

Changing Nature of Communicating Around Infrastructure

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Infrastructure communication, at the intersection of engineering and communication science, refers to the specialized practice of conveying technical infrastructure information across disciplinary boundaries to facilitate understanding, decision-making, and action among diverse stakeholders. This interdisciplinary effort addresses the critical challenge of translating complex engineering concepts into accessible information for varied audiences. It encompasses the development of multilevel discourse frameworks that can simultaneously serve engineers, policymakers, administrators, and the general public who use this infrastructure. By creating these tailored communication channels, infrastructure communication enables collaborative decision-making processes where technical experts and nontechnical stakeholders can meaningfully engage with one another.

At its foundation, infrastructure communication recognizes the sociotechnical nature of modern infrastructure systems, acknowledging that even the most sophisticated engineering solutions exist within social, political, and economic contexts that can significantly impact their implementation and effectiveness. This perspective necessitates communication approaches that address not only technical performance metrics but also social implications, community concerns, and policy considerations.

Central to effective infrastructure communication is the recognition of end users as active participants rather than passive recipients. Modern infrastructure systems increasingly rely on dynamic user engagement, with end users providing real-time data, feedback, and operational inputs that directly influence system functionality. This framing transforms traditional one-way information flows into interactive dialogues where users contribute to system optimization, problem identification, and solution development. Through user-friendly interfaces, mobile applications, and crowd-sourced reporting mechanisms, for instance, end users become essential components of the infrastructure ecosystem itself, creating a continuous feedback loop that enhances responsiveness and adaptability.

A vital component of infrastructure communication involves specialized methods for communicating risk, uncertainty, and reliability factors in ways that support informed decision-making without causing undue alarm or complacency. This requires careful cross-disciplinary translation that bridges terminology gaps between various engineering domains and between technical and nontechnical fields. Equally important are the structured feedback mechanisms

that gather, interpret, and incorporate stakeholder input into technical infrastructure planning and operations, ensuring that infrastructure development remains responsive to the needs of those it serves and leverages the collective intelligence of its user community.

The Essential but Invisible Nature of Infrastructure

We rarely pause to consider the complex interconnected infrastructure that enables our daily lives until they fail. Water flowing from taps, electricity powering our homes, roads we traverse to our destinations, and digital networks connecting us to information and each other all exist in a paradoxical state of being simultaneously essential yet invisible. This invisibility often persists until disruption occurs, such as when a water main breaks, power outages leave neighborhoods dark, roads deteriorate beyond usability, or internet service falters. Oftentimes, it is only in these moments of failure that we fully recognize our profound dependence on infrastructure systems.

Infrastructure's invisibility stems partly from design intention. Effective infrastructure often works best when unnoticed, quietly enabling rather than demanding attention. The water treatment plant operates largely out of sight, allowing treated water to arrive at our household taps without thought. Electrical grids distribute power, arriving at households without general public awareness of the complexity and fragility of this distribution. In other examples, digital infrastructure—the servers, cables, and wireless networks facilitating our constant connectivity—remains largely concealed. This intentional invisibility allows these systems to support modern life without constantly reminding us of their presence. Yet this very invisibility creates vulnerability. When infrastructure operates smoothly in the background, it becomes easy to defer maintenance, postpone necessary upgrades, or underestimate its importance in budgetary decisions. The hidden nature of infrastructure makes it challenging to communicate its value to the public and policymakers who ultimately determine funding priorities. The deterioration of critical systems occurs gradually, often imperceptible until reaching critical failure points.

Water infrastructure offers a compelling example of this invisibility paradox. With millions of miles of pipes beneath the ground in America, much of this system remains hidden from public view. Many of these pipes were installed generations ago and are now approaching or exceeding their intended lifespans. Yet because this deterioration occurs underground, the urgency of addressing aging water infrastructure often goes unnoticed until dramatic failures occur—water main breaks flooding streets, service disruptions affecting communities, or concerning contaminants present in tap water.

