The Economics of Time Zones

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Abstract

This paper examines how and why time zones were established in the United States in the late-nineteenth century, relating the process to theoretical work on standards adoption and convention formation. The analysis focuses on the roles of coordination, expectations, and pre-emption in determining the time-zone system that prevailed. The events highlight how private agents can abruptly change even a society's most entrenched conventions, and resolve difficult standards adoption problems without public sector assistance.

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1 Introduction

How are a society's standards and conventions established? This question has become important to a diverse set of problems in recent years, ranging from the influence of product standards on technological innovation to the economics of social norms.[1] A central theme of theoretical work in these areas is the possibility that society may settle on an inefficient standard or convention, or stick with an existing standard when technological change presents a superior alternative. This possibility underlies numerous academic and policy debates that center on whether markets generate adequate incentives to change outmoded but well-established standards and conventions, or whether non-market institutions—laws and government policies, most controversially—are sometimes necessary.

To better understand this issue, it is useful to examine situations where decentralized markets have succeeded in changing longstanding standards and conventions. This paper analyzes one such case: The adoption of standard time and the time-zone system in the late-nineteenth century. Contrary to popular impression, our familiar time-zone system was not established by a political process or law, nor following an international scientific consensus. Rather, it sprang from a meeting of a small group of private individuals who single-handedly determined the nation's system of time for generations to come. Understanding this process provides a striking demonstration of how private agents can induce society to abandon one longstanding convention of commerce and communication, and abruptly adopt a superior, yet incompatible, alternative.

The insights pertain to the role of the public sector in setting standards—an issue that today spans electronic communications technologies, the metric system, and even automobile child-safety seats. In these and other recent instances, government organizations concluded that market participants were unable to coordinate on desirable standards and so stepped forward to specify one.[2] Such observations raise the question of whether private agents can resolve difficult standards adoption problems without public sector involvement. The literature has examined this question when property rights over a standard are well-defined, or a "sponsored" standard's adoption.[3] However, when property rights over standards are

[1] Useful overviews of these literatures are Gilbert (1992), Katz and Shapiro (1994), and Farrell and Klemperer (2004) on technological standards in product markets, and Elster (1989), Young (1996), and Ostrom (2000) on the economics of social conventions and norms. See also Friedman (1993).

[2] The European Commission concluded in 1999 that commerce within the EU had failed to harmonize (on the metric system) of its own accord, and mandated the UK abandon the Imperial System within a decade (Dir. 99/103/EEC). In the US, the National Highway Traffic Safety Administration mandated a single, specific design for attaching infant car seats in all new passenger vehicles, citing insufficient standardization by infant seat and motor vehicle manufacturers (49 CFR §571, 596). Augereau, Greenstein, and Rysman (2004) discuss the costly proliferation of incompatible 56K computer modem standards until resolved by a government standards-setting body in 1998.

[3] See, for example, Farrell and Saloner (1985, 1988), Katz and Shapiro (1986, 1992), Gabel (1991), Farrell and Shapiro (1993), Besen and Farrell (1994), Liebowitz and Margolis (1994), Fudenberg and Tirole (2000),

ill-defined or non-existent—as in the metric system example—this becomes a matter of how conventions change that is not well understood. The analysis offered here is valuable in that it reveals *how* strategic elements central to the literature—*viz.,* pre-emption, costly signaling and communication, and shaping consumer expectations—are successfully employed to implement non-proprietary standards and new economic conventions, without public sector assistance.[4]

Two lessons are offered. The first is a pragmatic one. Can a small number of private agents successfully coordinate the *simultaneous* adoption of a new convention by millions of individuals? Even with today's mass media and communications systems this would seem an extraordinary task; to do so over century ago is almost inconceivable. Yet this is precisely what a handful of American railway managers were able to achieve: On a single day in 1883, the vast majority of the United States population voluntarily abandoned a then-prevailing system of hundreds of different local time conventions, and adopted the system of four time 'zones' that we use today. The lesson here for contemporary debates is that coordinating the simultaneous universal adoption of a new standard clearly need not proceed *de jure*. Private parties can orchestrate such feats well enough, provided there exists an adequate benefit in doing so.

Second, the case of standard time serves as an informative counterpoint to more extreme views on 'lock-in', or the efficacy of market forces in the presence of strong network effects. This issue has proved a point of contention in the academic literature over the last two decades. Arthur (1989) and David (1985) are pessimistic, arguing that long-run outcomes can be inefficiently determined by accidental short-run events; at the other extreme, Liebowitz and Margolis (1990, 1994) claim that standardization problems are readily and regularly overcome by conventional market mechanisms. The lesson of standard time for this debate is that while economic conventions and established standards are not trivial to change, viewing 'lock-in' as a permanent phenomenon seems ill-conceived. Private interests do find ways to abruptly change even a society's most entrenched conventions, as the record here attests.

The balance of the paper is organized as follows. Section 2 provides background on the market for time services in 19th century America, and the conflict that arose over standard-

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or Klemperer and Farrell (2004).

[4]This strategic emphasis differs from much prior work. Many analyses of standards competitions have focused on the theme of 'lock-in' to potentially inefficient standards due to (non-pecuniary) network externalities. A shortcoming of these studies is that limited attention is paid to the strategies pursued by a standard's proponents and adopters, leading to overly narrow views of how standards can change. Examples in this vein include the QWERTY keyboard of David (1985) (but see Liebowitz and Margolis (1990)), railway gauge and equipment standardization (van Vleck (1997), Puffert (2000, 2002), Scott (2001)), the alternating-current electrical system (David and Bunn (1988), David (1992)), AM versus FM radio (Besen (1992)), and early nuclear power technology (Cowan (1990)).

izing it. In Section 3 the interests of the railways in standard time are considered. Section 4 analyzes how the railways coordinated broad adoption of one among many incompatible competing standards—a general problem that economists study to this day. Section 5 then addresses pre-emption incentives and the first-mover advantage that the railway managers foresaw. This reveals precisely why they were motivated to define a new time standard when they did, and why it has persisted since. A brief conclusion closes.

