No Royal Roads: Diffusing the Constraints of Smoothness on Local City Streets

CHARLES DELAY JONES
Tulane University

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Like aqueducts, roads and streets are some of the earliest, most effective technological utilities related to sustained urban settlements. The smooth asphalt surface of a modern-day collector street connecting from arterial transportation networks to local city streets is one example. Like many fast-paced technological applications developed to outpace physiological adaptation, their benefit is counteracted with adverse impacts on various social-ecological systems.

Smoothness, a preferred street surface condition, is a technical overcorrection. Accelerated stormwater discharge can overwhelm drainage systems and cause chronic flooding. Therefore, the application of smoothness across multiple street typologies requires reexamination.

A textured, permeable surface can effectively mitigate this condition by diffusing water movement and storing it momentarily where it falls. Combined with other ecological systems, the surface geometry of the street and section can filter pollutants, increase mobility, and improve the spatial qualities of local streetscapes.

CONTEXT: REVOLUTIONARY CONSEQUENCES

The turn of the 20th century marked an era of exceptional innovation in the design and implementation of centralized urban infrastructure systems. It also marked the end of an era of alternative, historic paving applications. As metabolic processes throughout cities accelerated, these systems were designed and constantly refined to move waste and resources as efficiently as possible. Urban landscapes were regimented topographically through historic forms of cultivated road construction techniques. Mechanization and movement accelerated society's reliance on increasingly intensifying material extraction and refinement techniques to create smooth pavement surfaces.

Paved streets, and other centralized systems like stormwater drainage, widened the province of urban settlements and gave them command over land further from historic city centers and likely lower in elevation relative to adjacent water bodies like rivers, marshes, lakes, and oceans. New Orleans is one such city settled before the proliferation of land transportation networks and their associated technological advancements. Topographically, the city is a large bowl bounded by higher perimeter elevations. The crescent city emerged alongside the higher grounds of the natural levees and ridges formed by various courses of the Mississippi River. Over half of the city footprint today, developed primarily since the middle of the 20th century, continues to subside as sea levels rise.

Social pressures such as overcrowding, and sanitation helped accelerate unprecedented civil and mechanical engineering projects that resulted in one of the most innovative centralized drainage systems of its time. Smooth street paving applications were rapidly adopted alongside the implementation of this centralized stormwater drainage system. Not only was smoothness pursued to address some of the most problematic social and technical conditions[1] of the turn of the 20th century, but it also boosted the conveyance of energy and resources throughout cities, including stormwater discharge. Yet, like many accelerated technological applications, the benefit of smooth paving systems is counteracted by it's adverse impacts on various social-ecological systems.[2]

LOOSENING THE GRIP OF TECHNOLOGICAL ARTIFACTS

Today, technological artifacts of modern infrastructure, like paved streets and centralized drainage systems, grip cities in place. Society's reliance on these artifacts of the late 19th century forward is stifling the potential for more flexible interpretations of infrastructure to the degree that technological innovations in street paving are being outpaced by evolving social and environmental conditions. This static nature of urban infrastructure results from hyper-focused, technological solutions developed to solve singular functions at massive scales. Unique to humans, this resistance to change is a sociotechnical dilemma that locks social and economic systems in specific states and trajectories, which reduce the overall resilience and capacity to renew and reorganize.[3]

This paradox represents the dual nature of technological applications and suggests why society may have overlooked some

