Theories of Change: An Equity-Based Framework to Improve Engineering Efforts to Advance Environmental Justice

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Abstract

Civil and environmental engineering research and development are essential in the efforts to assess, design, improve, and implement infrastructure. Engineering disciplines are vital to adequately identifying infrastructure problems, improving designs, developing new technologies, and ensuring safety. While engineering is effective in assessing and improving infrastructure in general, it is significantly less effective in conducting research and development to combat fundamental environmental injustices. There exists no tool to design, execute and evaluate engineering infrastructure research and development through an environmental justice framework, which is vital to realize Justice 40 Executive Order 14008, which aims to invest in climate-resilient infrastructure that is specifically allocated towards environmental justice initiatives for disenfranchised communities. In the absence of a framework, various sectors, whether it be the private sector, philanthropy, academia, or government, each conduct engineering research and development under different theories as to how to realize positive change. Not only are some common engineering theories of change ineffective at addressing fundamental injustices, but many aspects result in the further perpetuation of inequities. Engineering disciplines need to adopt an equitable framework through which to engage in environmental justice efforts. The work herein presents a theory of change framework that various sectors can use to improve the equity and effectiveness of engineering research and development of infrastructure. We assess common engineering theories of change practiced in the private sector, philanthropy, academia, and government, and provide analysis, critique, and recommendations as to how engineering processes can effectively realize Justice 40.

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      Civil and environmental engineering research and development are essential in the efforts to assess, design, improve, and implement infrastructure. Engineering disciplines are vital to adequately identifying infrastructure problems, improving designs, developing new technologies, and ensuring safety. While engineering is effective in assessing and improving infrastructure in general, it is significantly less effective in conducting research and development to combat fundamental environmental injustices. There exists no tool to design, execute and evaluate engineering infrastructure research and development through an environmental justice framework, which is vital to realize "Justice 40" Executive Order 14008, which aims to invest in climate-resilient infrastructure that is specifically allocated towards environmental justice initiatives for disenfranchised communities. In the absence of a framework, various sectors, whether it be the private sector, philanthropy, academia, or government, each conduct engineering research and development under different theories as to how to realize positive change. Not only are some common engineering theories of change ineffective at addressing fundamental injustices, but many aspects result in the further perpetuation of inequities. Engineering disciplines need to adopt an equitable framework through which to engage in environmental justice efforts. The work herein presents a theory of change framework that various sectors can use to improve the equity and effectiveness of engineering research and development of infrastructure. We assess common engineering theories of change practiced in the private sector, philanthropy, academia, and government, and provide analysis, critique, and recommendations as to how engineering processes can effectively realize "Justice 40".

<u>Introduction</u>

The American Society of Civil Engineering has given the United States' infrastructure a 'C-' grade, indicating the need for significant investment in many categories. 43% of public roadways are in poor or mediocre condition, ~20% of the country relies on inadequate septic tanks, 45% of Americans have no access to transit, and 60% of all non-federal Superfund hazardous waste sites are in locations prone to flooding [1]. Marginalized status in society and dominance hierarchies are significant precursors for the burden of environmental injustices faced, disproportionately by communities that are low-wealth, indigenous, and are of color [2] [3] [4] [5]. Manifestations include, but are not limited to, inequitable access to safe drinking water, safe sanitation, recreation facilities, healthy food, clean air, and other environmental necessities, often a result of landfills, industrial manufacturers, air pollution, climate patterns, and other environmental hazards [6]. This includes planning, mapping, and zoning that fail to include historic Black and Indigenous communities, places of worship, and burial grounds. Changing climate patterns of rising sea levels, floods, droughts, and other extreme events stress already compromised infrastructure and exacerbate vulnerabilities and failures that disenfranchised communities experience [7] [8] [9] [10].

The federal government understands the vital need for infrastructure investments and environmental justice (EJ) approaches. However, there exists no framework to design, execute,

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[1] ASCE. 2021. "A Comprehensive Assessment of America's Infrastructure." https://infrastructurereportcard.org/wp-content/uploads/2020/12/National_IRC_2021-report.pdf.

