The Missing Link: A Historical Analysis of Pedestrian Signal Design and How it Demonstrates Shortcomings in the Innovation Process

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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He who knows how to wait need make no concessions.

—Sigmund Freud, *Group Psychology and the Analysis of the Ego*

❶ Introduction

On an almost hourly basis, a pedestrian is killed by a vehicle in the United States. When was the last time you decided to cross against a pedestrian signal telling you to wait? On the other hand, when was the last time you deliberately ran a red light? The odds are good that the former case is much more recent. Pedestrian-involved accidents are at their highest point in decades (National Highway Traffic Safety Administration [NHTSA], 2024). These instances are frequently the fault of the pedestrian in legal terms (Baltimore County Government, 2017); however, rather than implicating the individual actors, this pattern points to deeper flaws in our transportation systems. Why are pedestrians, inherently the most flexible mode of transportation, having such difficulty navigating the streets? Pedestrian behavior can often be unconscious (Yıldırım et al., 2023), and frequent experiences with poor sequencing (such as the inability to activate a pedestrian signal after its paired vehicular cycle has started) or ambiguous right-of-way (such as a yield indication for right-turning vehicles despite the lack of activation of the pedestrian signal) can lead to pedestrians not trusting the ‘intelligence’ of their lights, resulting in the development of disobedient habits. In many instances, this may be of minimal consequence – but the more such habits encroach into society, the greater the risk for disaster.

Modern signal controllers have unprecedented capabilities. While signal timing methods have changed greatly over time, very little has changed in the physical design of signal heads, or their coordination with pedestrian signals. Logical improvements to numerous issues, including those briefly mentioned above, have failed to develop. Conflicting driver and pedestrian psychologies present a clear danger that is verified by the statistics and warrants improvements. The objective of this paper is to conduct a multilevel analysis of the history of pedestrian signal development in order to make observations about barriers to positive change, as well as how this can be managed moving forward. I argue that a fundamental change to the processes by which pedestrian signal standards are implemented and updated is necessary, and that further research needs to utilize this mindset in order to generate more substantial innovations towards improving pedestrian safety.

❷ Problem Definition: Putting Pedestrian Problems on a Pedestal

In 2022, pedestrian fatalities in the United States were at a 40-year high. 7,522 people died, meaning that roughly every hour and ten minutes, someone new was killed by a vehicle strike. Those people accounted for 18% of all traffic fatalities. In addition, nearly 70,000 pedestrians were injured, equaling one every eight minutes (NHTSA, 2024, p. 1-3). Given that an estimated 30% of pedestrian collisions go unreported, and there are likely to be several near-misses for every actual collision, it is apparent that there is a significant and growing problem in the way that drivers and pedestrians interact (Calma et al., 2021). Figure 1 below shows the steadily increasing fatality rates in recent years.