2 Time in Mid-19th Century America

In the nineteenth century, time was not freely-available public information as it is today. Rather, it was a valuable service to be bought and sold. To understand the standards competition that arose over it, it is necessary to note a few practices and the technology of the day.[5]

2.1 The Local Time System

Until the telegraph's invention in the 1840s, time standards were strictly local in nature. In American towns and cities, a central clock tower was typically maintained by a local jeweler or amateur astronomer who set the clock to noon when the sun appeared directly overhead. Along a meridian these local times varied only slightly, but across meridians the traveler found a continual array of local time conventions. Figure 1 shows the local time standards of selected cities in 1857. When it was noon in Chicago, for example, it was 12:19 in Columbus, 12:13 in Atlanta, 11:50 in St. Louis, and 11:27 in Houston.

The telegraph dramatized the lack of coordination in time standards, and simultaneously ushered in a new market for time services. In the 1850s observatories began to use the telegraph to determine precise meridians and distances, a process involving the exchange of exact local (sun) time from two distant locations. The more entrepreneurial of these observatories soon offered time services over the telegraph network to surrounding communities. Over the next thirty years, most railroad companies established contracts with a local observatory for time services.

Observatories quickly realized the commercial potential of their time services, and railroads benefited from these services in improved train operations. Nevertheless, individual railways' time standards were largely incompatible, and enjoyed limited adoption among the public. Rarely did adjoining railroads' system use the same meridian (city) for their standard; for example,

[5] The development of time-keeping systems and standards is well-documented in the historical literature; see, e.g., Bartky (2000), Howse (1980), Landes (1983), or O'Malley (1990). This background draws on *PAMS* (1883), Allen (1904), and Corliss (1953).

> A traveler from Portland, Maine, on reaching Buffalo, NY, would find four different kinds of 'time': The New York Central Railroad clock might indicate 12:00 (New York City time), the Lake Shore and Southern Michigan clocks in the same room 11:25 (Columbus time), the Buffalo city clocks 11:40, and his own watch 12:15 (Portland time). At Pittsburgh, Penn., there were *six* different time standards for the arrival and departure of trains. (Howse (1980, p. 120)).

Furthermore, although small towns along a specific railroad line sometimes followed the railway's time standard, most communities and cities followed their longstanding local sun time standard. By one estimate, in the 1870s there were some 8,000 individual local time conventions being kept by towns and communities across the nation. Abandoning this local time system was inconceivable—as late as 1882, a U.S. Senate report on this haphazard state of affairs concluded that "it would appear to be as difficult to alter by edict the ideas and habits of the people in regard to local time as it would be to introduce among them a novel system of weights, measures, volumes and money." (Senate Reports (1882)).

2.2 The Federal Conflict over Standardizing Time

The expanding economic importance of time services soon led to conflicts over time-keeping standards.[6] In the public sector, an important element of this conflict arose between two federal agencies with interests in time-keeping systems. The U.S. Signal Service Bureau's advocacy of a national standard clashed with the support for local time of the U.S. Naval Observatory; their protracted dispute set the stage for the unilateral action of the railroads, who determined the time zone system that ultimately prevailed.

The U.S. Signal Service Bureau, part of the Department of War (predecessor to the Department of Defense), used the telegraph network to compile meteorological and other information from around the nation. The Bureau was frustrated by the difficulty of achieving concurrent reports from field offices using a system of innumerable local times, often with unknown relation to one another. In 1875 the Bureau's director, Cleveland Abbe, contacted the American Metrological Society in the interest of developing a national time-keeping standard.[7] With Abbe's participation the society proposed a plan of five meridian-based time standards for North America, each differing by one hour. In 1879, the society began actively promoting the idea to railroad and government officials.

[6]By the 1870s, commercial time services had become a lucrative field for observatories and telegraph networks. Each observatory sold a slightly differentiated product: Astronomers had come to acknowledge that only one observatory could define a 'standard' time, for with the existing technology no two independent observers could exactly agree on the true (astronomically based) time. As a result, an observatory often had a local monopoly on its standard for time—and a flow of economic rent associated with the local standard.

[7]The American *Metrological* Society (1873-1897?) is not to be confused with the contemporary American *Meteorological* Society. The Metrological Society was a scientific organization interested in establishing uniform standards of measurement for science and commerce.

The Signal Service concurrently pursued a plan to establish time balls in major cities using the Signal Service's distribution of Greenwich-indexed signals on this new system.[8] With the assistance of the Harvard Observatory, a time ball on the new system was established in Boston. Proposing that cities and towns discontinue the use of local time altogether, in 1881 the Signal Service planned a time ball on the new standard for New York City. New York, however, ran on local time using signals transmitted by Western Union from the U.S. Naval Observatory in Washington D.C.

John Rodgers, the Superintendent of the Naval Observatory through 1882, was an influential advocate of local time. Beginning under his predecessor in 1865, the Naval Observatory and Western Union developed a close and mutually beneficial relationship. The Naval Observatory provided Western Union with highly-accurate time signals free of charge; Western Union then transmitted these signals to numerous ports and Navy facilities for setting ships' chronometers (used at sea for determining longitude). Western Union converted the Naval Observatory's signals to local times and profited from selling the resulting time services throughout the nation. One of Western Union's major customers was the City of New York, whose time ball fell atop the Western Union tower at precisely noon *local* time.

Western Union and the Naval Observatory criticized the Signal Service's plans, which would effectively end the Western Union monopoly on government-derived time signals in many cities. In an effort to maintain the local time system, Western Union and the Navy had introduced in Congress in 1882 a bill to establish time balls on the customs houses in port cities, under the control of its Washington observatory and set to mark local noons. Although the bill failed, federal action on the alternative standard supported by the Signal Service ended as well: With the assistance of the Navy, Western Union was able to defeat plans for advancing a national standard by convincing the Secretary of War that the Signal Service Bureau was operating outside its mandate.

Nevertheless, the conflict by then managed to pique the attention of William F. Allen, who headed a trade association of American railway managers. Correspondence with Cleveland Abbe alerted Allen to the activities of the scientific community and the armed services on standard time. Allen correctly perceived the substantial implications for the railroads of a national time standard, and the costs to be borne if a patchwork of local times was mandated by legislation. With this in mind, Allen began in late 1881 to pursue vigorously the matter of standard time in railway publications and before the railways' aptly-named trade association, the General Time Convention.