[2] Cassel, John. "The Contribution of the Social Environment to Host Resistance: The Fourth Wade Hampton Frost Lecture." American Journal of Epidemiology 104, no. 2 (1976): 107–23. https://doi.org/10.1093/oxfordjournals.aje.a112281.

[3] Wilson, Sacoby M., Christopher D. Heaney, John Cooper, and Omega Wilson. 2008. "Built Environment Issues in Unserved and Underserved African-American Neighborhoods in North Carolina." Environmental Justice 1 (2): 63–72. https://doi.org/10.1089/env.2008.0509.

[4] Wilson, Sacoby M., Lashanta Rice, and Herbert Fraser-Rahim. 2011. "The Use of Community-Driven Environmental Decision Making to Address Environmental Justice and Revitalization Issues in a Port Community in South Carolina." Environmental Justice 4 (3): 145–54. https://doi.org/10.1089/env.2010.0049.

[5] Heaney, Christopher D., Sacoby M. (Sacoby Miguel) Wilson, and Omega R. Wilson. 2007. "The West End Revitalization Association's Community-Owned and -Managed Research Model: Development, Implementation, and Action." Progress in Community Health Partnerships: Research, Education, and Action 1 (4): 339–49. https://doi.org/10.1353/cpr.2007.0037.

[6] Robert D. Bullard, "Race and Environmental Justice in the United States," *Yale Journal of International Law* 18, no. 1 (1993).

[7] Charles Fant et al., "Climate Change Impacts and Costs to U.S. Electricity Transmission and Distribution Infrastructure," *Energy* 195 (2020): 116899, https://doi.org/10.1016/j.energy.2020.116899.

[8] Peñaloza, Diego, Martin Erlandsson, and Anna Pousette. 2018. "Climate Impacts from Road Bridges: Effects of Introducing Concrete Carbonation and Biogenic Carbon Storage in Wood." Structure and Infrastructure Engineering 14 (1): 56–67. https://doi.org/10.1080/15732479.2017.1327545.

[9] Thaduri, Adithya, Diego Galar, and Uday Kumar. 2020. "Space Weather Climate Impacts on Railway Infrastructure." International Journal of Systems Assurance Engineering and Management 11 (s2): 267–81. https://doi.org/10.1007/s13198-020-01003-9.

[10] Howard, Guy, Roger Calow, Alan MacDonald, and Jamie Bartram. 2016. "Climate Change and Water and Sanitation: Likely Impacts and Emerging Trends for Action." Ssrn. https://doi.org/10.1146/annurev-environ-110615-085856.

and evaluate engineering infrastructure research through an EJ framework. Equitable outcomes to Justice 40 will not be realized if there are failures to address oversight, compliance, enforcement, and corrective actions under Title VI of the Civil Rights Act-1964 (legal foundation for environmental justice) at all government levels. As written, Justice 40 leaves measurable outcomes to cities, counties, and states that openly profess barriers to justice for people of color, where engineering, planning, mapping, and zoning support permanent physical and social barriers to public and environmental health.

Here we propose a theory of change framework to provide insight and guidance to engineering-related disciplines, sectors, and organizations that work to realize Justice 40. Theory of change is a methodology used to develop a strategy, action plan, and evaluation framework to realize social change. It is a backwards-design process that identifies a desired impact and maps out step-by-step causal events in reverse order (outcomes, outputs, activities, and inputs) as to how that outcome will be achieved. This commentary manuscript suggests that centering a theory of change framework can significantly improve the traditional paradigms of how engineering and planning-related disciplines engage and address environmental injustices and unrecognized public risks.

Root Problem Identification

The first step is having an in-depth understanding of the problem(s) and the root issues that create the problem(s). It should be recognized that understanding how and where engineering can have adverse impacts does not require degrees in engineering from academic institutions. As impacted communities are experts of their own context, they are best equipped to define what problems they experience. Universal access to safe and affordable infrastructure (i.e. equality), will never be realized without intentionally prioritizing resource allocation to improve life for those most disenfranchised (i.e. equity). Similarly, liberation from inequities (i.e. environmental justice) will never be realized without a thorough understanding of the institutional systems of oppression which create, perpetuate, and exacerbate those inequities (i.e. the causes of injustice).