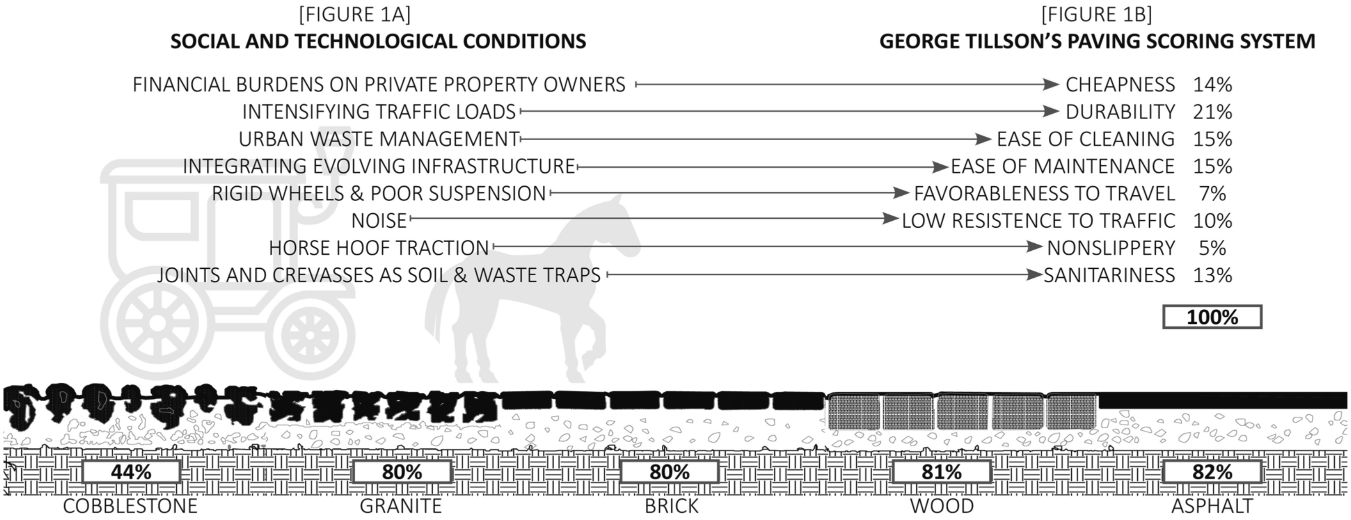


Figure 1.Socio-technical Influences on Paving Design Criteria. Author.

advantages of previous paving systems before they were rapidly phased out in the first quarter of the 20th century (Figure 1A). Rough street surfaces were terrible for wheeled travel. Waste and water collected in their crevasses and fused into stagnant, unsanitary mixtures. Horseshoes and wooden wheels pounded the pavements and reverberated through the streets. With innovations in concrete and asphalt applications, these persistent nuisances were paved away. Free, uninterrupted movement became a fixation for cities, and transportation surfaces promoted this conquest by collapsing the irregular texture of historic, modular paving systems, into smooth, impermeable, monolithic surfaces.

URBAN OBDURACY AND PAVING TECHNOLOGY

Obduracy is a quality of being obdurate; a determined refusal to alter a pre-existing course. This condition refers to an unwillingness to change paths or beliefs based on predetermined or pre-established practices. Anique Hommels, a scholar of Technology and Social Studies, uses obduracy to describe the immovable frameworks of urban policy and planning development stating that "once in place, urban structures become fixed, obdurate, securely anchored in their own history and in the histories of the surrounding structures."[4]

An unprecedented street restoration project is currently taking place in New Orleans. The scope of work is to restore four hundred miles of infrastructure, primarily damaged by flooding due to Hurricane Katrina. The mileage represents about 30% of the entire city street network. However, the street surface, section, and spatial configuration are being reconstructed with design standards developed at the turn of the 20th century. In addition to the conditions driving the paving system towards smoothness, efforts to maintain the street surface and foundation as an impermeable membrane meant to shed water rapidly are inherent traits that remain unchanged.

A typical one-way local street in New Orleans, from corner to corner, contains over 5,000 square feet of impermeable area. This represents the minimum threshold for new developments before more strict stormwater detention requirements are enforced by the city.[5] However, current design standards in New Orleans do not consider increased surface permeability of the primary paved street surface. Water travels directly from the street surface to subsurface drainpipes via catch basins. What was once a modern engineering marvel, is now partially responsible for the accelerated subsidization of ground conditions which increase risk exposure for lower areas.

PAVING POTENTIAL, PAST AND PRESENT

Having dissected each of the prominant factors seem to influence the design and construction of city street pavements, George Tillson, surmises:

"An ideal pavement should be cheap, durable, easily cleaned, present little resistance to traffic, non-slippery, cheaply maintained, favorable to travel, and sanitary."[6]

Tillson, an influential civil engineering consultant in New York City, translated these seven qualities into an evaluation matrix with weighted scores to help guide the ongoing development of city paving system (Figure 1B). Together, these standards formed the dominant design drivers of paving systems.

The turn of the 20th century marked the end of an era of a highly experimental period of street paving technology. With most city streets moving at a slower pace, sheets of asphalt pavement were not in high demand, nor was the material readily accessible until the late 1800s. In a way, urban centers were still remote from one another. With limited transportation and communication between cities, certain geographic and economic factors influenced their respective approaches to street paving.