[8] Now an anachronism, time balls provided accurate time on a daily mark in an era of inaccurate watches and clocks. Placed atop a pole on a tall building, the large metal globe was dropped to signal local noon to the city. See O'Malley (1990, pp. 87–89) for details and pictures of the 1877 Western Union time ball in Times Square.

3 The Railroads: Incentives and Actions 1870–1882

The railroads confronted time-keeping as a problem for the coordination of operations. Incompatible standards at the points where lines met presented confusion and inconvenience for the traveler, as well as a coordination problem for freight transfer and through trains on single track lines. Stephens (1989) documents numerous wrecks attributed to the failure of conductors to coordinate with synchronized time; in fact, the General Time Convention (GTC hereafter) was established in 1872 precisely "to settle questions of running times for through trains." (Allen (1883, p. 30)).

By the 1870s there had evolved a system of railway times and a workable if awkward mechanism by which adjoining railways coordinated transfers. Several attempts at a more systematic coordination mechanism were made, but the railways were in little mood to cooperate with one another. The Panic of 1873 and ensuing rate wars created fierce competition between many railways, and the climate left little disposition for cooperation on standardization issues. Other rate wars broke out sporadically through 1882, leading to infrequent meetings of the Convention.

Despite the conflicts, by the early 1880s several different time standardization proposals were put forward to individual groups of railway managers. One of note was developed by Charles F. Dowd. Dowd's proposal divided the nation into four zones, each spanning 15° (1 hour) and with precise vertical (longitudinal) boundaries between each zone—see Figure 2. However, Dowd proposed that only railways should use the new standard and that towns and cities would continue on local time. In an 1870 circular, Dowd tabulated the differences between local and the proposed railway time for thousands of towns and cites on five hundred railway lines, and suggested his table be used as a guide for railway passengers (Dowd (1883, p. 93-4)). He promoted the guide to numerous railway officials, who acknowledged his ideas had merit but cautioned that achieving them appeared infeasible as a practical matter.

Hesitation to adopt a new time standard also arose among railway managers from anticipation of a negative public reaction. In 1881 the GTC received reports from Cleveland Abbe (of the U.S. Signal Service), Prof. Frederick Barnard of Columbia, who chaired the American Metrological Society, and the American Association for the Advancement of Science, all advocating similar ideas for a system of time 'zones'. The reports were basically ignored as the work of cloistered scientists, however. One prominent railroad executive asserted that the centuries-old local time system "and the hold it has upon the literature, manners, and customs of the people is clearly beyond the power of the greatest power in the land [the railroads] to alter."[9]

[9] Frederick T. Newberry, letter to William F. Allen. In *PARA* (1893, pp. 684–5).

4 Splintering and Bandwagon Equilibria: Understanding the Adoption Process

Allen was not so convinced of the railroads' limitations in effecting change, however. Standardized time, while not a tangible technological innovation in the traditional sense, is a convention subject to the same compatibility problems as technologies with classic network effects (as examined in Katz and Shapiro (1994) or Liebowitz and Margolis (1994)). In particular, standardized time is characterized by strong complementarities between users: The value of adopting the standard increases with the total number of same-standard users. As Allen was well aware, the problem of achieving adoption of a desired standard is one of coordination.

In terms of the modern theory of standards, the local time system comprises a *splintering equilibrium* (Klemperer and Farrell (2004)). It was a stable situation in which many different, incompatible standards were simultaneously in use in different locales, rather than one single, common standard prevailing everywhere. This system worked fine over the long history before the railroads and telegraph, but became increasingly inefficient with the growth of trade and information by these means in the 1870s and 1880s. Yet there was no simple way for local time conventions to evolve toward a common standard. The cost of changing a longstanding local time convention would be incurred by a city's residents and businesses, but the benefit would arise only if *other* locales changed as well. This asymmetry discouraged any unilateral moves toward a different convention.[10]

Further insight is gained by considering the situation from a game-theoretic standpoint. Suppose that each of N players non-cooperatively chooses whether to adopt a new standard or not. To capture the complementarities that give rise to standardization benefits, let the relative payoff from adoption to player i take the form $V_i(n) = n^{\alpha_i} - c_i$ where n is the number of *other* agents that adopt, $c_i > 0$ is a one-time cost of switching incurred by player i, and $\alpha_i > 0$ is a preference-intensity parameter reflecting differences among players of the benefits of widespread adoption. An essential feature of time-keeping or measurement conventions is that no one wishes to adopt a standard used by no one else; thus, $V_i(0) < 0$. Note that because people in the 1880s took their time from a city's clock tower or time ball each day (see §2.1), the relevant 'players' in this context were the local town or city authorities that oversaw this mark.

With two cities, the standardization problem is illustrated by the familiar ('stag-hunt') coordination game in Figure 3-a. Here each city simultaneously decides whether to stay with

[10] In principle, this problem could be overcome with a multilateral contract among a region's towns and cities to adopt a common time standard (which becomes binding only if agreed to by enough participants). It appears the railways viewed the transaction costs of arranging such mutual assurances between cities to be prohibitive. The possibility of state legislation as a solution is discussed in §5.

		City 2	
		Switch	Stay
City 1	Switch	$1-c_1,\ 1-c_2$	$-c_1,\ 0$
	Stay	$0,\ -c_2$	$0,\ 0$

Figure 3-a

its existing local time, or to switch to a new time standard. In the interesting case where the cities' switching costs are not prohibitively high ($c_i < 1$), there are two pure strategy equilibria: One in which both adopt, and one in which neither does. That is, even if the railroads could arrange for cities to make a decision on switching to a common time-keeping standard, that alone would not guarantee they would abandon their local times—even if jointly doing so might be better for all.

Overcoming this coordination problem among the towns and cities spanning nineteenth-century America is the crux of the problem the railways faced in implementing standard time. Resolving it requires not only common recognition that a new convention would be more efficient *if* broadly adopted; it also involves, as Klemperer and Farrell (2004) evocatively put it, a leadership-like ability to exhort "let's all do X instead." The railways sought to do essentially that, as an alternative to obtaining mutual assurances from hundreds of towns and cities across the nation.

