-digit year in early coding. According to the World Health Organization (WHO), errors in time calculation would lead not only to administrative issues, but also to fatal risks for patients, such as incorrect radiotherapy doses caused by miscalculating the decay of a radioactive source (1999, p. 3). The report documents the vitality of accurate time measurements, proving that institutions understood the importance of time, knowing such breakdown would severely disrupt systems like healthcare. However, by over relying on complicated and fragile software systems, time infrastructure was still overlooked in the foundational design of these operations.

This example also provides insight into our cultural values regarding time infrastructure and the labor that sustains it. At the moment of crisis, the invisible labor maintaining time systems (such as IT workers and computer engineers) was temporarily exposed, only to fade back into obscurity once the immediate threat had passed. Since the world didn't end, the event was retrospectively regarded as a hoax rather than a success against a genuine threat. Reflecting on this, David Eddy, one of the programmers who helped fixing the Y2K bug, stated in a radio interview, "the reason why nothing bad happened was that so many people put so much hard work to it … doing a good job made them invisible" (Winter, 2005). Invisibility is not coincidental: as infrastructure becomes seamless, it becomes obscured. Although the Y2K panic was an isolated instance, this invisibility persists through daily life, underscoring a need to understand time in a broader context. In the following section, I introduce a pluralistic view of time that acknowledges its multifaceted nature in sociotechnical systems.

Plural Time

The passage of time is an absolute parameter in any system, and much of our current infrastructure is built around standardized, measured time. However, how this time exists and is experienced is a long contested issue. This was famously debated between Albert Einstein and Henri Bergson in 1922, where the scientist and the philosopher disagreed on a fundamental quality of time (Thompson, 2024). Einstein argued that time is a measurable, geometric entity that depends on an observer's velocity and gravitational field. In his view, time exists only as a physical dimension, with no deeper flow or lived experience that physics requires to explain. On the other hand, Bergson maintained that while physics describes time as a dimension, it fails to account for it as a fundamental, lived reality. According to Bergson, lived time cannot be reduced to clocks, as it inherently involves memory, change, and consciousness. The fundamental divide between these arguments marks a significant turning point in understanding time infrastructure.

Einstein's explanation of time as a measurable and relative quantity aligns with how current time infrastructure operates. Measured time is an absolute technical requirement, especially in fields that depend on precise synchronization, such as the medical sector or financial markets. This extends to bureaucratic and societal regulations, all of which treat time as a standardized, rigid quantity. While it is undeniable that measured time plays a crucial role in maintaining infrastructure, institutions often overlook the lived reality of time.

The notion that time is social is not particularly contested; in fact many thinkers, such as philosopher Martin Heidegger and political philosopher Antonio Negri who expanded on the Bergson v. Einstein's debate, arrived at very similar conclusions (Scott, 2006). However, a common misconception that still divides this discussion in sociotechnical contexts is the polarization of measured and lived time. In this paper I argue that both technical and social time are simultaneously essential to the foundation of infrastructure, and prioritizing one over the other

inevitably leads to failures. Time cannot be removed from its social and technical contexts because they're not opposites, but interdependent (Greenhouse, 2018).

This argument ultimately points toward a pluralistic approach in time infrastructure. In the context of William Connolly, renowned for his work on neo-pluralism in political philosophy, pluralism is a framework that acknowledges the incommensurability of values, experiences, and culture, emphasizing the importance of coexisting truths rather than enforcing a universal standard (2005). When applied to time infrastructure, I argue that measured time alone cannot account for how time infrastructure operates in society. A pluralistic view of time recognizes that while technical systems are necessary for coordination, they must coexist with lived and variable temporalities which are actively shaped by social structures and personal experience.

Having established what time infrastructure is in a pluralistic context, the next section will explore how time infrastructure functions within capitalist society. I will then examine both technical and social case studies to demonstrate how the failures of time infrastructure expose systemic inequities, arguing that a plural perspective offers a fundamental in depth view of understanding these breakdowns.

Demolishing Distances: Time, Technology, and Culture

In physics, speed is the rate at which distance changes. In capitalist society, speed can be similarly understood as the rate of change in capital accumulation. While physical speed can vary, being either slow or fast, discussions of speed in capitalist and contemporary society often assume it to be inherently fast. This assumption is tied to concepts like efficiency, which is defined as performing work in the least amount of time and at the lowest cost, and acceleration, which refers to the increasing speed of economic, social, and technological processes. Although this paper will refer to speed as inherently fast, it is crucial to examine the relationship between speed, distance, and time to better understand their role in current time infrastructure.

The invention of the railway permanently changed our relationship with time (Tomlinson, 2007, p. 15). Most notably, it did so literally, as it necessitated physical time infrastructure like standardized time zones (Brown, 2024). However, it also fundamentally altered how we experience movement through time: it introduced speed. While historians and social theorists debate which invention truly created acceleration, it is undeniable that we have experienced a compression of space and time especially within the last few decades (Wajcman, 2020).