For instance, cypress and pine were abundant in New Orleans. They were used to surface many elevated footpaths and planked roads throughout the city. Paving materials larger than shells and gravel often came by ship ballasts transported from the northeast down the Mississippi river valleys or from Europe via oceanic shipping routes.

Over time, health and sanitation concerns became common crises for many cities to address which led to smoother, homogeneous paving systems. These emergent conditions had an enduring impact on accepting asphalt as the most versatile, economical paving system. This unique time coincides with the rapid growth of American cities and the increasing levels of municipal control over the function of urban streets.[7]

Increases in asphalt application also coincided with the rapid increase in energy production, given that the primary binding agent of asphalt is a byproduct of crude oil refining. The typical life span of an asphalt city street is 30 years. The higher turnover rate presents opportunities for innovation to command high degrees of functional use. Adapting to higher degrees of social and ecological functionality requires re-examining these dominant social and technological frameworks that have locked in smooth, impermeable surfaces as ideal paving system characteristics.

A Modular paving system is ideal to address the manifold nature of future street functionality. It also helps detect subsurface issues by gradually conforming to the underlying soil conditions where monolithic paving applications maintain rigidity to a certain degree before rupturing abruptly as subsurface conditions change. Homogenous, sheet-applied paving systems like asphalt and concrete, as opposed to modular paving systems, are more prone to failure from soil heaving, freeze/thaw cycles, and unstable groundwater conditions. The open joint incorporated into many emerging permeable paving systems is favored over the sealed, bituminous, and grout-filled joints of historic modular paving techniques.

A VERNACULAR FOR RESILIENCE

Due to decades of re-urbanization, the spatial qualities of streets are being reconfigured in cities across America to incorporate trans-modal forms of mobility, including pedestrian and cycling networks. Emerging guidelines for increased social distancing due to recent the COVID outbreak are changing traditional understandings of street and sidewalk ownership. Flexibility and adaptation are emergent qualities that should challenge the dominant social and technological frameworks that have locked in smooth, impermeable surfaces as ideal paving system characteristics.

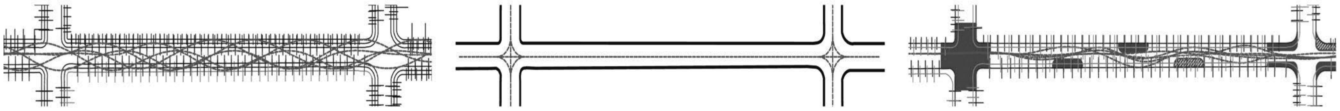
Characteristics of historic city growth that supported slower street life (Figure 2A) were transformed by the demand for efficient vehicular movement. The diffused functionality of the New Orleans streetscape was compressed into discreet zones to serve unimpeded automobile flow (Figure 2B). However, the dominance of rigid boundaries such as raised curbs are being challenged today. The emerging research values ambiguous; animate surfaces that generates conditions of "friction and

1889_New Orleans_Royal Street 2009_Sussex, New England_East Street 2020_Sussex, New England_East Street

Source:
New Orleans Historic Collection

Source:
Google Street View

Source:
Google Street View



CLEAR BOUNDARIES,
DIFFUSED CIRCULATION
[FIGURE 2A]

CLEAR BOUNDARIES,
COMPRESSED CIRCULATION
[FIGURE 2B]

DIFFUSED BOUNDARIES,
DIFFUSED CIRCULATION
[FIGURE 2C]