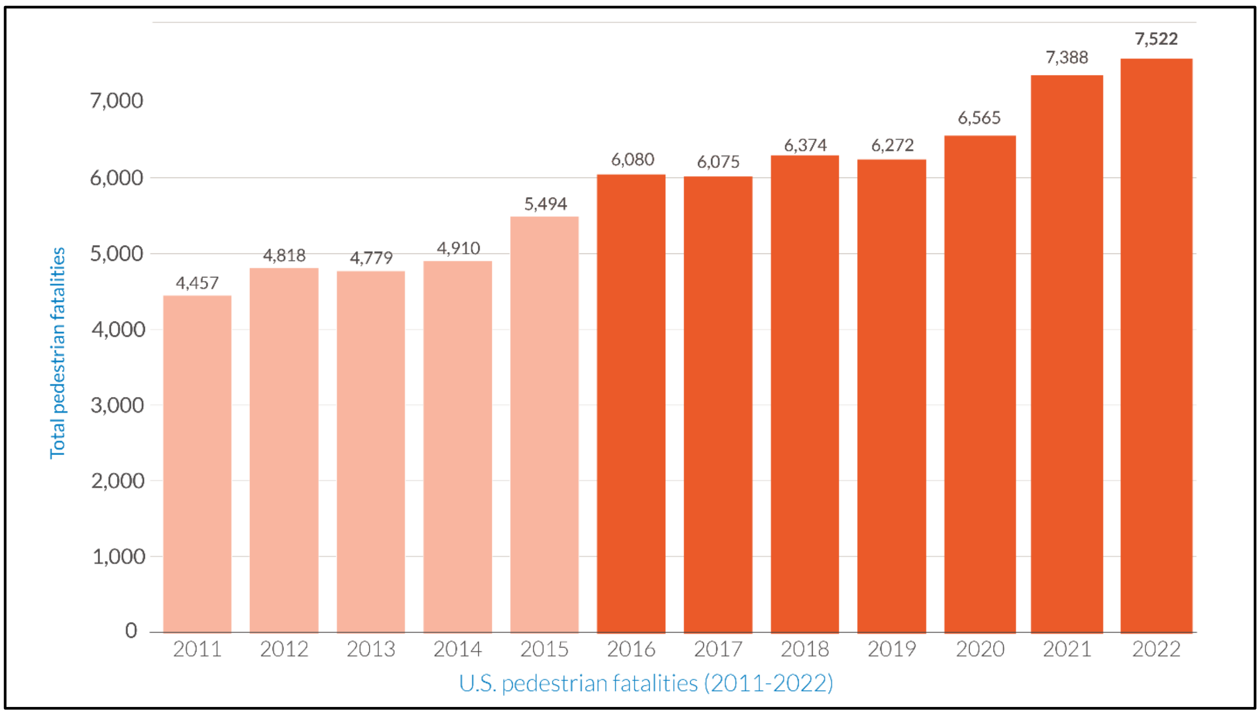

Figure 1: U.S Pedestrian Fatalities from 2011 to 2022 (Cova, 2024)
This graph demonstrates the starkly steady rise is pedestrian deaths over the past decade.

Around 40% of pedestrian accidents occur at intersections (Lord, 1997). While data with a distinction between signalized and unsignalized intersections is difficult to find, it is fair to assume that the former provides a significant contribution to the total. To further quantify the problem, 80% represents the approximate value of several key statistics from 2022. The first is the rate of pedestrian fatalities involving only one vehicle, at 88% (NHTSA, 2024). This shows that most of these deaths occur as a straightforward act of a driver hitting a pedestrian without outside factors (for example, a catalytic accident between two vehicles propelling one of them onto a sidewalk). The second is the percent of cases in which pedestrians are found at fault in a collision, at 80% (Baltimore County Government, 2017). This figure can be controversial amongst groups who advocate for more pedestrian-friendly laws; nevertheless, it demonstrates the massive risk associated with a lack of compliance to traffic control devices (Alter 2018). The third is the percent of pedestrian fatalities that occur at night, at 78% (NHTSA, 2024). This is indicative of the danger presented by disobedient habits. During the day, jaywalking pedestrians are more easily detected by drivers, and accidents are better avoided. At night, however, the same habitual patterns followed in daylight become much deadlier.

Pedestrians have a demonstrated tendency to disobey traffic control devices. One study observed nearly 25% of pedestrians disobeying their signals (Russo et al., 2018). Another showed 20% disobedience rates, along with a 30% rate of participation in a distracted activity (such as cell phone usage) while crossing (Thompson et al., 2012). An informal survey of numerous college students conducted during a pitch of this paper showed an even higher disobedience rate. In contrast to this behavior, 93% of drivers in a Federal Highway Administration (FHWA) survey stated that red light running is unacceptable (FHWA, n.d.). In another, 97% believed that it is a major safety concern (NHTSA, 2004). Assuming an average of the two, only 5% of drivers approve of any red light running. However, it is important to address the distinction in these statistical methods. The pedestrian disobedience rates are based on observed data, while the driver obedience rates are based on survey data (the first source even reports that 1 in 3 drivers admit to having run a red light in the past 30 days). In behavioral analysis, it can be the case that different statistical formats facilitate a more accurate comparison when there is a fundamental difference in the groups being compared. Pedestrian movement is very flexible; their trajectory and speed can be changed instantly. As such, crossing against a signal is inherently a deliberate action which could be avoided by simply not taking said action. Accidental jaywalking, assuming that the signal is noticed in the first place, is a near impossibility. On the other hand, drivers are faced with a concept known as the dilemma zone, which is the region prior to a signalized intersection in which the relative safety of braking to a stop or proceeding through at speed is uncertain upon seeing a yellow light. This can result in drivers running red lights in an objectively accidental (and mostly harmless) way if they misjudge the yellow time. As a result, comparing the 25% of pedestrians who *actually* disobeyed their signals to the 5% of drivers who *do not condone* running red lights is best to accounts for intentions and avoids technicalities.