Racial Discrimination

Many municipalities established their jurisdiction boundaries and zoning to exclude Black communities and other communities of color from their city limits, known as "racial underbounding" which intentionally deny safe, sustainable, and resilient drinking water and sewer infrastructure installation due racism and laws that still support structural barriers like extraterritorial jurisdictions (ETJs) [11] [12]. Racial discrimination is such a strong driving force of

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[11] Johnson, James H, Allan Parnell, Ann Moss Joyner, Carolyn J Christman, and Ben Marsh. 2004. "RACIAL APARTHEID IN A SMALL NORTH CAROLINA TOWN James." The Review of Black Political Economy, no. 2.

[12] Robert D. Bullard, "Race and Environmental Justice in the United States," Yale Journal of International Law 18, no. 1 (1993).

environmental injustice that nationally race is the strongest predictor of which communities have access to affordable safe and drinking water and sanitation [13] [14].

Colonization & Neo-Colonization

Despite having the resources to significantly improve access to sanitation and poverty in their previous colonies, countries including Britain, France, the United States, Spain, Portugal, and the Netherlands continue to economically reap colonial benefits while their corresponding colonial countries like India, Haiti, the Philippines, Guatemala, Angola, and Indonesia, respectively, continue to bear the burden of widespread poverty and environmental injustice. For example, it was found that the duration of extractive colonial era for any given African country can be attributed to up to 34% of variability in proportion of population with access to improved sanitation, consistent despite identity variability of the colonizing nations [15].

Capitalism

Domestically, the top one percent have extracted over $50 trillion from the bottom 90 percent [16]. Globally, despite trillions going to the global south via forms of foreign aid, investment, and income, since 1980, there has actually been a total net flow of $16.3 trillion that flows from the global south to the global north every year [17]. Capitalism's massive wealth extraction through inequitable corporate trade deals, tax havens, for-profit corporate social responsibility, and other mechanisms significantly exacerbate environmental injustices [18].

The Role of Engineering

Similar to how environmental injustices result from racial discrimination, engineering research and development traditionally excludes racial minorities from core processes [19]. Similar to how environmental injustices result from colonization, research can extract and exploit

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[13] United Church of Christ, "Toxic Wastes and Race in the United States: A National Report on the Racial and Socio-Economic Characteristics of Communities with Hazardous Waste Sites," 1987, https://doi.org/10.1097/COC.0000000000000347.

[14] US Water Alliance, "Closing the Water Access Gap in the United States," 2019.

[15] Ambe J. Njoh and Fenda A. Akiwumi, "The Impact of Colonization on Access to Improved Water and Sanitation Facilities in African Cities," *Cities* 28, no. 5 (2011): 452–60, https://doi.org/10.1016/j.cities.2011.04.005.

[16] Time, "The Top 1% of Americans Have Taken $50 Trillion From the Bottom 90%—And That's Made the U.S. Less Secure," 2020, https://time.com/5888024/50-trillion-income-inequality-america/.

[17] Centre for Applied Research, Norwegian School of Economics, Global Financial Integrity, Jawaharlal Nehru University, Instituto de Estudos Socioeconômicos, and Nigerian Institute of Social and Economic Research. 2015. "Financial Flows and Tax Havens Combining to Limit the Lives of Billions of People," no. December: 113.

[18] Prem Sikka, "SMOKE AND MIRRORS: CORPORATE SOCIAL RESPONSIBILITY AND TAX AVOIDANCE," *Working Paper No. WP 09/04*, 2009, 1–46, https://doi.org/10.1016/j.aos.2009.01.004.

[19] Campbell, G.; Denes, R.; Morrison, C. 2000. Access Denied: Race, Ethnicity, and the Scientific Enterprise. Oxford University Press.

experiences and expertise from community members and take credit for it [20]. Similar to how environmental injustices result from capitalism, the engineering research industrial complex is capitalistic in nature and prioritizes quantity over quality, speed over thoroughness, efficiency over effectiveness, and knowledge production over tangible impact to communities [21]. Engineering disciplines, whether through education, employment, interaction with marginalized communities, or application of construction, have an obligation to adequately address systemic root causes and exacerbators of injustices and conduct research and development under an equitable theory of change paradigm.