Figure 2. Street Functionality and Edge Conditions. Author

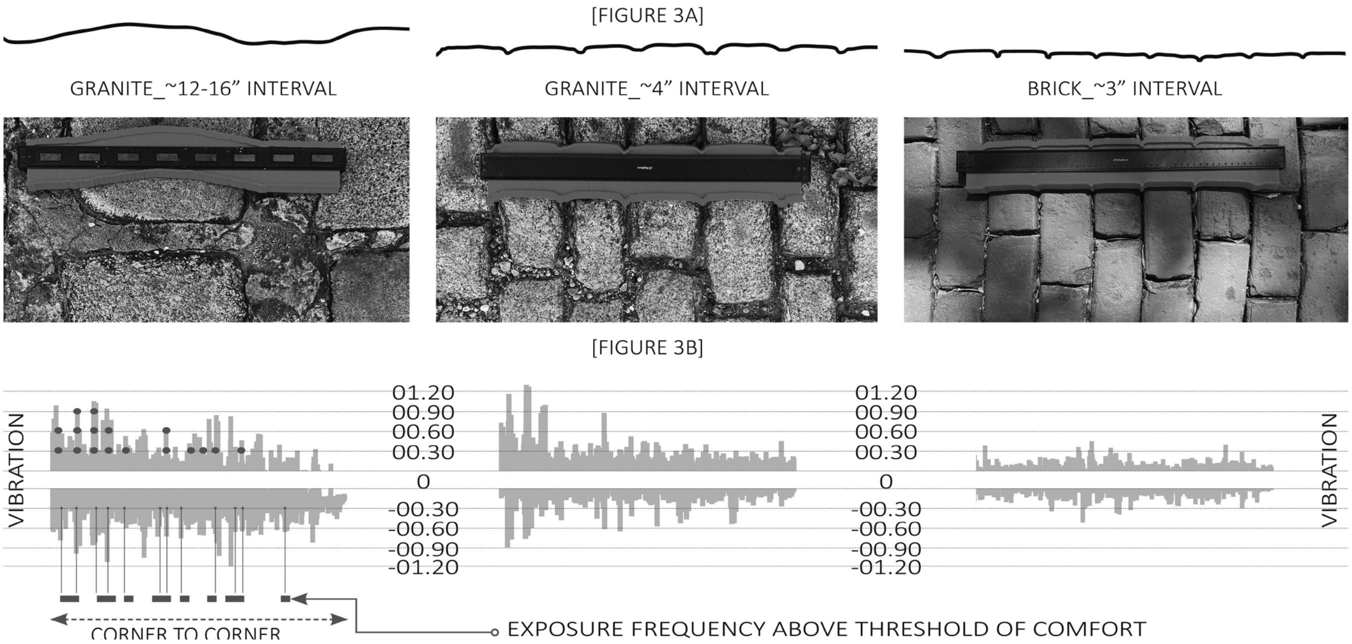


Figure 3. Vibration Analysis of Historic Paver Types. Author.

unpredictability".[8] Users navigate these conditions with caution. Antithetical to the general understating of utility and perceived safety of street habitation, these conditions create opportunities for more open interpretations of street functionality (Figure 2C).

Current street configurations are not likely to change any time soon. This is reflected in the amount of street surfaces dedicated to vehicular movement and on-street parking. However, the spatial allocation of street space must change over time to address new problems. There are a few emerging environmental and social concerns that are becoming apparent in cities such as New Orleans. Chronic flooding, increased surface temperature due to the urban heat island effect, and pedestrian inaccessibility are concerns that create strain on city life.

Alternative street uses are embedded in the cultural landscape of New Orleans. Dancing, marching, and parading occur at various scales throughout day-to-day life in the city. These rituals play out in a range of uses from the marching of Mardi Gras Indians to funeral processions that take to the streets in the form of second lines. Street spectacles such as these serve as a constant reminder of how cultural practices continuously shape the public space of urban streetscapes.

COLLAPSING THE CROWN AND CURB

Street section reconfigurations emerge from a reexamination of the street's sectional profile, gutter, and curb conditions. The crowning of the street finds its origins in paved roads of antiquity designed to shed water efficiently. Shedding water fast is becoming increasingly problematic. Due to increasing rain intensity frequencies, it is now understood that slowing down water and holding it where it falls is a more sustainable strategy by mitigating drainage system inundation and allowing for water to infiltrate and recharge soils. The transverse slope of the street does not necessarily need to be constructed symmetrically with the highest point in the center of the street. The gutter and curbing of street edges have transformed alongside the implementation of centralized subsurface drainage systems. Deep gutters along street edges for surface water storage and conveyance have transformed into smooth, mountable catch basins with no surface storage capacity. Increasing surface and subsurface stormwater storage capacities, and slowing down water movement, are newly established driving forces behind the proposed street design.