The railways were quite sophisticated in how they carried this out. First, there was the essential matter of feasibility: There would have to be a detailed plan for the new time standard so cities could consider whether or not to adopt it. Here, the railway managers realized an important opportunity to define—in their own interests—the nation's time system.

Allen and the GTC developed a standard time 'zone' proposal for both the United States and Canada by modifying ideas circulating in the scientific community to the preferences of the railroads.[11] Although most zone system proposals were based on meridians 15° apart, the boundaries either ignored existing commercial activity and political entities or were altogether unspecified. Among the railroads, it was common practice to make time changes at the meeting of independent railway lines or between eastern and western divisions of a single large company. Although the resulting jagged, uneven boundaries made little sense from a geophysical or political point of view, for the railroads they greatly facilitated day-to-day operations.

At the time Allen began to develop his proposal in 1882, over fifty different 'railway

[11] This summary is based upon Allen (1883, 1904), Bartky (1989, pp. 46–8), and O'Malley (1990, pp. 110–18). Historians generally credit William F. Allen for the railways' plan and its success (e.g., Bartky (1989) p. 45 ff.); Blaise (2000) also credits railway engineer Sir Stanford Fleming, who steered the time-zone system toward adoption internationally in 1884.

times' governed the running times of trains. Allen proposed consolidation to five zones: Intercolonial, Eastern, Central, Mountain, and Pacific.[12] The meridians indexing these zones were not of overriding interest to the practical-minded members of the GTC, however. In defining the zones, what railway managers valued highly was a system that minimized their switching costs—that is, a plan that altered existing time division breaks between railways as little as possible. Drawing upon existing railway maps, Allen proposed a system that fit the new zone boundaries to the termini of the railways. The Eastern and Central zones, for example, met at Pittsburgh, where the Pennsylvania Railroad's two divisions had long switched from 'Philadelphia time' to 'Columbus time'. Allen's plan was designed so that no railroad would have to reprint schedules or change running times. Most would simply have to reset their clocks and watches a few minutes.

As the railways were well aware, achieving universal adoption of this plan would not require simultaneous adoption by *all* towns and cities. Rather, a successful strategy would require only a smaller, critical mass of adopting cites initially. The railways correctly perceived that once a sufficient number of cities adopted, a holdout faces a different situation than that in Figure 3-a. It could continue to hold out, or join a set of cities it knows are already using a common standard. Facing that situation, the benefit of joining a large and growing base of common-standard users would quickly become too large for most communities to ignore. Thus, even if many cities took a wait-and-see approach to abandoning their local time convention, standard time would spread (geographically) if enough key cities and railways adopted initially. In modern theory, this is a *bandwagon equilibrium* (Farrell and Shapiro (1993)): Each player is willing to adopt if many others have adopted as well, and expectations are required to assure the initial movers are willing to do so—that is, 'to get the wagon rolling'.

Initial adoption of the new standard, however, was crucially dependent upon participants' expectations. This dependence arose not only because of the coordination problem among the cities illustrated in Figure 3-a, but also because a similar problem emerged among the railways party to the GTC. Many members were willing to abandon their system of railway times and commit to the new time-zone system *only if* the cities they served could be expected to follow. That hesitation was clear in April 1883, when Allen's time-zone proposal was put to a full meeting of the GTC. The plan met with provisional acceptance, but Allen was ordered to secure the acquiescence of the managers of every railroad in the nation and to report at an October meeting. In fact, several railways expressed reservations about adoption and concerns over public rejection. A number of New England railways, for

[12] Now known as the Atlantic time zone, Intercolonial time is used in Canada east of Maine. The Greenwich Mean Time standard by which the zones are indexed was formally adopted at the International Meridian Conference one year later. See Howse (1980).

example, agreed to adopt the new time only if the Harvard Observatory agreed to drop its time ball by the same standard.[13]

By October Allen had received responses from railways representing 78,000 miles of track, out of the 113,000 total miles in service in the U.S. The majority of these favored the change.[14] At the October 1883 meeting, Allen's plan was presented with maps of the incumbent system of fifty-odd railway times and the new standard of five—see Figure 4. At his vigorous urging, the GTC members set a tentative time for the change to the new system: Twelve o'clock noon on November 18, 1883, when the railways would shift to their customary winter train schedules that year.

The approving railways publicly touted their intentions to adopt a uniform time system. Publicizing the changeover date, and timetables for various cities to change to the new time zones, allowed for a simultaneous, coordinated move to the new standard. Several observatories agreed to disseminate detailed information about the change, including the Yale College Observatory which issued time for Connecticut railways. With the willingness of leading observatories to supply the new time, the railroads now had a credible plan for a new time system.

One non-trivial problem remained, however: How to ensure that enough cities (and railways) would adopt on the target date. Privately, Allen and his supporters within the GTC were far from certain of success. Indeed, in early October 1883 Allen confided to the president of the Michigan Central that he "feared that nothing short of Congressional action is likely to bring about any uniformity."[15] In short, if enough cities were not expected (or, more precisely, did not expect one another) to adopt standard time come November 18, then the effort would likely fail entirely. The challenge facing Allen and proponents was therefore to shape these expectations, so as to achieve an initial outcome from which adoption would then spread universally.

Here, Allen and the GTC hit upon a simple yet surprisingly powerful strategy to resolve this canonical standards adoption problem. They co-opted a number of large cities that were receptive to the plan into 'signaling'—in a costly, but non-binding way—an intention to adopt on November 18th.[16] This signaling took the form of public pronouncements by a

[13]For the game-theoretically inclined, this problem within the GTC ruled out a sequential adoption strategy by the railroads from the start. The railroads as a whole were unwilling to move unilaterally to adopt standard time, as many members feared the public might not be willing to follow their lead. Technically, successful sequential adoption relies upon iterative backward induction among cities, rather than solving the coordination problem in Figure 3-a. Given the number of railways and cities involved, it seems plausible to dismiss a counterfactual sequential adoption argument that requires a long chain of backward induction to support adoption.

[14]Concurrent sources indicate that by November 7, 1883, about 100,000 miles of track had pledged to replace their individual railway times with the new time-zone system. The remaining 13,000 indicated their intentions to conform to the new standard if adopted by others (Allen (1883, p. 42)).