As discussed earlier, speed not only depends on time, but also distance. The relationship between spatial awareness and temporality is deeply embedded in language. Although its framework varies across cultures, the use of spatial metaphors to define time appears to be universal (Boroditsky, 2000). For example, English speakers refer to the future as “ahead”, and the past as “behind”, while Mandarin speakers use vertical metaphors such as “down” for the future and “up” for the past. The linguistic and cognitive connection between time and space is physically reinforced through technological innovation, such as the railway, the telegraph, and later, cars and phones. These inventions not just introduced speed into daily life, they also reshaped our perception of distance. As sociologist Tomlinson, renowned for his works in speed and globalism,

explains, they do not just allow for faster travel and communication, they effectively "demolish distance" (2007, p. 21). What once was far away is now within reach, accelerating daily rhythms and feeding an ongoing cycle between technological innovation and societal change (Wyatt, 2008).

However, the very technologies invented to save time have instead led to an overwhelming sense of urgency. Social theorist Rosa (2004) coined the term *acceleration society* to describe this paradox. According to Rosa, as technological speed fragments time into smaller units, the continuity of time is disrupted, leading to a sense of instability. Expanding on this, Wajcman (2015) explains that time scarcity is more complex than a shortage of hours. She argues that habits of multi-tasking contribute to the feeling of running out of time, making time scarcity more about how time is experienced rather than a lack of numbers on the clock.

Cowan (1987), a credible and historically grounded scholar, portrays this paradox through her distinguished work in the acceleration of domestic labor. The maintenance and upkeep of household routines is a form of time infrastructure, one that relies on continuous and invisible labor. Advanced household appliances such as washing machines, vacuum cleaners, and dishwashers were marketed as labor and time-saving devices, yet they often intensified domestic work. These technologies created higher standards of cleanliness and efficiency, often leading to increasing expectations for multi-tasking and further fragmenting experienced time. Innovations designed to optimize time use instead created new demands and time scarcities, reinforcing the acceleration society paradox.

Interestingly, Cowan concludes her analysis with a simple yet important counterpoint to the criticism of speed. She points to the mother, the person expected to execute domestic labor, constantly negotiating time with overlapping demands and temporalities. Yet, according to Cowan, despite the mother's new anxieties, she no longer fears her children's survival through advancements in medicine, significantly reducing fatal risks that once governed daily concerns.

While speed in technology has intensified labor, it has not been inherently negative, as it has provided security.

The tension between the benefits and burdens of speed raises a broader question about whether slowing down would truly offer relief. Connolly (2005, p. 97) suggests that it might be tempting to romanticize pre-industrial timekeeping, where the uncertainties of the sundial allowed for a more fluid and slow experience of time. However, in a world structured around plane departures, sensitive financial markets, class schedules, and work hours, such fluidity is no longer feasible. Speed has become an essential component of capitalist life. As much as a culture of speed fosters valid anxiety, Tomlinson argues that societies have repeatedly chosen speed time and again (2007, p. 39).

While this is true, the excess of speed has proven to be dangerously destabilizing. Examples like algorithmic scheduling in the gig economy reveals this fragility. While online platforms like Uber offer hyper-flexibility, allowing workers to choose their hours with apparent efficiency and precision, this system threatens autonomy (Kaldokar et al., 2024). Time becomes unpredictable, governed by opaque algorithmic scheduling that prioritizes system efficiency over worker stability. As a result, workers, especially those in low-wage sectors, can experience time as fractured and uncertain, something imposed upon them for surveillance. This volatility undermines long-term financial security, upward mobility, education, and family well-being, revealing how excessive speed can deepen inequalities (Boushey & Ansel, 2016). Burnout, stress, and lack of financial security create a fragile workforce, ultimately threatening healthy economic growth and advancement in innovation (Sanchez-Gomez et al., 2021).

Speed evolved not by accident, but as a result of changing social standards and technical innovations. While speed has driven global change, its unchecked excess has fostered instability. Ultimately, time infrastructure is a multidimensional system with profound social implications.

The Power of Time

As discussed previously, the increasing pace within capitalist societies requires carefully managed time infrastructure. While time has highly technical qualities, its design, benefits and consequences are deeply social, like any other infrastructure. Given this, the failures of these systems reveal inequalities and inefficiencies, exposing that time is not only measured, but controlled and allocated. In this section, I examine how technical breakdowns and systemic failures in time infrastructure reveal these imbalances.

On May 6, 2010, the US stock indices lost almost $1 trillion during what became known as the 2010 Flash Crash (CFI, n.d.). While the market partially recovered within an hour, the crash highlighted the volatility of financial markets, creating a lasting impact. In a system where transactions occur within microseconds, the slightest discrepancies in time can have significant consequences, making precise time synchronization essential to maintain fair and efficient trading (Oehler, 2023). While the initial trigger for the 2010 Flash Crash was a large sell order, the subsequent market turmoil was exacerbated by high-frequency trading (HFT) algorithms operating without proper synchronization.