STRIATING THE SMOOTH

To establish surface design parameters, a series of street and paving types are documented to determine the relationship between depth and frequency of surface geometry changes that impact the comfort of wheeled and foot traffic (Figure 3A). The comfort threshold must be balanced with the requirement to dampen the speed of stormwater runoff across the street's surface. Therefore, three parameters establish the primary design drivers for developing a paving surface texture:

1. the technical requirements for maximum vertical discontinuities [9]

2. survey and analysis of surface geometry characteristics of three historic paving systems

3. a comfort vibration analysis performed by driving from one corner to another across the three surveyed paving systems

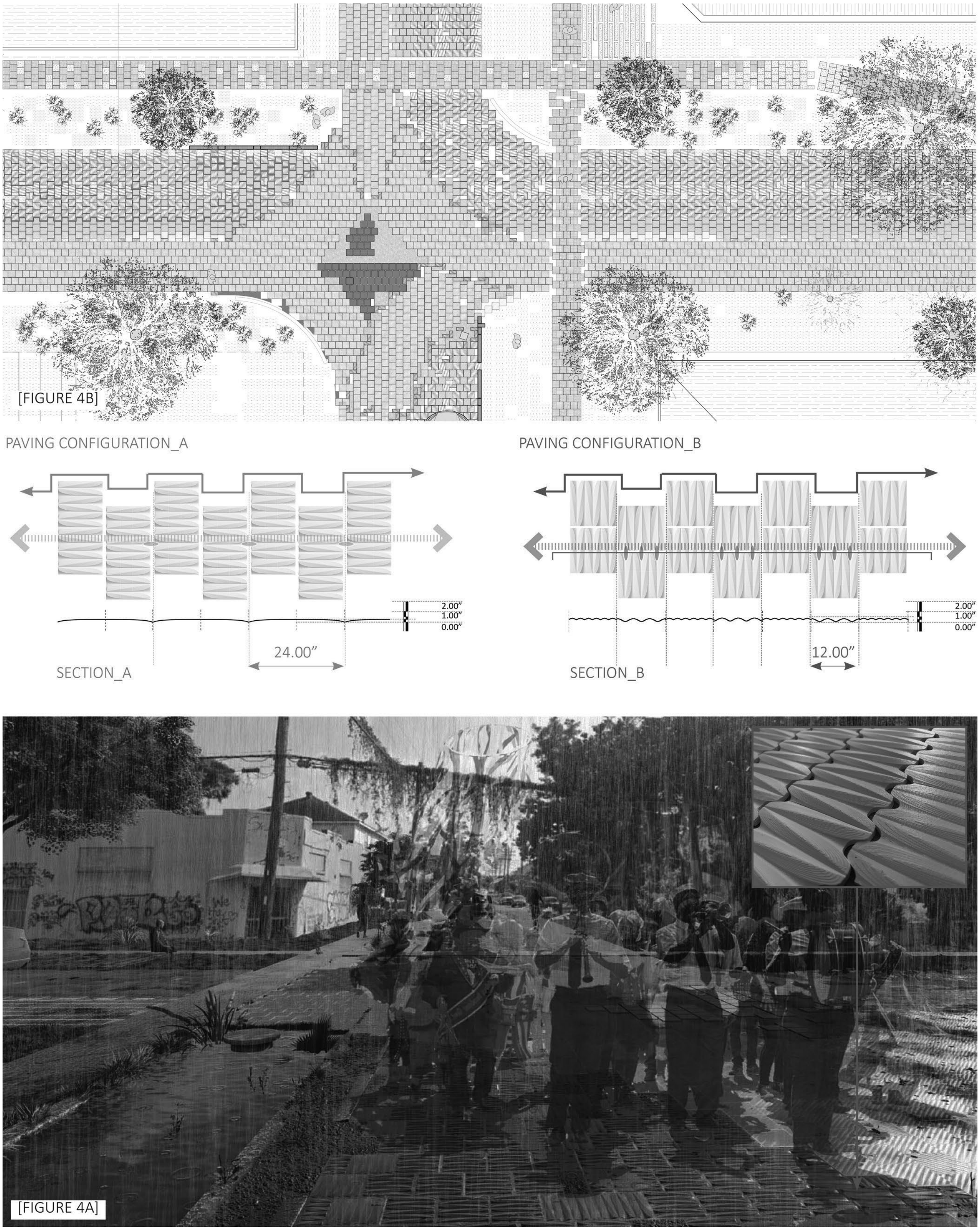


Figure 4.Design Implementation and Paver Configurations. Author.