An important mindset through which to analyze this difference in behavioral tendencies is utilitarianism. The competing philosophies of act-utilitarianism and rule-utilitarianism, which align closely with driver and pedestrian behavior in terms of the authority each group perceives in traffic control devices, are fundamentally incompatible in life-or-death circumstances. Yet, they must coexist in surface transportation systems, which have deadly potential. Because of this, traffic control devices have the burden of striking a balance between the two. Traffic signals have been a centerpiece of our streets for a century now, and in that time the technology controlling them has made significant advancements. From controllers run by a motor turning gears to highly-sophisticated computer systems, capable of real-time analysis, adjustments, and coordination with other controllers, vehicular traffic flow has never been more efficiently managed. Despite this, the design of the actual lights themselves has changed relatively little over the same period of time. Worse, the interface between vehicular and pedestrian signals is shockingly disparate, despite being so necessarily intertwined. Pedestrian signals are often an afterthought in the design of signal systems, if they are even implemented at all. The perpetuation of such shortcomings is certainly not due to the lack of technical capabilities, as many modern controllers are under-utilized. It is not for lack of necessity either, as the dangers presented by the current system have already been established. It is seemingly not for any practical reasons that signaling systems could not be improved in logical ways. So, why have things not changed? To answer this question, this paper delves into past cases of failed innovations in the signal industry, analyzing them through the framework of a multilevel perspective for sociotechnical systems (MLP) as used in Geels' 2007 historical analysis of the Dutch highway system.

❸ Research Approach: Applying the Multilevel Perspective and Utilitarianism Theory

There are many factors to consider when observing the traffic signal industry. Externally, the users (drivers and pedestrians) define the system. Internally, it is a network of inventors, manufacturers, local governments, and federal organizations such as the Federal Highway Administration (FHWA), the Institute of Transportation Engineers (ITE), and the American Association of State Highway and Transportation Officials (AASHTO). This amalgamation of actors is best analyzed through the MLP framework and the theory of utilitarianism.

The System

In “Transformations of Large Technical Systems: A Multilevel Analysis of the Dutch Highway System, 1959-2020,” Geels (2007) evaluates the post-WWII Dutch highway system using the MLP framework. This research was a departure from previous applications of the MLP, which centered on radical disruptions within a sociotechnical environment, by instead applying it to the gradual evolution of an environment that lacks one defining moment of trajectorial change. The basis of the MLP is described as follows:

> This perspective distinguishes three conceptual levels: a “niche” level in which radical novelties emerge, a “regime” level that refers to cognitive rules shared in social networks related to the existing system, and a “landscape” level that refers to exogenous developments. (p. 126)

There are four steps through which these layers interact in a sociotechnical environment: (1) technological niches develop under visions for the future; (2) a shift occurs in the sociotechnical landscape, creating waves that open new opportunities to enter the regime; (3) the niches evolve to a point where they can permeate the regime; and (4) the regime stabilizes around the accepted niche. This process in turn affects the landscape, which continues to inspire new niches. An in-depth diagram of this process is shown in Figure 2 below.