This event stands out among other market crashes, such as the 2012 Knight Capital collapse caused by a software bug (Popper, 2012) or the 2020 Tokyo Stock Exchange crash due to a hardware malfunction (Dooley, 2020). The 2010 Flash Crash wasn't simply a technical error, but a systemic flaw influenced by a lack of regulation and a culture of high-speed efficiency. The crash occurred because HFT was reacting faster than the market could process the data, causing mismatched price signals (Oehler, 2023). While some exchanges halted temporarily, others continued, fueling the discrepancy loop. Those with access to speed, HFT, gained significant advantages while those without it suffered losses.

In the aftermath of the 2010 Flash Crash, exchange officials and policymakers tested the implementation of circuit breakers to prevent sudden massive fluctuations and to force synchronization mechanisms to artificially slow down the market when there is an overload (Subrahmanyam, 2013). This action further proved that time is not one dimensional or neutral; it is actively controlled and shaped by policy, requiring regulation to prevent collapse.

The financial market operates on extreme precision and synchronization, yet its failures show that technical time alone is insufficient. The crash was not just a technical failure but a failure of governance, demonstrating an over-reliance on speed without considering broader systemic stability. However, financial markets are definitely not the only systems where time creates structural advantages and disadvantages. Bureaucratic time also operates as a form of control. This is especially evident in immigration and asylum systems, where time is controlled as a means of authority**.**

In immigration systems, time is not an evenly distributed resource; it is actively manipulated to regulate mobility and access to rights. Bureaucracies impose rigid timelines for application deadlines, while also utilizing speed for the "detection, interdiction, and removal of [detained] immigrants" (Boyce, 2020). However, this system simultaneously enforces deliberate waiting periods that can stretch for years, keeping individuals in a state of legal and social limbo. To expand upon this, Griffiths (2014) explores the temporal uncertainties of refused asylum seekers and the time infrastructure within immigration experiences.

As opposed to the speed we are accustomed to within daily life, the slowing of time still exists in the form of bureaucracy. Referencing the work of Medlicott (1999) on the temporal experiences of prisoners, Griffiths states that time can create significant suffering on its own. While the slowing of time could promise a fruitful end or change, the destructiveness of immigrant

detention is sourced from the sense of suspended time and stasis. As asylum seekers experience minimal change over long periods of time, bureaucratic systems can suddenly flux, switching into a more frenzied pace of change, creating excessive temporal distress in the detainees (Griffiths, 2014). This can make the immigration experience *Kafkaesque*, a term coined after the author Franz Kafka, where the suspended time of immigration detention can turn into a series of bizarre and arbitrary existences (Moynihan et al., 2022). These measures of enforcement aim to manipulate speed to intentionally create uncertainty to prevent, deter, or punish immigrant detainees (Boyce, 2020).

The intentional manipulation of time in immigration systems reveals that time is not just a neutral infrastructure, but a contested resource with multiple stakeholders. Just as financial markets engineer timekeeping to navigate sensitive economies, immigration bureaucracies manipulate time as a tool of governance, determining who can move and who must wait. This system is not static, as different stakeholders engage with time in distinct ways, each shaping and experiencing time infrastructure according to their power, interests, and vulnerabilities.

While one case is highly technical and the other more social, both illustrate how time infrastructure, when pushed to extremes, can collapse under its own contradictions. Whether in financial markets or immigration systems, these failures serve as an example of what happens when one dimension of time, intentionally or not, dominates without regard for broader consequences. Just like pipes, wires, and sewers, time infrastructure is a technical system embedded in social structures, and cannot be separated from lived experience. To fully understand infrastructure failure and inequality, time must be recognized as plural.

Conclusion: Harmonizing Time

In examining the complexities of time infrastructure, this paper highlights how time is not a neutral mechanism, but a multifaceted network that shapes both technical and social realities. The failure in time infrastructure reveals the fragilities and inequities embedded in today's societal structures, exposing how both measured and lived time are inextricably linked. As we further fracture time, the need for a pluralistic approach to time infrastructure becomes increasingly urgent in order to understand the broader implications of capitalist vulnerabilities.

While the implications and limitations of applied pluralism exceeds the scope of this paper, it provides an interesting foundation for further research on time infrastructure. The wide range of examples explored in this paper, from historical and cognitive to technical and societal, only scratch the surface of how deeply interwoven and expansive time infrastructure is. Further research could narrow the scope to focus on daily failures of time infrastructure, and question whether pluralism, when or if applied physically, offers a viable solution to existing fragilities.

Ultimately, without rethinking the dimensions of time, we risk repeating cycles, turning in circles, much like the generations Úrsula witnesses in repeated recurrence. While individual awareness and acceptance of time may offer some escape from its burdens, a broader reexamination might foster relief in the growing instabilities in society.

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