The challenge of aging infrastructure extends across sectors. America's infrastructure systems were largely built during distinct periods of investment and expansion—for instance, transportation networks during the interstate highway boom of the 1950s and 1960s (Federal Highway Administration, 2012), water and wastewater systems in the early-to-mid-20th century (Tarr, 2024), and electrical grids that have evolved unevenly over decades. Many of these systems now operate well beyond their intended design lives, creating cascading vulnerabilities that threaten public health, economic productivity, and quality of life. The American Society of Civil Engineers regularly documents this deterioration in its Infrastructure Report Card (American Society of Civil Engineers, 2025). Recent assessments reveal concerning patterns of deferred maintenance and inadequate investment across multiple infrastructure categories. This aging infrastructure creates direct costs through inefficiencies—pipeline breaks result in non-revenue water loss as treated water does not reach the consumers, or deteriorating roads increase vehicle maintenance costs. But the indirect costs may be even greater, including diminished economic competitiveness, environmental degradation, or compromised public safety.

Compounding this challenge is the growing workforce crisis spanning infrastructure sectors. As skilled infrastructure workers retire, many fields face significant knowledge and labor gaps. Infrastructure providers increasingly struggle to recruit and retain qualified personnel. This workforce challenge threatens to accelerate infrastructure deterioration as institutional

knowledge about system operation and maintenance is lost through retirement without adequate knowledge transfer to newer employees.

Infrastructure revitalization represents not merely a maintenance requirement but an essential reinvestment in societal foundations. Comprehensive infrastructure renewal offers multiple benefits beyond simply preventing system failures. Modernized infrastructure can incorporate advances in materials science, engineering practices, and digital technologies that make systems more efficient, resilient, and environmentally sustainable, improving the quality of life across society.

Perhaps, most importantly, infrastructure revitalization offers an opportunity to correct historical inequities in infrastructure access and quality. Past infrastructure decisions often reflected and reinforced social disparities, with disadvantaged communities receiving lower-quality systems or being excluded entirely from infrastructure networks. Thoughtful revitalization efforts can address these disparities by prioritizing investments in historically underserved areas and ensuring new infrastructure meets the needs of diverse communities.

Effective communication plays a critical role in this revitalization imperative. Because infrastructure remains largely invisible until it fails, building public understanding and support for necessary investments requires strategic communication efforts. Engineers, policymakers, and communication scientists must collaborate to translate technical infrastructure needs into compelling narratives that resonate with public concerns and priorities. Without such communication, the invisible nature of infrastructure will continue to deter the sustained investment needed to ensure these essential systems serve society effectively for generations to come.

The Communication–Infrastructure Connection

At the crucial sociotechnical interface lies one of the most persistent vulnerabilities in our infrastructure: the communication gap between those who design and operate infrastructure systems and those who use them. Engineers and infrastructure developers frequently express frustration that people are not using their carefully designed systems as intended. This sentiment reveals a fundamental misalignment in infrastructure development. When engineers create solutions that they believe are optimal but users fail to adopt them as intended, the problem is not simply user error—it is a communication failure at the sociotechnical interface. This response often indicates that technical experts do not fully understand the users, they are trying to apply a single solution to many audiences at once, or simply, the public's needs have changed from the original design. There is rarely one universally “right” way to use a system; instead, successful infrastructure requires designing with diverse users' needs in mind. People are complex and varied in their behaviors, which makes it impossible to design one solution that works for all stakeholders or all types of audiences.

This misalignment manifests in different approaches to metrics and measurement. Engineers prioritize actionable metrics—measurements that enable system changes. From an engineering perspective, if a metric does not allow for changes to be made to the system, it typically has limited value. This reveals a fundamental difference in how engineers and social and behavioral scientists approach problems, where engineers often need measurements that lead to concrete actions, while social scientists may be more interested in understanding underlying phenomena, regardless of immediate actionability.

Consider an example from healthcare infrastructure measuring patient anxiety. Multiple measurement approaches might include blood pressure readings, self-reported scales, and voice pitch analysis to capture anxiety's complex nature. But from an engineering standpoint, measurements that do not enable immediate intervention have limited utility. Medical professionals might prefer focusing on patient complaints because they can respond to them directly, even though this approach misses many instances of patient anxiety that do not result in formal complaints.

This difference extends to how each field approaches the concept of “operationalization.” For social scientists, operationalization means defining the measurement for a theoretical concept. For engineers, it means “putting it in play” or implementing something in a functioning system. One field focuses on conceptual precision; the other on practical application. The question “Why would I measure something that can’t do anything?” seems self-evident from an engineering perspective but reveals a profound difference in disciplinary priorities.