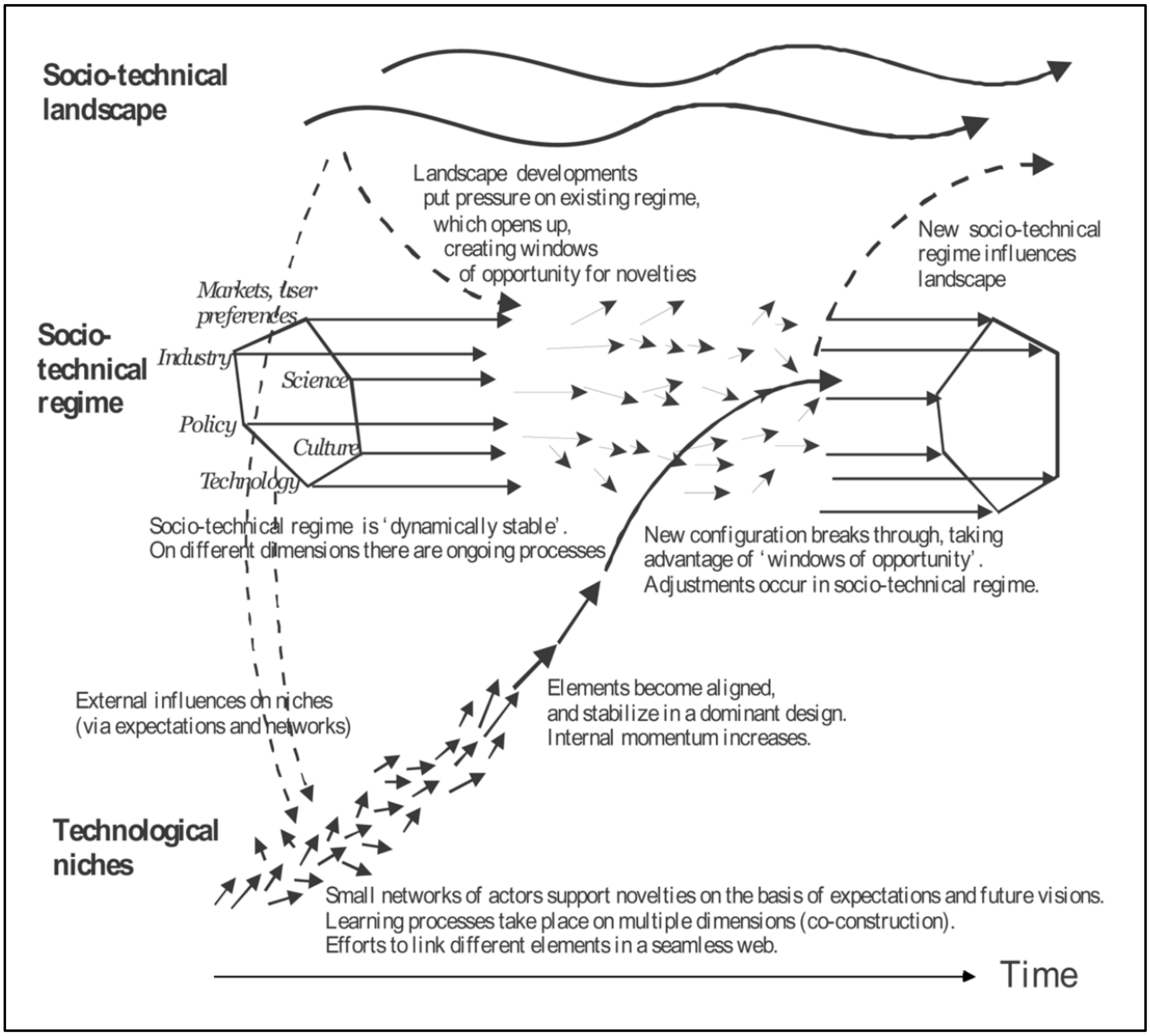

Figure 2: The Multilevel Perspective (Geels, 2007, p. 130)
This diagram showcases the complex nature of how interactions occur between the three levels of the MLP.

As an example of Geels' MLP application, he explained that the sociotechnical landscape was altered due to an outside shift in government structure. This created a wave in the regime in the form of new voices having a say in the choices that were made. While the car-forward transportation ministry previously centered their plans largely around highway development without much oversight, other organizations with newfound influence pushed for alternate means of transportation. This gave niches relating to bicycles and public transit the attention they needed to evolve, and ultimately permeate the established regime, creating the car-offset society we know the Dutch for today.

The Psychology

In the chapter "Moral Reasoning and Ethical Theories" of *Ethics in Engineering*, Martin & Schinzinger define utilitarianism as the concept that any action one undertakes should be done with the intention of producing the most good for the most people. This philosophy has different implications depending on how you perceive the concept of 'good', and is shown to be split into two key types: rule-utilitarianism and act-utilitarianism. The former is the idea that rules are inherently designed to produce the most good, and so they should always be followed. Even in instances where disobedience would seem to cause no detriment, individual judgement may not be accurate a majority of the time, so following the rules is the best way to ensure the most good. Act-utilitarianism, on the other hand, sees the authority of rules as less concrete. While following the rules is the best practice in general, individual judgement is sufficient to determine the particular consequences of an action, and "the rules should be broken whenever doing so will produce the most good in a specific situation" (p. 53). This is elaborated in Figure 3 on the following page. Utilitarianism is just one of several philosophies described in the text regarding moral foundations for responsibility in the professional world, including issues such as keeping promises and refraining from bribery; however, this particular dichotomy applies quite well to traffic behavior.