The surface qualities are then analyzed based on AASHTO's surface texture classifications. A macrotexture is defined as "a family of wave-shaped road surface characteristics that have wavelengths from 0.5 mm up to 50 mm and affect the interaction between the road surface and the tire footprint."[10] This unit of measure serves as the upper dimensional threshold for surface undulation along the direction of travel.

An analysis of rider comfort also supports the two-inch range limitation for paving surface articulation and undulation. To perform this analysis, a single block street segment of three historic paving types, from corner to corner, is driven along, accelerating to a top speed of 15 MPH, to collect vibration using a free iPhone application for detecting vibrations. This vibration analysis application relies on the iPhone's accelerometer to detect changes in G force. Converted data is reformatted into a graph showing the single street length along the x-axis and the G force acceleration in the y-axis. Based on standards for evaluating human exposure to mechanical vibration[11], the various paving types can be classified according to the vibration that falls within the comfort threshold range of 0.0-0.6G (Figure 3B).

The goal of this vibration analysis is to demonstrate that an increase in consistent, surface texture is a productive characteristic of the street surface rather than a disruptive condition. An interval of two inches horizontally, and a half-inch vertically is established as maximum distance ranges for designing a paver with an undulating surface.

IMPLEMENTATION: HOLLYGROVE, CORNER TO CORNER

Reshaping the street, through this methodological process, creates a new socio-ecological aesthetic for New Orleans (Figure 4A). By recovering historic street cultures and landscapes, streets can strengthen adaptive planning efforts in the short term by increasing walkability and in the long term by implementing stormwater management practices that address higher frequencies of intense rain fall events. Transforming the smooth, impermeable surface into a textured, modular paving system demonstrates how technological innovation can support a rapidly evolving ecological environment and reinforce the cultural significance of New Orleans streets.

Flexible pedestrian networks and urban ecologies can increase if the spatial composition of the existing streetscape is redistributed. The intersection of apple and eagle street is a local street corner in the 17th Ward of New Orleans, the Hollygrove neighborhood. This area resides on the edge of the city's topographic 'bowl' that sits below sea level and experiences significantly higher average temperatures in the summer due to lack of tree cover. These conditions promote the testing of this methodological design approach. Eagle street is bookended by a vacant lot and a vacant corner store. Approximately 60% of the street is dedicated to on-street parking with four residences having off-street parking.

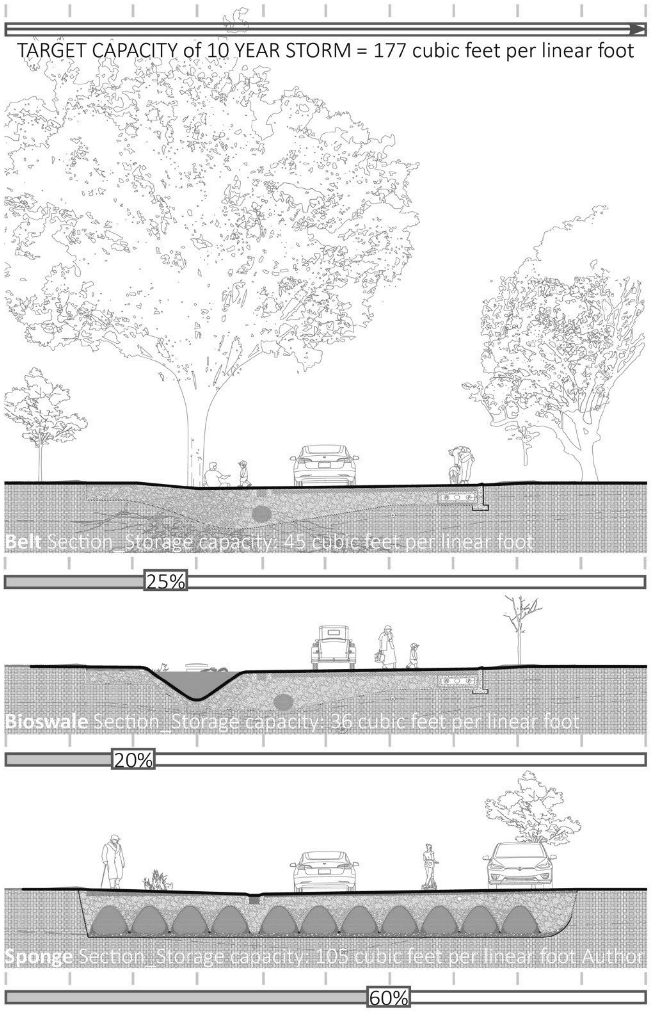


Figure 5. Street Section Configurations. Author.