Many infrastructure failures that seem purely technical often have communication breakdowns at their core. When people are unhappy with water service, simply measuring dissatisfaction is not enough—the utility needs to understand specifically what people are unhappy about. Perhaps they are dissatisfied with the communication modality or would prefer information in a different language. Without this level of specificity, infrastructure managers cannot take appropriate action.

Similarly, safety communication offers a powerful example of how communication theory can help prevent infrastructure failures. When infrastructure managers try to enforce safety protocols with strongly prescriptive language (i.e., “You must do this, you must do that”), they often encounter resistance. People react to these commands through a process known as psychological reactance (Brehm & Brehm, 1981). This reaction can lead people to ignore safety protocols, potentially causing infrastructure failures that could have been prevented through better communication approaches (see Chapter 19 for more examples of this concept). Audience tailoring and targeting are another ways communication research can help messages reach intended audiences, and this is discussed in many chapters in this handbook. For example, recent work in the state of Texas in the U.S. questions whether the well-documented safety message of Turn Around Don’t Drown, a U.S. National Weather Service message explaining the importance of turning a vehicle around instead of driving through floodwaters, works for all audiences. Specifically, early findings from these studies suggest that young adults feel invincible and do not believe they will drown. The Turn Around Don’t Drown message is less effective than reminding them to protect their vehicles because insurance and repairs are costly (Stephens et al., 2026). Furthermore, the common U.S. road safety sign, Low Water Crossing, which is meant as a caution in case water has crossed the road, can be misunderstood and not interpreted as a caution (Stephens et al., 2026).

Time perspectives represent another critical area where communication failures occur across infrastructure sectors. In studies of multidisciplinary teams, research has shown that different professional groups often do not understand one another because of the different time windows in which they operate (Ballard, 2007). This temporal misalignment creates fundamental communication challenges, even when all parties are committed to the same goal.

Why This Handbook Now?

The convergence of communication and infrastructure fields has reached a critical juncture, creating an unprecedented opportunity to transform how we conceptualize, develop, and maintain the systems that underpin modern society. This handbook arrives at a time when the traditional boundaries between technological systems and human behavior are increasingly recognized as artificial constructs that hinder, rather than help, effective infrastructure development and management. For decades, infrastructure development has predominantly focused on technical considerations, such as engineering specifications, material properties, and physical performance. Communication aspects were often treated as secondary concerns, addressed only after technical decisions had been finalized. This traditional approach, while producing technically sound systems, frequently resulted in infrastructure that failed to address human needs or gain public acceptance and support fully.

Infrastructure professionals increasingly recognize that technical excellence alone cannot ensure successful outcomes. A technically perfect water treatment facility provides little benefit if community members distrust the water it produces and do not use it. A brilliantly engineered public transit system fails if ridership remains low due to confusion about routes or schedules. A cutting-edge renewable energy installation may face insurmountable opposition if local communities feel excluded from the planning process. This recognition has created ground for collaboration between the infrastructure and communication fields. Engineers and infrastructure planners increasingly seek insights from communication and social science scholars about how to effectively engage communities, build public trust, and design systems that account for diverse human needs and behaviors. Simultaneously, social scientists have discovered rich research opportunities in infrastructure contexts, allowing them to apply and extend theoretical frameworks in meaningful real-world settings.

The growing importance of resilience in infrastructure planning further accelerates this convergence. As extreme and unexpected weather events increase in frequency and intensity, infrastructure systems face unprecedented stresses. Building resilience requires not only robust physical systems but also effective communication networks that enable rapid response and recovery. Communication before, during, and after disruptions plays a crucial role in determining how well communities withstand and recover from infrastructure challenges.

Infrastructure sectors across the United States face significant workforce challenges as experienced personnel retire and technological advances create demands for new skills. The American Water Works Association estimates that up to 50% of water utility workers will be eligible for retirement within the next decade (U.S. Environmental Protection Agency, 2020). Similar patterns appear across transportation, energy, and other infrastructure sectors. This looming “silver tsunami” threatens to drain these fields of critical institutional knowledge accumulated over decades of experience. Addressing this workforce challenge requires effective communication on multiple levels. Industry organizations must communicate the rewarding career opportunities available in infrastructure fields to attract new talent. Educational institutions need clear information about evolving skill requirements to develop appropriate training programs. Current workers require knowledge transfer systems that capture and preserve the expertise of retiring personnel.