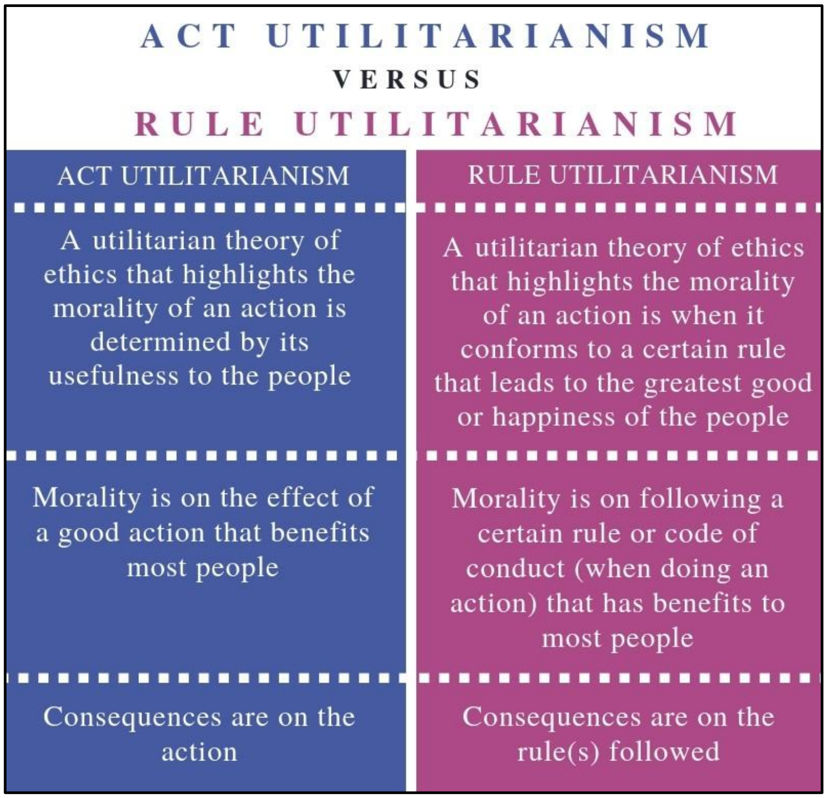

Figure 3: Act Utilitarianism vs. Rule Utilitarianism (Upen, 2019)

This graphic demonstrates how theory is differentiated within the two primary factions of utilitarianism, along with their implications on morality and assignment of blame.

The Synthesis

The two forms of utilitarianism draw significant parallels to the behavior of drivers (rule) and pedestrians (act). Given an absence of any conflicting traffic, drivers are still unlikely to run a red light, even though there is no apparent downside. This is indicative of a collective belief that uniform obedience of traffic signals is the best practice. In the same situation, however, pedestrians are more likely to 'run' the light. They override the rules with their judgement that the most good is achieved in the form of their personal expedience. It is easy to see why these differing perspectives may have developed, as the actions involve two fundamentally different states of mind. Walking (or otherwise self-propelling) is a foundation of human nature, with very little inherent restriction to it. When interacting with traffic, one is suddenly faced with rules intrinsically alien to any other aspect of life that they must voluntarily follow, which can unconsciously feel unwelcome and create impatience. The action of driving, on the other hand, only occurs within the system specifically designed for it – as such, the rules of that system are more readily accepted as an inherent necessity for its use. When analyzing traffic infrastructure, this is a necessary lens through which to view the viability of innovations.

The relevance to this paper is readily apparent in both the subject matter and framework of Geels' work. Not only is the industry being analyzed similar, but the systems' trajectories align in how they have evolved gradually over time, with no one radical innovation changing the regime completely. In that way, this paper is a continuation of his research, as his final sentence stated (referring to the application of the MLP to such systems) that "further research on transformation is needed to claim broader generalizability" (p. 57). A shift in the landscape mentioned in step 2 of the transformation process (such as the Netherlands' change in governmental structure) is less evident in this case; rather, the continuous increase in dominance of automobiles over pedestrians within the American transportation landscape has created a perpetual state of shifting, through which continuous innovations are necessary to be created in order for pedestrians to utilize the systems. The primarily chronological analysis to follow delves into why the most significant innovations in pedestrian signaling over the past 100 years have either succeeded or failed to infiltrate the regime, while simultaneously using the utilitarianism perspective to analyze how these innovations align with user behavior.

❹ Results: Examining the Barriers to Pedestrian Signal Progression

By 1929, there was nearly a 1:1 ratio of cars to households in America (Cochrane, 2024), and the signal industry was in full swing. Because of many conflicting design practices, the Manual on Uniform Traffic Control Devices (MUTCD) was created in 1935 in order to standardize them. It was initially published by the AASHO (predecessor of AASHTO), although it would later be taken over by the FHWA. This manual introduced the first signal for pedestrians in the form of adding a fourth color, white (printed with the word “WALK”), to the existing three-color indication system (AASTO, 1935; Chevrolet, 1937). In 1942, the MUTCD began requiring WALK indications to be paired with ones reading “WAIT”, standardizing the first signals exclusively for pedestrians (AASTO, 1942). In 1948, the option of using the wording “DON’T WALK” instead of WAIT was added to better visually differentiate from WALK (AASTO, 1948). This edition specifically notes that “special pedestrian signals are not as yet in extensive use and experimentation with their design details, subject to the conditions stated… is desirable” (p. 158). As such, pedestrian signals were still developing as niches.