The primary circulation spine of the new one-way local street is approximately 18'-20' wide. The entire cross-section of this circulation surface is composed of articulated, modular, hydraulically pressed pavers that provide opportunities for diffusing water runoff while increasing functional detection of the street surface through tactility. Pavers can be arranged in multiple orientations and configurations to achieve suitable physical and visual characteristics of the street surfaces. For instance, orienting the paver texture parallel to wheeled travel creates a longer, smoother frequency, while a perpendicular orientation creates a rougher texture (Figure 4B). Pavers with texture oriented perpendicular to vehicular travel are utilized as a buffer between the adjacent pedestrian surface and are placed with increased frequency closer to street intersections. Higher concentrations of this paver orientation and configuration dampen vehicular traffic speed and signals crossing traffic at corners.

Consolidating the vehicular and pedestrian surface creates greater pedestrian network stability and larger open areas between the paved street and adjacent private property boundaries. Many cast-in-place concrete sidewalks have major vertical faults and cross slope issues due to mature tree root interference and accelerated subsidence over subsurface infrastructure systems. To mitigate these accessibility obstacles, the pedestrian surface can become a conduit for sub-surface utilities, including transitioning to below-ground power distribution. Shifting power lines below ground would eliminate the existing spatial constraints that prevent any living or built system from being close to uninsulated electrical lines. It is important to note that relocating power below grade may only be feasible in areas with higher elevations and deeper groundwater levels.

Increased permeability along the surface and section serves three primary functions: slowing down stormwater runoff, pollutant filtration, and increased local storage capacities. The open joints of the paving surface increased open area adjacent to paved surfaces, and increased void space in foundations are all characteristics that can create higher amounts of the permeable surface area along a street. Each of the three section solutions described below considers these characteristics. The solutions all propose inverting the crown so that the surface itself can hold water directly in peak rainfall conditions. The bioswale, the belt, and the sponge create opportunities to increase local storage and slow stormwater upstream. Bioswales can have depths calibrated based on their location in the city and their ‘at grade’ elevation relative to groundwater conditions. Bioswales also act as a frontline pollutant filtration system by capturing sediment from stormwater runoff.

The belt strategy utilizes mature trees as ecological armatures to develop around, given their multivalent ecological benefits. These include assisting energy conservation through shading, which mitigates urban heat island effects, improves air quality, consumes water through absorption above and below grade, and provides biophilic aesthetic benefits in strengthening connections between humans and the natural world. Treading lightly in these areas is essential for the ongoing health of mature trees, so these contexts are suitable for creating green belts that act as seamless extensions of the paved street surfaces.

The Sponge, which can increase local storage capacity along with interruptions in the subsurface stormwater system, can triple the local storage capacity of the bioswale and the belt section strategies. This increased capacity is only possible by creating a higher ratio of subsurface void space that is difficult to achieve with aggregate-based foundation systems. An alternative, cellular system is proposed, composed of a matrix of cast, or formed vessels that can be arrayed along the length and width of local streets. This subsurface system’s continuous, uninterrupted deployment can hold half the volume of peak 10-year storm rainfall rates.

These strategies offer insight into alternative ways to prioritize design criteria for future street reconstruction projects (Figure 05). Introducing new arrays of street trees in areas that experience significantly higher average summer temperatures may occur ahead of the full street reconstruction. Additionally, unused street space at corners, primarily reserved for additional turning space and improved sightlines, can serve as a starting point for transforming the streetscape. Elevating the ground plane of the street towards the corner can create extensive areas of curb-less transitions while replacing century-old masonry utility holes with precast vessels that have a flexible connection to the street surface. Reconfiguring street corners and edges can increase filtration, local storage and decrease pedestrian travel distances.