Communication plays an equally important role in preparing the infrastructure workforce to navigate increasingly complex stakeholder environments. Today’s infrastructure professionals must engage with diverse communities, explain technical concepts to nontechnical audiences, build public support for necessary investments, and navigate politically charged decision processes. These tasks demand communication skills that have not traditionally been emphasized in engineering and technical education.

Traditional approaches to infrastructure communication—technical reports, engineering specifications, and jargon-laden presentations—no longer suffice in our contemporary environment. The public increasingly demands clear, accessible information about infrastructure systems that affect their lives. Technical expertise alone no longer commands automatic deference; trust must be earned through transparent, respectful communication that acknowledges community concerns and priorities. Moving beyond technical jargon to accessible public communication represents a fundamental challenge for infrastructure fields. Years of specialized training have led many infrastructure professionals to communicate in ways that make sense to technical peers but remain impenetrable to broader audiences. Breaking through this communication barrier requires conscious effort and specific strategies that translate complex technical concepts into language that resonates with public audiences.

Engaging diverse stakeholders in infrastructure planning and maintenance has likewise become essential rather than optional. When infrastructure decisions proceed without meaningful public involvement, they often face resistance that delays or derails implementation. Effective stakeholder engagement requires sophisticated communication approaches that

foster genuine two-way dialogue, rather than simply disseminating predetermined plans. These approaches must accommodate diverse communication preferences, knowledge levels, and cultural contexts.

Addressing equity concerns through better communication has emerged as another crucial priority. Historical infrastructure decisions have often reinforced or exacerbated social inequities, with disadvantaged communities receiving lower-quality infrastructure or bearing disproportionate burdens from infrastructure placement. Correcting these patterns requires communication approaches that prioritize inclusion, create accessible participation opportunities for marginalized communities, and transparently address historical injustices.

This handbook arrives precisely when these communication challenges have become impossible to ignore, yet remain inadequately addressed in both academic literature and professional practice. By bringing together diverse perspectives from infrastructure and communication fields, it offers a foundation for the interdisciplinary collaboration needed to create infrastructure systems that are not merely technically sound but also responsive to human needs, equitably distributed, and publicly supported. The moment for this integration has arrived, and this handbook serves as both guide and catalyst for this essential transformation in how we communicate about the systems that sustain modern society.

Handbook Structure and Navigation

This handbook provides a comprehensive exploration of infrastructure through six interconnected parts. “Part I: Frameworks, Foundations, and Stakeholders in Infrastructure Communication” establishes the conceptual groundwork, examining methodological approaches, stakeholder engagement, funding mechanisms, and social justice dimensions that form the foundation for understanding infrastructure communication. “Part II: Essential Infrastructure in the Built Environment: Systems and Society” focuses on physical infrastructure systems—energy, transportation, and water—that sustain daily societal functioning, with special attention to underserved communities. We acknowledge that other systems are essential infrastructure, and many are touched on in different chapters. We focus here on these sectors in this section because they demonstrate critical vulnerabilities at the sociotechnical interface, where engineering expertise must be complemented by effective communication practices to ensure equitable access, sustainable management, and public support. These systems are simultaneously ubiquitous yet often invisible in daily life until they fail, creating unique communication challenges. “Part III: Digital Communication Ecosystems: Networks, Data, and Intelligence” explores rapidly evolving digital infrastructures from global networks to artificial intelligence applications that increasingly support modern infrastructure management. “Part IV: Infrastructure in Society: Social Networks and Community Engagement” broadens the discussion to include social infrastructure systems, community empowerment, and stakeholder management through innovative communication approaches. “Part V: Communicating Complex Infrastructure: Strategies Across Formats and Cultures” offers theoretical and practical guidance on strategic communication approaches, addressing challenges in conveying technical information across visualization techniques, numeric complexity, and cultural-linguistic diversity. “Part VI: Infrastructure in Crisis: Emergency Communication and Resilience Strategies” examines infrastructure vulnerabilities during disasters, exploring emergency alert systems, social media analytics, and specific challenges across flood, wildfire, and severe weather events, with particular attention to vulnerable populations. Together, these six parts provide an interdisciplinary foundation for understanding and improving communication around the vital systems that enable modern society to function. Let us turn next to describe each section in more detail.