The Case of DON’T LEAVE CURB

In the 1950s, a new niche emerged with a fundamentally different message – “LEAVE CURB” and “DON’T LEAVE CURB”. An example from a 1958 catalog of signal manufacturer Crouse-Hinds is shown in Figure 4 on the next page. The catalog states:

> [This] signal gives a very explicit instruction. The result is that pedestrians tend to wait on the sidewalk rather than in the street. Furthermore, any pedestrians caught in the center of the street when the signal changes are not instructed to “Don’t Walk” as in other

> types of pedestrian signals. The signal simply changes from a green “Leave Curb” indication to a red “Don’t Leave Curb” indication. (sect. 601, p. 28)

The implication was that the wording is linguistically superior in that LEAVE CURB defines a more specific action (crossing the threshold from the sidewalk to the street) than WALK, and DON’T LEAVE CURB in the same way inherently does not apply to (or potentially confuse) someone who is already in the street as a WAIT or DON’T WALK command does.

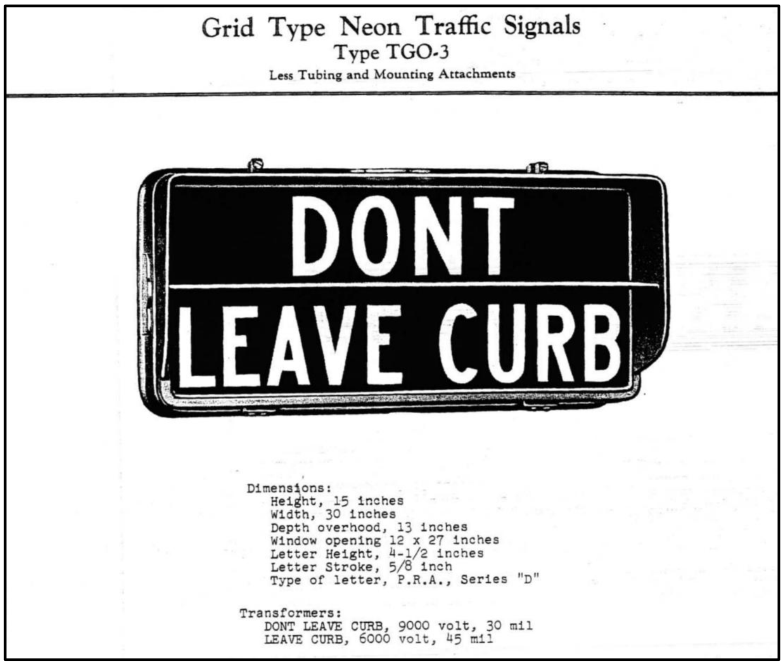

Figure 4: Example of a Neon DON’T LEAVE CURB Signal (Crouse-Hinds, 1958, p. 27)
A catalog image showing a pedestrian signal product utilizing the new wording.

A 1955 article from the Traffic Digest and Review, written by the city traffic engineer of Hammond, Indiana, further elaborates on this principle:

> The “Leave Curb” indication implies “now you may enter the street.” The “Don’t Leave Curb” does not say anything to the pedestrian who has already left the curb. Pedestrians who left on the “Leave Curb” indication continue to cross the street at their normal gait, and none return to the curb they left. (p. 7-8)

This development is significant in being the first time that behavioral design was used in the development of a pedestrian signal. It received overall positive feedback (Hoffman, 1955; Icky, 1957). The main barrier to the spread of this niche was the need for displaying three words, as opposed to the two required by WAIT–WALK or DON'T WALK, making it impossible to convert existing signals. As a result, the spread was largely limited to new installations, slowing adoption and allowing the new wording to be eclipsed by a different niche prior to reaching its full potential. This latest development – a flashing DON'T WALK phase – was introduced to differentiate the time after the end of the WALK phase from the absolute end of the cycle. This intended to accomplish the same goal as the DON'T LEAVE CURB signals, which was to prevent confusion by pedestrians whose signal changes while they have already begun crossing. It was later proven that the addition of the flashing phase did not change pedestrian behavior, likely due to a lack of implicit meaning (FHWA, 1977) – despite this, the implementation of the flashing phase was a much easier change to make than replacing existing signals. This became more widespread, and ultimately was made standard by the 1961 MUTCD (AASHO, 1961), leaving the DON'T LEAVE CURB signals to fade into obscurity. This demonstrates a tendency for practice to bend toward cost considerations over actual public reception, skewing the adoption potential of niches.