[15]Letter to H. B. Ledyard, Oct. 4, 1883. In *William F. Allen Papers* I; see O'Malley (1990, p. 116).

[16]Of course, if it had been possible to achieve binding multilateral agreements to adopt among enough

city's officials detailing the plan, the rationale for adopting it, and so forth. These occurred through public meetings, newspaper announcements, and the like. Such announcements were far from binding upon a municipality's officials, but were privately costly for several reasons. One is the direct cost of publicizing information about the change and reasons therefor. More important, however, was the potential for confusion and disarray in all manner of commerce if a city did not follow through with the time change after announcing it—blame for which would fall heavily upon a city's civic leaders.

The railways worked to elicit adoption announcements primarily from the largest East Coast cities. The targets of these public announcements were not only a city's residents, but—importantly—were the *other* cities in the region. The railways then did their part to ensure that any city's favorable public announcement was widely disseminated to other cities that had not yet declared intentions on the matter. As for why certain cities were individually willing to make these costly announcements, the historical record is suggestive but incomplete. Undoubtedly, some cities viewed the plan as highly beneficial (esp. those served by multiple railways with conflicting railway times), and were motivated to publicize their intentions to increase the likelihood of successful adoption regionally. In some cases, however, the railroads appear to have lobbied and co-opted key cities through personal connections, unpublicized influence, and the occasional strong-armed tactic.[17]

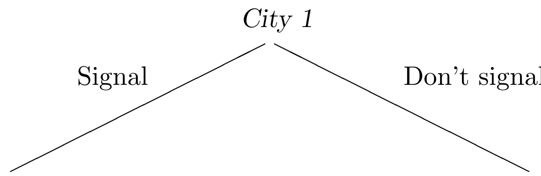
To see precisely why cities' announcements can overcome the coordination problem and lead to universal adoption, consider things again from a game-theoretic perspective. Adoption with pre-announcements is usefully viewed as a two-stage game, illustrated in Figure 3-b for two cities. Here city 1 has a first-stage option of either signaling—at a cost—or not signaling its intention to adopt standard time. At the second stage, all players simultaneously choose whether or not to adopt the new standard. Absent a signal, the two cities face the same simultaneous adoption subgame as before (*i.e.,* Figure 3-a). If city 1 does signal, however, its payoffs change: a city choosing to announce its intentions to the public incurs a non-recoverable publication (signaling) cost $m > 0$ in doing so.[18]

It is this publication cost that selects an equilibrium outcome with broad adoption of the new standard. Publicly announcing an intention to adopt is a costly signal, and not

cities, then the coordination problem of Figure 3-a would be moot. As noted above, the transaction costs of obtaining such agreements appears to have made that approach infeasible.

[17]Personal connections and behind-the-scenes lobbying appear to have been particularly important in Boston and New York City. O'Malley (1990, p. 122) notes how expected resistance from Western Union—which provided New York City's local time, a lucrative business—was dealt with: Charles Pugh, a Vice President of the powerful Pennsylvania Railroad, told Allen "I will arrange to have some little pressure brought to bear upon Messrs. Eckert and Bates" (Western Union's General Superintendents). Western Union soon after agreed to drop its New York time ball on the new standard.

[18]As noted earlier, practical considerations suggest that the cost to city 1 from signaling might be large only if it did not follow through with the switch. This modification of the payoffs would not change the ensuing analysis.



	Switch	Stay
Switch	$1-m-c_1,\ 1-c_2$	$-m-c_1,\ 0$
Stay	$-m,\quad -c_2$	$-m,\quad 0$

	Switch	Stay
Switch	$1-c_1,\ \ 1-c_2$	$-c_1,\quad 0$
Stay	$0,\quad -c_2$	$0,\quad 0$

Figure 3-b

announcing is strictly preferable except to the extent that signaling successfully induces others to adopt. In Figure 3-b, for city 1 the strategy (*signal, stay*) is strictly dominated by (*don't signal, stay*); thus city 2 should expect city 1 to switch if city 1 does signal. And city 1 is willing to signal its intentions, as long as its switching and signaling costs are not prohibitively high relative to the value it associates with widespread adoption. In essence, the signal of a costly public announcement—while non-binding upon its maker—shifts other players' expectations such that all cities without large switching costs adopt at the simultaneous-move stage.[19] Stated in other terms, a city's announcement that it will adopt is credible because it would then be costly for the city not to follow through. And if adoption by several key cities is expected, then other towns and cities with which they interact will prefer to do the same.

Now known as 'the day of two noons', Sunday, November 18, 1883, witnessed the smooth adoption of Standard Railway Time (as it was quickly labeled) in towns and cities across the United States. Newspapers described crowds forming before the public clocks in major cities to witness the change. The crowd gathered before the Western Union building in New York City watched the time ball drop at noon *twice*—once at the local time noon, then again four minutes later on the new Eastern Standard Time. Seventy of the 100 principal cities in the U.S. adopted the new time system immediately. Just as the railways anticipated, elsewhere the population 'joined the bandwagon' soon after and switched to standard time (despite some outcry over adapting themselves to the needs of the railways). One modern scholar states that 85 percent of U.S. towns with over ten thousand inhabitants had adopted standard time by one year later (Howse (1980, p. 126)). "The system adopted by you," Allen boasted to the Convention in October 1884, "now governs the daily and

[19] This is technically a forward induction argument, in the sense of van Damme (1989) and Ben-Porath and Dekel (1992). Unlike Ben-Porath and Dekel (1992), however, there is no incentive for a player to engage in costly counter-signaling here. That only city 1 has the opportunity to signal follows from the railways' efforts to induce only the largest cities to make such public announcements. I ignore the possibility of signaling an intention to not adopt, as it is a dominated strategy and did not occur in practice.

hourly actions of at least fifty million people" (*PARA* (1893, p. 703)). In short, local time was soon forgotten throughout most of America.

5 Pre-Emption Incentives: The Timing of the Railroads' Decision

The analysis of how the railways achieved adoption of the new standard nevertheless leaves an important question unanswered: *Why* did the railways adopt standard time? Their system of numerous railway times had proven workable and satisfactory to many. Proposals for standard time has been circulating since at least 1870 (see §3), and the railways had shown nothing but disinterest in such schemes. Rate wars throughout this period left little *esprit de corps,* and the April 1882 meeting of the GTC was altogether abandoned by the warring members. Yet at their October meeting, the railways were uncharacteristically motivated to act on the issue of standard time.