Part I: Frameworks, Foundations, and Stakeholders in Infrastructure Communication

The opening part establishes the conceptual foundations necessary for understanding infrastructure communication. Beginning with “Chapter 1: Changing Nature of Communicating Around Infrastructure,” this introductory chapter explains how infrastructure categories organize the handbook and argues for coupling engineering solutions with communication practices both internally within organizations and externally with the public. This foundation is expanded upon in “Chapter 2: Understanding Stakeholders Involved in the ‘Communicating About Infrastructure’ Space,” which examines the changing nature of stakeholder engagement in infrastructure design, planning, implementation, and governance. As infrastructure systems become more complex and interconnected, increased stakeholder engagement emerges as both a consequence and driver of change in how we approach infrastructure.

“Chapter 3: Using Mixed Methods to Explore Sociotechnical Infrastructure Systems” highlights the evolution from purely quantitative engineering approaches to mixed-methods research that captures the sociotechnical complexity of infrastructure. This chapter clarifies the purpose of different mixed-methods designs and addresses common misconceptions that have limited their application in infrastructure research. “Chapter 4: Federal Infrastructure Investment: Bridging Policy and Engineering Practice” explores how federal funding mechanisms have been used to serve communities better, addressing the disconnects between policy and practical engineering needs that have contributed to infrastructure failures such as the Flint Water Crisis. The section concludes with chapters that address social justice dimensions: “Chapter 5: Multidisciplinary Perspectives on Infrastructure Communication and Social Disparities” maps the justice implications of four approaches to infrastructure communication, while “Chapter 6: Making Justice REAL: Bringing Infrastructure Front and Center” introduces a framework emphasizing representativeness, empathy, accessibility, and learning in service provision decisions.

Part II: Essential Infrastructure in the Built Environment: Systems and Society

This part examines critical physical infrastructure that sustains daily societal functioning. “Chapter 7: Energy Infrastructure” explores how the energy sector underpins economic well-being and how disruptions can create devastating cascading effects. “Chapter 8: Transportation Infrastructure” and “Chapter 9: Public Involvement in Transportation Planning” examine how these highly visible systems require effective communication to improve operations, promote safety, manage disruptions, and engage the public during development projects. Water-related infrastructure receives focused attention through “Chapter 10: Is my Water Safe to Drink?” which discusses the vital role of 2 million miles of pipes safeguarding public health, “Chapter 11: Indigenous Water Infrastructure: Lessons from Alaska Native Communities,” which reveals the power of including indigenous communities in their own water planning, and “Chapter 12: Wastewater Reuse Infrastructure,” which explores alternatives to conventional water systems and the critical role of stakeholder communication in implementing water reuse projects. Wrapping up this part of the handbook is “Chapter 13: Colonias with a Lack of Infrastructure,” which examines broad infrastructure deficits in informal communities along the U.S.–Mexico border.

Part III: Digital Communication Ecosystems: Networks, Data, and Intelligence

This part explores rapidly evolving digital infrastructures that increasingly underpin modern society. “Chapter 14: The Digital Backbone: Elaborating Modern Communication Infrastructure’s Role in Society” reviews core elements of contemporary communication

systems across technological, social, and economic dimensions. “Chapter 15: Connecting Humanity from Submarine Cables to Starlink” examines global digital infrastructures—from underwater cables to satellites—and communication strategies that illuminate their impacts. “Chapter 16: Cyberinfrastructure: Managing and Transforming Big Data for Infrastructure Development” introduces this sociotechnical system centered around managing big data, exploring its historical development and future prospects. “Chapter 17: Artificial Intelligence Supporting Infrastructure Decisions” examines AI’s transformative potential across design, construction, operation, and maintenance of infrastructure systems while addressing ethical considerations and technical challenges. The section concludes with “Chapter 18: Human–AI Collaboration in Social Media Emergency Management,” which explores how social media analytics and human-centered AI approaches enhance situational awareness during disasters, particularly in infrastructure-related contexts.