Theories of Change

The private sector, academia, philanthropy, government, and community-based organizations exercise fundamental differences in their approach as to how they engage with environmental injustices. Different sectors have different institutional goals, and thus develop theories of change that align with their institutional incentive structures. While there are many variations, we present the following theories of change traditionally used to conduct engineering research and development in different sectors.

Private Sector

The private sector can be defined as entities that are not owned or operated by the government which operate for profit. A common theory of change is to develop engineering products or services to maximize profit or to invest in research to better understand needs for potential target markets to profit. An example is construction engineering companies using materials that aren't the most robust or sustainable but are the most profitable to use. In addition to decreasing operational costs, there are also incentives to lobby to decrease regulations to allow for more creative freedom to further optimize profitability. For example, local governments issue permits that allow for profit private corporations to mine construction resources (granite, steel, soil, etc.) in and near people of color communities and then dump construction waste in these same communities where they deny access to first-time infrastructure installation. This is a historic cycle of institutional racism that if often not holistically addressed. Corporate lobbying also manifests into collusion to be awarded contracts to install yesterday's engineering technologies that do not adequately address engineering challenges of climate change, rising water tables, extreme weather events, and other problems of today and tomorrow. The private sector often does not effectively combat the systemic roots of environmental injustices, as it incentivizes profits over the health, safety, and well-being of people. Even corporate social

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[20] Lourdes A. Vera et al., "When Data Justice and Environmental Justice Meet: Formulating a Response to Extractive Logic through Environmental Data Justice," *Information Communication and Society* 22, no. 7 (2019): 1012–28, https://doi.org/10.1080/1369118X.2019.1596293.

[21] Marc A. Edwards and Siddhartha Roy, "Academic Research in the 21st Century: Maintaining Scientific Integrity in a Climate of Perverse Incentives and Hypercompetition," *Environmental Engineering Science* 34, no. 1 (2017): 51–61, https://doi.org/10.1089/ees.2016.0223.

responsibility initiatives, under the guise of charitable acts, are heavily calculated strategic acts of relatively small investments to ultimately make larger returns as a result [22].

Philanthropy

Philanthropies or foundations are non-government organizations which operate using donated assets which are managed by the organizations. These entities aim to improve the wellbeing of humankind by addressing societal problems, as defined and prioritized by the philanthropy or foundation. A common theory of change is to invest in engineering initiatives to fill governmental and corporate funding gaps. For example, the Gates Foundation's "Reinvent the Toilet Challenge" funds innovative on-site treatment and reuse technologies to be privatized in establishing for-profit start-up sanitation companies (that may not be approved and permitted by most local governments, especially former slave holding states). Private philanthropies and foundations have incentives to inflate the social change implications of their investments to garner more guilt-alleviating donations, an effective mechanism for tax mitigation. Despite having aims to address public issues, most philanthropies are private, act in their own self-interest of accumulating even more economic, social and political capital, and do not have thorough mechanisms to be held accountable by the communities they engage with.

Government

Government is the political and legal authority which controls the actions and affairs of a society. The government sector determines the priorities of its constituent body and allocates resources to support societal needs. A common theory of change is allocating funds into external sectors and within itself, in the form of internal departments, agencies, institutes, and sub-government units. An example is federally allocating funds to the Department of Transportation which then develops and awards grants to an academic research group, a private asphalt corporation, or a State Department of Transportation to research and develop technologies. The executive and legislative branches of our government sector have incentives to serve its constituents to the extent to which voters will maintain political parties' positions of authority. Though, it's worth noting that government priorities, and thus executed theories of change, can significantly and swiftly change, as a result of its leadership changing with election cycles. The politics of red states and slow response of blue states continue to be barriers in 2022, including to the realization of Justice 40. The "theory of change" is greatly challenged and handicapped when it comes to super-conservative state general assemblies and congressional representation in Washington, DC. The power of planning, mapping, zoning, and permitting construction still lies with local and state governments that will receive Justice 40 and billions in new federal infrastructure appropriations, and thus play a gatekeeping role and may not use government resources to mitigate the long history of denying access to people of color communities. Because of politics, lack of inter-agency coordination, and the nature of

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[22] Bhardwaj, Pradeep, Prabirendra Chatterjee, Kivilcim Dogerlioglu Demir, and Ozge Turut. 2018. "When and How Is Corporate Social Responsibility Profitable?" Journal of Business Research 84 (November 2016): 206–19. https://doi.org/10.1016/j.jbusres.2017.11.026.

outsourcing research and development labor among other sectors, there is significant variability in how equitable government initiatives are as a result.