Their awakened interest stemmed from realizing the high cost of conforming to an alternative standard (such as Figure 2), and the understanding that adoption would be facilitated if no systematic alternative was yet available. Foremost among their concerns was a patchwork of local times, established either by a cascading set of state legislative decrees or by federal action.

In an April 1883 address to the Convention, Allen cited the case of Connecticut where—against the objections of the Boston railways—the state legislature had enacted a statute making the time of New York City the state standard. Raising the ominous prospect of ensuing legislation in other states, and the possibility of the railways pre-empting such actions with a standard of their own design, Allen remarked:

> The Legislature of Connecticut has passed a law making New York [City's local] time the standard for all railways in that State; but we should settle this question among ourselves, and not entrust it to the infinite wisdom of the several State legislatures. (*PARA* (1893, p. 691)).

Of no less concern was the possibility of federal initiative. As noted in §2.2, in late 1881 Congress received a proposal sponsored by the Naval Observatory to establish a time ball in all port cities based on *local* time using the Naval Observatory's signals. Such a bill would give federal endorsement to the hodge-podge status quo of local times, possibly inducing cities to maintain local time at the expense of the railroads' standards. Although the bill was not enacted in 1882, re-introduction in the following session remained a major concern.[20] Allen confided to a colleague, "Congressional action ... is to be depreciated, as

[20] Lt. E.K. Moore, U.S.N., in addressing the GTC in October 1883, stated that he "had no doubt the originator of the present bill would reintroduce it .... The present bill would have passed at the last session so far as any opposition was concerned, and only failed for want of time." (*PAMS* (1883, p. 76)).

. . . there is little likelihood of any law being adopted in Washington, effecting [*sic*] railways, that would be as universally acceptable to the Railway Companies as this movement has proved to be."[21]

With Allen's prompting, the railways recognized the value of pre-emptively instituting a standard tailored to their interests. The gains from replacing complicated time-interchange tables with the new zone system paled in comparison with the benefits of forestalling legislative intervention, and the railroads deigned to present the federal government with a *fiat accompli:*

> If we agree that the system of hour standards here proposed is the one best adapted for practical use on our railway lines, whether it be the best for scientific purposes or not, whether it conforms to the whims of . . . our legislatures or not, it is clearly [our] duty . . . to adopt the measure.[22]

In short, the railroads' primary motivation in implementing standard time was to pre-empt public adoption of an incompatible standard. The incentive to pre-empt arose not only from forestalling legislative support of local times, but also because the network effect characterizing adherence to standard time would subsequently make it more difficult to change a single, widely-adopted convention.

From an economic perspective, this is a striking example of the *installed-base effect* in the theoretical literature on standards adoption (Farrell and Saloner (1986), Gabel (1991)). By providing the first standard time convention, the railways had the opportunity to build a broad 'base' of similar time-standard users. Any subsequent alternative standard would face the challenge of competing for a marginal city whose opportunity cost of adopting the alternative standard is higher, via the incentive remain part of the 'installed' base of first-standard users. Furthermore, complementarities between users of the same standard imply that cities adopting the railway's initial time standard stand to gain from convincing a marginal city to maintain it.

The interesting implication is that it matters not simply *how many* ultimately adopt the new standard, but *when* they adopt. A sequential adoption process, or slow diffusion of the new convention, builds a small base of committed users and hence an incompatible standard (via legislation) might not be deterred. In contrast, simultaneous adoption establishes a large installed base immediately, possibly foreclosing the introduction of an incompatible standard entirely. This is precisely the effect exhibited by the adoption of Standard Time: No state enacted statute incompatible with it after 1883, and Connecticut immediately modified its standard to achieve compatibility with the railways' new Eastern Standard Time zone. Federal action on the matter of standard time, including the Naval

[21] Letter to H. B. Ledyard, Oct. 4, 1883. In *William F. Allen Papers* I, op cit.

[22] Allen addressing the General Time Convention, April 1883 (*PARA* (1893, p. 691)).

Observatory's efforts to promote local time, ended altogether. The railways' time-zone system was ultimately incorporated into federal law in 1918, when Daylight Savings Time was created to reduce fuel consumption during World War I.[23]

6 Concluding Remarks

Two closing points are noteworthy. First, while this paper has not pursued the welfare consequences of alternative conventions, some observations on it are clear. The system of local times used until 1883 would have become increasingly burdensome on the American economy if it had continued unchanged. Given the growth of inter-regional trade and commerce over subsequent decades, adopting *some* common standard for time-keeping seems indisputably more efficient than using thousands of local times. On the other hand, it is also clear that global welfare was not the concern of the railways. There is no obvious justification for viewing the time zones with the initial, erratic boundaries the railways crafted as optimally chosen from a social standpoint. And indeed, the boundaries (especially between the Eastern and Central zones) have moved considerably since, as a comparison of Figure 4 with any current national map readily confirms.

The second point concerns how economic conventions originate. Broadly speaking, economists have identified two ways in which conventions become established: One is through the fiat of central authority, and a second is through the gradual accretion of precedent (Friedman (1993), Young (1996)). This second mechanism focuses on chance events and historical 'accidents' as the seeds of convention formation. It has also become the subject of a great deal of research in recent years, building upon related work by Kandori, Mailath, and Rob (1993), Ellison (1993), Young (1993), and others. In contrast, the analysis of standard time offered here suggests a third, distinct mechanism for the origins of economic conventions. This is the initiative of private agents who see opportunity in the inefficiencies of outmoded conventions, and develop strategies to establish a better alternative. This third perspective de-emphasizes the role of 'accidents' and random events in explaining how longstanding conventions suddenly change, and instead emphasizes their formation as a result of familiar economic incentives. Private interests can change even a society's most entrenched conventions when they become outdated and inefficient, as the record here attests.

[23]This 1918 law (40 Stat. 450) stipulated that subsequent changes to time-zone boundaries shall be made by the U.S. Interstate Commerce Commission having "regard for the convenience of commerce and the existing junction points and division points of common carriers," and remains in effect (15 U.S.C. §261).