CONCLUSION: SOCIO-ECO-TECHNO SYNERGIES

Technology and culture are inseparable. This research supports the necessity for humans to utilize the connective potential technology offers between society and ecology rather than technology’s equal potential to form stagnate boundaries between the two. The stagnant nature of technological change aligns with Anique Hommels’ concept of urban obduracy. Obduracy refers to the slow-paced nature of adaptations related to urban policy, planning, and infrastructure innovations. Hommels describes this phenomenon further by stating that “the interlinkages between material, institutional and political actors can create an entity that exists in a self-perpetuating cycle.”[12]

The treatment of the road surface as a sealed, waterproof membrane is a concluding example of a technological boundary established to displace water rather than embrace it. This hyper-technical focus on eliminating moisture intrusion from the paving assembly effectively pushes other problems downstream. Therefore, pursuing any future changes in the technical endeavors of urban infrastructure requires extraordinary linkages between social and ecological conditions. After all, streets leave the most enduring impact on our understanding of contemporary cities. Physically and conceptually, they symbolize the unfolding of humanity’s persistent social and industrial rituals whose ecological impact must become symbiotic.

ENDNOTES

1. *Clay McShane, “Chapter 4 The Uses and Abuses of Streets,” in Down the Asphalt Path: American Cities and the Coming of the Automobile (New York, NY: Columbia University Press, 1994), pp. 57-80.*
2. *Road and street construction represent one of the most expansive modern, engineered systems. As such, they impact society and ecology on multiple scales, including pedestrian mortality rates, remote material extraction, heat island effects, habitat loss, and hydrologic cycles. For further descriptions of their ecological impact, see Brandt, Denise Hoffman, and Seavitt Catherine Nordenson. “Gray Matters.” Essay. In Waterproofing New York, 44–50. New York City, NY: Terreform, Inc., 2016. See also US Environmental Protection Agency, Arkansas Natural Resources Commission, and Jeff Huber, Low Impact Development: A Design Manual For Urban Areas § (2010). See also Thomas J. Van Dam et al., “Towards Sustainable Pavement Systems: A Reference Document,” Towards Sustainable Pavement Systems: A Reference Document § (2015), https://www.fhwa.dot.gov/pavement/sustainability/hif15002/hif15002.pdf.*
3. *Li Xu, Dora Marinova, and Xiumei Guo, “Resilience Thinking: a Renewed System Approach for Sustainability Science,” Sustainability Science 10, no. 1 (2014): pp. 123-138, https://doi.org/10.1007/s11625-014-0274-4.*

4. *Anique Hommels, “Chapter 1 Obduracy in the City: Three Conceptual Models,” in Unbuilding Cities: Obduracy in Urban Socio-Technical Change (Cambridge: The MIT Press, 2014), pp. 1-39, 10.*
5. *New Orleans City Ordinance 27702, Section 121.8-10 states that new or substantially improved construction projects of five thousand (5,000) or more square feet of impervious surface area must detain the first one and one quarter (1.25”) of rainfall, on site, for a period of no longer than 24 hours*
6. *Tillson, George W. Street Pavements and Paving Materials. A Manual of City Pavements: The Methods and Materials of Their Construction. . Seconded. New York, NY: John Wiley & Sons, 1912. p. 158*
7. *Anastasia Loukaitou-Sideris and Renia Ehrenfeucht, Sidewalks: Conflict and Negotiation Over Public Space (Cambridge, MA: MIT Press, 2012), 27.*
8. *Denise Hoffman Brandt and Seavitt Catherine Nordenson, “Gray Matters,” in Waterproofing New York (New York City, NY: Terreform, Inc., 2016), pp. 44-50. Redundant end note*
9. *The United States Access Board establishes these technical requirements. See Access Board, “Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way,” Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way § (2011), https://www.access-board.gov/prowag/.*
10. *American Association of State Highway and Transportation Officials. Standard Practice for High Friction Surface Treatment for Asphalt and Concrete Pavements. Washington, DC, 2014.*
11. *International Standard of Organization. ISO 2631-1 – Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole-Body Vibration. See also Nihlatul Falasifah and Dhany Arifianto, “Comfort Evaluation on the Drivers Using Transfer Path Analysis,” 23rd International Congress of Acoustics, 2019, https://pub.dega-akustik.de/ICA2019/data/articles/000896.pdf, Table 1, p. 2.*
12. *Anique Hommels, “STS and the City: Techno-Politics, Obduracy and Globalisation,” Science as Culture 29, no. 3 (April 2020): pp. 410-416, https://doi.org/10.1080/09505431.2019.1710740, 413.*