Part IV: Infrastructure in Society: Social Networks and Community Engagement

This part broadens the discussion to include social infrastructure systems and community engagement. “Chapter 19: Social Care Infrastructure” introduces systems organizing complex health and human service networks, providing a framework for comparing social infrastructure investments across municipalities, states, and countries. “Chapter 20: Creating a Model for Communication to Expand Capacity and Build Infrastructure for Community Environmental Justice Efforts” details approaches for amplifying local voices and returning agency to community-based organizations by identifying key stakeholders and building coalitions. “Chapter 21: Digital Innovation in Stakeholder Management: Navigating Infrastructure Controversies” explores how organizations develop and implement innovative technologies to understand controversies and manage stakeholder relationships during infrastructure development.

Part V: Communicating Complex Infrastructure: Strategies Across Formats and Cultures

This part provides practical guidance on strategic communication approaches. “Chapter 22: Instructional Communication Messages in Infrastructure” examines how applied instructional communication serves diverse publics facing infrastructure challenges, while “Chapter 23: Persuasive Message Design for Infrastructure Communication” explores how strategic messaging informed by communication theory can enhance stakeholder engagement. “Chapter 24: Using Visualization to Communicate About Infrastructure and Make Decisions” distinguishes between scientific visualization for expert analysis and information visualization for broader audiences, and reviews diverse ways that visualizing infrastructure risks can help tackle many of the infrastructure communication challenges highlighted throughout this handbook.

The challenges of communicating complex information receive dedicated attention in “Chapter 25: Strategies for Communicating Complex Numeric Information About Infrastructure Projects,” which addresses public difficulties in comprehending large numbers like those in infrastructure spending. “Chapter 26: Incorporating Culture Into Messages About Infrastructure” highlights cultural responsiveness in message design, including techniques like using *dichos* (Spanish-language sayings) to inform the public about infrastructure behaviors. “Chapter 27: Nuances of Multilingual Communication” explores challenges in

translating risk information for the one-in-five Americans who speak a language other than English at home.

Part VI: Infrastructure in Crisis: Emergency Communication and Resilience Strategies

The final part addresses infrastructure vulnerabilities during crises and disasters. “Chapter 28: Wireless Emergency Alerts” examines this crucial preparedness and response infrastructure that distributes life-saving messages during emergencies. “Chapter 29: Organizational Crisis Communication: The Effects of Social Media Platforms and Beyond” explores how social media has transformed crisis communication infrastructure while also highlighting the importance of integrating analog channels to address digital divide concerns.

Several chapters focus on specific disaster contexts: “Chapter 30: Advancing Flood Resilience Through AI-Enhanced Mapping Strategies” explores how AI-driven methods improve flood risk identification, “Chapter 31: Challenges Explaining Wildfire Water Infrastructure Contamination” examines how wildfires can contaminate water distribution systems, and “Chapter 32: Severe Weather and Infrastructure” focuses on communicating complex information during extreme weather events. “Chapter 33: Older Adults and Mobility-Impaired Individuals in Infrastructure-Related Disasters” addresses the unique challenges faced by these growing demographics, proposing communication strategies to enhance their resilience during infrastructure-related disasters.

The handbook concludes, in Chapter 34, by synthesizing key insights from across chapters, providing a framework for integrating sound communication practices with infrastructure planning and implementation to build greater transparency and trust with affected communities. By bringing together diverse perspectives spanning engineering, communication, public policy, and community engagement, this handbook offers comprehensive guidance for scholars, practitioners, and policymakers working to address the complex challenges of infrastructure in contemporary society. It underscores that effective infrastructure requires not just technical excellence but also thoughtful communication strategies that engage stakeholders, address social justice concerns, and build public understanding and support.

The Value of Persevering Through Challenges

Interdisciplinary infrastructure research offers substantial benefits that make the effort worthwhile. Social and behavioral scientists bring theoretical frameworks that can be applied across contexts, helping engineers understand human behavior patterns that affect infrastructure adoption and use. Engineers bring concrete problem-solving approaches and technical expertise that ground communication and community-engaged research in practical applications. When these perspectives combine effectively, they can address infrastructure problems that individual disciplines cannot solve alone. The infrastructure challenges facing society today—aging systems, workforce development needs, and resilience against extreme weather events—demand interdisciplinary approaches. No single discipline possesses all the knowledge and tools needed to address these complex, multifaceted problems. By recognizing the challenges of interdisciplinary work and implementing strategies to overcome them, we can develop infrastructure solutions that are both technically sound and human-centered; we can create infrastructure that not only functions well but also serves the diverse needs of all who rely on it.

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