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COMPARATIVE TIME-TABLE,

SHOWING THE TIME AT THE PRINCIPAL CITIES OF THE UNITED STATES.

COMPARED WITH NOON AT WASHINGTON, D. C.

There is no "Standard Railroad Time" in the United States or Canada; but each railroad company adopts independently the time of its own locality, or of that place at which its principal office is situated. The inconvenience of such a system, if system it can be called, must be apparent to all, but is most annoying to persons strangers to the fact. From this cause many miscalculations and misconnections have arisen, which not unfrequently have been of serious consequence to individuals, and have, as a matter of course, brought into disrepute all Railroad-Guides, which of necessity give the local times. In order to relieve, in some degree, this anomaly in American railroading, we present the following table of local time, compared with that of Washington, D. C.

NOON AT WASHINGTON, D. C.		NOON AT WASHINGTON, D. C.		NOON AT WASHINGTON, D. C.	
Albany, N. Y.	12 14 P.M.	Indianapolis, Ind.	11 26 A.M.	Philadelphia, Pa.	12 08 P.M.
Augusta Ga.	11 41 A.M.	Jackson, Miss.	11 08 "	Pittsburg, Pa.	11 48 A.M.
Augusta, Me.	11 31 "	Jefferson, Mo.	11 00 "	Plattsburg, N. Y.	12 15 P.M.
Baltimore, Md.	12 02 P.M.	Kingston, Can.	12 02 P.M.	Portland, Me.	12 28 "
Beaufort, S. C.	11 47 A.M.	Knoxville, Tenn.	11 33 A.M.	Portsmouth, N. H.	12 25 "
Boston, Mass.	12 24 P.M.	Lancaster, Pa.	12 03 P.M.	Pra. du Chien, Wis.	11 04 A.M.
Bridgeport, Ct.	12 16 "	Lexington, Ky.	11 31 A.M.	Providence, R. I.	12 23 P.M.
Buffalo, N. Y.	11 53 A.M.	Little Rock, Ark.	11 00 "	Quebec, Can.	12 23 "
Burlington, N. J.	12 09 P.M.	Louisville, Ky.	11 26 "	Racine, Wis.	11 18 A.M.
Burlington, Vt.	12 16 "	Lowell, Mass.	12 23 P.M.	Raleigh, N. C.	11 53 "
Canandaigua, N. Y.	11 59 A.M.	Lynchburg, Va.	11 51 A.M.	Richmond, Va.	11 58 "
Charleston, S. C.	11 49 "	Middletown, Ct.	12 18 P.M.	Rochester, N. Y.	11 57 "
Chicago, Ill.	11 18 "	Milledgeville, Ga.	11 35 A.M.	Sacketts H'bor, NY.	12 05 P.M.
Cincinnati, O.	11 31 "	Milwaukee, Wis.	11 17 A.M.	St. Anthony Falls	10 56 A.M.
Columbia, S. C.	11 44 "	Mobile, Ala.	11 16 "	St. Augustine, Fla.	11 42 "
Columbus, O.	11 36 "	Montpelier, Vt.	12 18 P.M.	St. Louis, Mo.	11 07 "
Concord, N. H.	12 23 P.M.	Montreal, Can.	12 14 "	St. Paul, Min.	10 56 "
Dayton, O.	11 32 A.M.	Nashville, Tenn.	11 21 A.M.	Sacramento, Cal.	9 02 "
Detroit, Mich.	11 36 "	Natchez, Miss.	11 03 "	Salem, Mass.	12 26 P.M.
Dover, Del.	12 06 P.M.	Newark, N. J.	12 11 P.M.	Savannah, Ga.	11 44 A.M.
Dover, N. H.	12 37 "	New Bedford, Mass.	12 25 "	Springfield, Mass.	12 18 P.M.
Eastport, Me.	12 41 "	Newburg, N. Y.	12 12 "	Tallahassee, Fla.	11 30 A.M.
Frankfort, Ky.	11 30 A.M.	Newburyport, Ms.	12 25 "	Toronto, Can.	11 51 "
Frederick, Md.	11 59 "	Newcastle, Del.	12 06 "	Trenton, N. J.	12 10 P.M.
Fredericksburg, Va.	11 58 "	New Haven, Conn.	12 17 "	Troy, N. Y.	12 14 "
Frederickton, N. Y.	12 42 P.M.	New London, "	12 20 "	Tuscaloosa, Ala.	11 18 A.M.
Galveston, Texas	10 49 A.M.	New Orleans, La.	11 08 A.M.	Utica, N. Y.	12 08 P.M.
Gloucester, Mass.	12 26 P.M.	Newport, R. I.	12 23 P.M.	Vandalia, Ill.	11 18 A.M.
Greenfield, "	12 18 "	New York, N. Y.	12 12 "	Vincennes, Ind.	11 19 "
Hagerstown, Md.	11 58 A.M.	Norfolk, Va.	12 03 "	Wheeling, Va.	11 45 "
Halifax, N. S.	12 54 P.M.	Northampton, Ms.	12 18 "	Wilmington, Del.	12 06 P.M.
Harrisburg, Pa.	12 01 "	Norwich, Ct.	12 20 "	Wilmington, N. C.	11 56 A.M.
Hartford, Ct.	12 18 "	Pensacola, Fla.	11 20 A.M.	Worcester, Mass.	12 21 P.M.
Huntsville, Ala.	11 21 A.M.	Petersburg, Va.	11 59 "	York, Pa.	12 02 "

By an easy calculation, the difference in time between the several places above named may be ascertained. Thus, for instance, the difference of time between New York and Cincinnati may be ascertained by simple comparison, that of the first having the Washington noon at 12 12 P. M., and of the latter at 11 31 A. M.; and hence the difference is 43 minutes, or, in other words, the noon at New York will be 11.17 A. M. at Cincinnati, and the noon at Cincinnati will be 12 43 P. M. at New York. Remember that places *West* are "slower" in time than those *East*. and *vice versa*.

Figure 1. The local time conventions of selected cities prior to the time-zone system. *Source:* Dinsmore (1857).