The Case of the Three-Color Signal

This principle of cost impact was further demonstrated in an extensive 1977 FHWA study of new pedestrian signal designs, some of which are shown in Figure 5 on the next page. This included the first introduction of symbolic indications, and also included the addition of a third indication in solid yellow to replace the flashing DON'T WALK phase. Regarding an initial survey of designs, the report noted that "the three section signal head appeared to be favored over the two section signal, which was a bit surprising because all of the three section head displays were consistently rated too costly and too difficult to implement" (p. 23). As with the DON'T LEAVE CURB signals, these cost concerns refer to the difficulty of retrofitting. Since the behavioral analysis testing that followed was limited to swapping lenses in existing two-section signals, the three-color designs were never field-tested. So, this promising innovation never had a chance to get off the ground. The ultimate winner of the experiment was the upraised hand and walking man symbol pair, which proved to be the best understood.

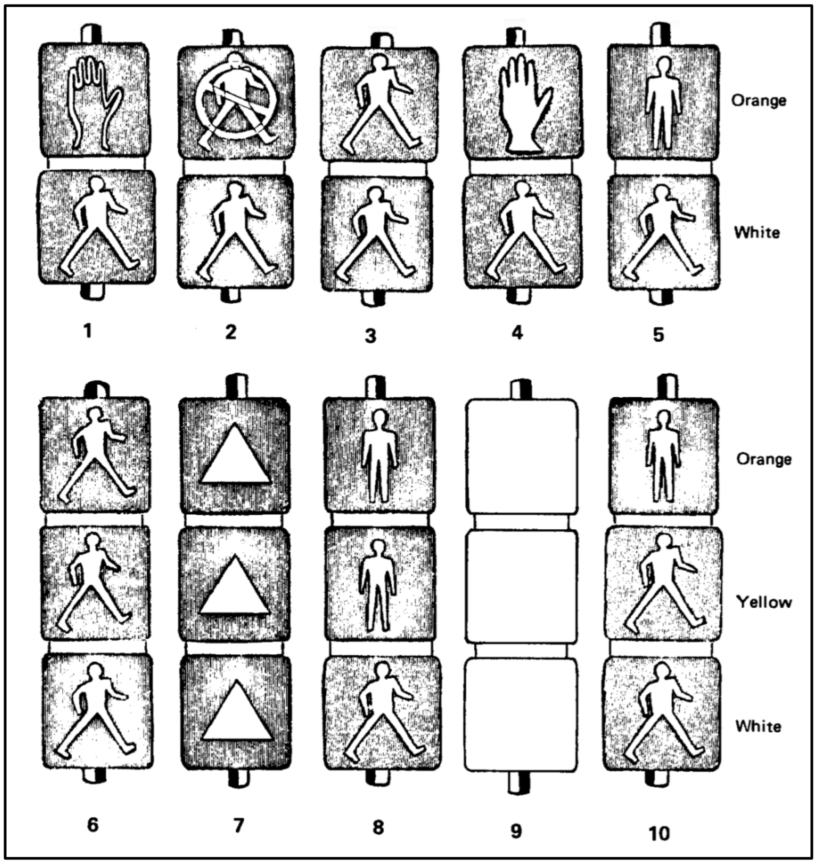

Figure 5: Initial Sample of Potential Pedestrian Signals (adapted from FHWA, 1977)
Numerous different symbols and combinations thereof shown here were used in surveys to consider the best signal designs to be implemented in the on-street experiments.

The transition to symbols was spurred by the desire for a larger target area for illumination, as well as lowering direct reliance on the English language. These considerations worked in favor of pedestrian comprehension, thus showing a balance between cost and reception in the niche development. The symbols were included as an option in the MUTCD the following year, and were made standard in 2000 (FHWA, 1978; FHWA, 2000). This study was also the first attempt to scratch the surface of the most glaringly missing link in pedestrian signalization – coordination with vehicle signals – in the form of a flashing WALK indication to indicate the presence of turning vehicles. This was unsuccessful due to a lack of user understanding (FHWA, 1977).

The Case of the Animated Eyes

With the advent of LEDs, a similar concept to flashing WALK was introduced in the late 1990s in the form of animated eyes that mimicked looking back and forth across the street, as shown in Figure 6 below. This was easily understood by pedestrians as a message to watch for turning vehicles, and was proven to be effective in reducing collisions (Van Houten et al., 1999; Florida Department of Transportation, 2000; Van Houten, 2001). The eyes were shortly included as an option in the 2003 MUTCD (FHWA, 2003).