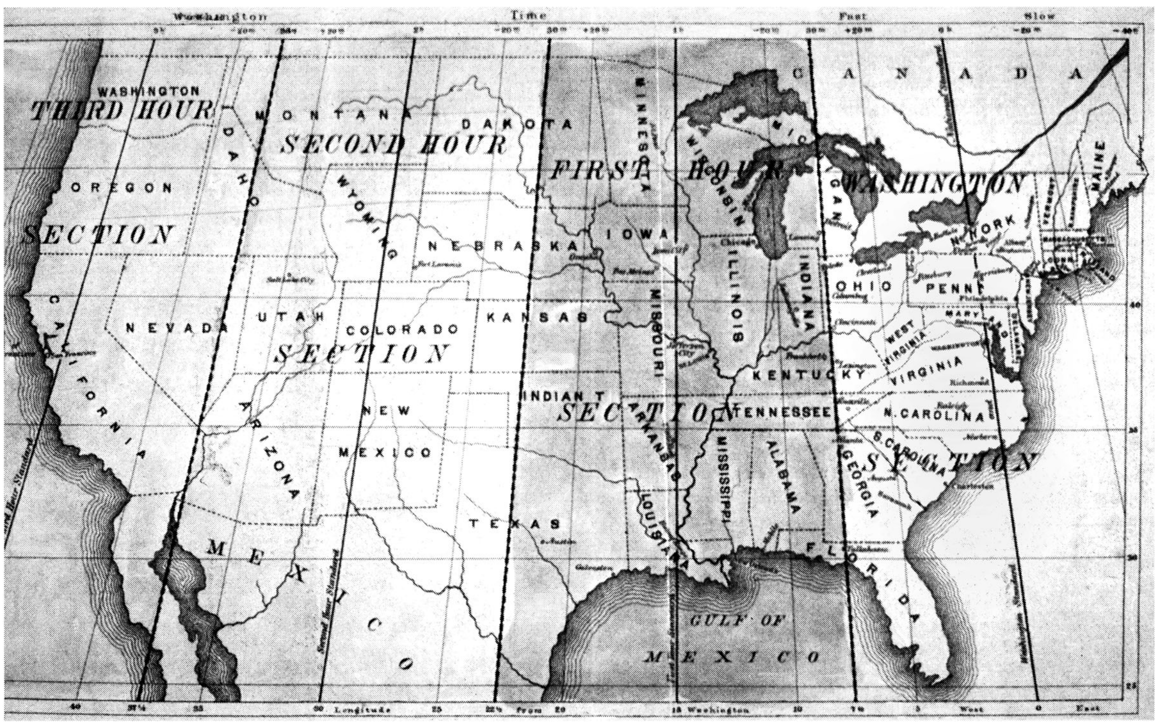

Figure 2. Dowd's 1870 map dividing the United States into four zones with precise longitudinal boundaries between the zones. The zones are indexed to the U.S. Naval Observatory's meridian in Washington D.C., not Greenwich, England. *Sources:* Dowd (1870) and Bartky (2000).

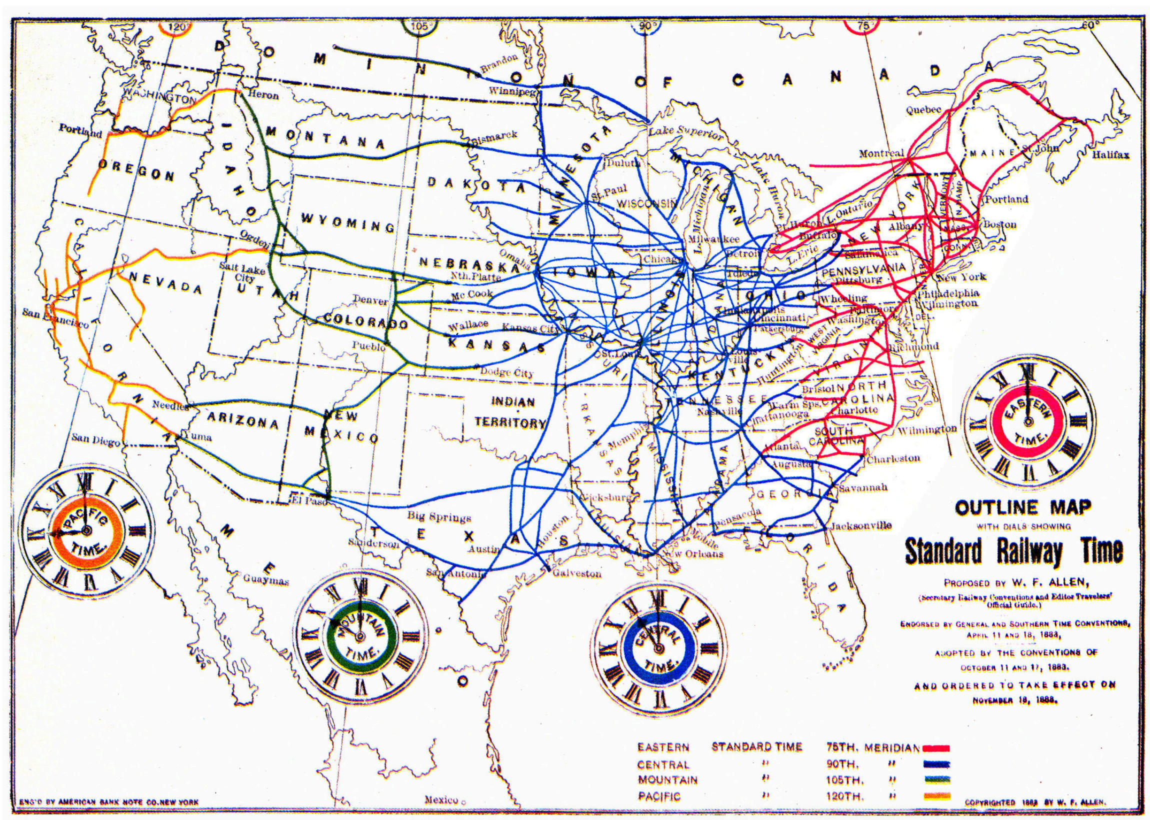

Figure 4. Allen's 1883 map showing the initial time zone system adopted on November 18th that year. The irregular zone boundaries (in color) were chosen to fit the boundaries and termini of the nation's railways. *Source: PAMS* IV (1884).