Figure 6: Animated Eyes Pedestrian Signal (Van Houten, 2001)
A pedestrian signal featuring the LED scanning eyes from their initial study is shown.

However, animated eyes products were only produced by one manufacturer, and were discontinued in 2003 prior to the company's closure (as shown by the Internet Archives of their former website, Relume.com). Today, none of these signals exist in service. Even so, as of the 2023 edition, their effectiveness is still sanctioned by the MUTCD (FHWA, 2023). This is a unique instance where an innovative niche successfully entered the regime on paper, but became totally extinct in practice. The FHWA ultimately failed to promote their accepted technology, as well as to establish effective guidelines for its use. For example, if they had mandated the inclusion of animated eyes when turning vehicle conflicts are present, rather than just leaving it as an option, they would likely be in common use now. Instead, a potentially life-saving technology is all but forgotten.

The Case of the Yellow Border

In the direction of integration with vehicle signals, another concept that proved successful in recent studies but failed to permeate the industry was the use of an LED yellow outline around a pedestrian signal that would illuminate when a pedestrian presses the call button, as shown in Figure 7 below (CaltransVideo, 2015). The intention was to indicate to drivers when a pedestrian was waiting to cross (promoting yielding while turning), and also served to notify pedestrians that their call was placed (promoting patience and serving to curb the act-utilitarian desire to cross against the signal).

Figure 7: The Yellow Border Process (adapted from CaltransVideo, 2015)
These are screenshots from a video demonstrating the functionality of the yellow border.

Despite studies showing their success in both regards, the signals were only custom-made for the trials and never produced commercially, nor were they included in the MUTCD (Musabbir et al., 2019).

The Overview

The following table, Figure 8, synthesizes the results of this multilevel analysis on pedestrian signal innovations, showing several different mechanisms for failure and success.

New Configuration *Or New Feature	**Socially Accepted**	**Achieved Widespread Use**	**Reached Regime Adoption**	**Explanation**
WAIT WALK	Yes	Yes	Yes	*The first design*
DON'T WALK WALK	Yes	Yes	Yes	*Visual improvement to WAIT–WALK*
DON'T LEAVE CURB LEAVE CURB	Yes	Yes	No	Cost became barrier to standardization
*Flashing DW Clearance	No	Yes	Yes	Standardized despite lack of proven effectiveness
*Yellow Clearance	Theoretical	No	No	Cost concerns prevented adequate experimentation
[HAND] [MAN]	Yes	Yes	Yes	*Visual improvement to DON'T WALK–WALK*
*Countdown Clearance	Yes	Yes	Yes	*Visual improvement to clearance phase*
*Animated Eyes	Yes	No	Yes	Failure of regime to adequately mandate or advocate led to its loss
*Yellow Border	Yes	No	No	Was not advocated at regime level beyond localized experimentation

Figure 8: Summary of Findings (created by author)

This table shows the relative acceptance, use, and regime infiltration for each of the innovations analyzed. This helps explain the mechanisms by which innovations are either accepted or stifled.

❺ Conclusion

This report has demonstrated several cases in which promising pedestrian signaling innovations have been stunted. These mechanisms include cost being a prohibitive factor to adoption by the regime, or even being tested in the first place, when the innovation would have otherwise logically succeeded from the data at hand. On the other hand, adoption by the regime can occur even without social support in furtherance of a cheaper resolution. This demonstrates a repeated conflict of interest between cost and safety that affects the development process. New MUTCD standards do not have to be retroactive, so a focus on retrofittability creates an unnecessary barrier to more advanced changes. Because of this, **retrofitting concerns need to be eliminated from consideration** when gauging the potential impact of an innovation. Additionally, such as in the case of the animated eyes signals, the regime can adopt a niche and still allow it to fail by being too passive with its implementation. As the primary regulatory power over the regime, **the FHWA must take an active role in promoting the innovations** that they have adopted. For example, the MUTCD could have been explicit about not only requiring animated eyes signals where turning vehicle conflicts exist, but also prohibiting their use when the crossing is fully protected. This would establish a uniform basis for their usage and meaning, producing a greater chance of implicit comprehension and behavior adaptation among pedestrians, as well as maintaining commercial viability. To that end, none of these innovations have fully grasped the utilitarianism dichotomy, and as a result, an effective solution to habitual signal disobedience is yet to be developed. **Further research must use this perspective as a basis** in order to generate positive change in that field and increase pedestrian safety for future generations.

❻ Appendix

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