Academia

Academia is considered to be institutes of higher education and research, with primary goals of knowledge production through research and degree conferment through teaching. A common theory of change is to generate knowledge, publish findings, and disseminate information in hopes that other parties use their generated knowledge to affect change. Academia has incentives to create innovative technologies to establish for-profit companies themselves or to otherwise sell or license intellectual property to other sectors, often for profit. When this is not profitable through other sectors, knowledge generated from research serves as a product in and of itself, in the form of published manuscripts. The academic research industrial complex is capitalistic in nature and incentivizes a high quantity of research production. There are disincentives to develop and execute action plans around discovery research because this does not yield a high return on investment under its capitalistic publish-or-perish operation model. Significant measures are usually not taken to redistribute power, influence, or resources to communities and results in academia benefiting disproportionately more than impacted communities. As academic culture values individual productivity and differentiation from competing colleagues, there are incentives to extract novel information and resources from disenfranchised communities and take credit for produced works. It's common to use federal grant funds to study the pain and suffering of Black, Indigenous, and Latinx communities for the benefits of student degrees and faculty advancement, without making efforts to correct the disparities that they research, in some cases in their own backyards. This is magnified when academic initiatives are funded by other entities, such as the private sector, and further operate under a capitalistic paradigm.

Community-Based Organizations

Non-profit community-based organizations are those which are developed by communities which seek to improve collective well-being and functioning, without seeking a profit. These entities strive to build the capacity of communities to increase economic stability, health, safety, education, etc. A common theory of change is to leverage and center community knowledge, resources, influence, and leadership to explore their own research questions to drive community-driven solutions. For example, the North Carolina Environmental Justice Network uplifts community voices, experiences, expertise, and ingenuity to advance advocacy, investment, and equity in achieving safe and affordable infrastructure for disenfranchised communities. These entities have incentives to empower and uplift a community's capacity to improve collective well-being. There are disincentives adopt paradigms which decreases a community's capacity to thrive. While this sector often incorporates principles of inclusion, diversity, equity, and reparations into their theory of change, they often systemically lack adequate economic, social, and political capital to affect change on a large scale. Funding for infrastructure upgrades or first-time installations often go directly to local governments, which pay contractors for construction for public infrastructure, as directed by government planners,

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without investing in community-based organizations as a part of the process. Investments from other sectors directly into community-based organizations could be a mechanism that increases effectiveness to combat environmental injustices.

<u>Factors of Importance</u>

Diversity

Engineering needs to include communities that are both from and otherwise share demographic identities with the communities of interest. Engineering teams and decision makers from all sectors should be diverse with respect to income level, race, ethnicity, gender, and more. These include city, county, state, and federal government planners that participate in the National Environmental Justice Advisory Council (NEJAC) national, regional, and virtual meetings.

Inclusion

According to the U.S. EPA "[Environmental Justice] will be achieved when everyone enjoys the same degree of protection from environmental and health hazards and equal access to the decision-making process to have a healthy environment in which to live, learn, and work" [23]. Engineering research must be community-inclusive, meaningful, actionable, and have continuous participatory processes [24]. "Responsible parties" should include paid contractors and subcontractors who assist government planning offices to produce mapping and zoning that exclude people of communities from installation of basic public health amenities (WERA, 2022).

Equity and capacity building

Engineering sectors must allocate resources to communities proportionate to what they need. Co-creating and sharing information, resources, and power with impacted communities is vital to building their capacity to rectify environmental injustices. This includes access to funding, analysis tools, education campaigns, assistance with grant writing, etc.

Self-determination

Communities should have agency to define their experienced problems, prioritize their needs, self-determine appropriate solutions, and be able to lead, manage, and facilitate any engineering initiative pertaining to them. Communities must be presented with all necessary information and implications of engineering efforts in order to be able to provide thorough informed consent regarding decisions that affect them.

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[23] US EPA, "Environmental Justice," 2019, https://www.epa.gov/environmentaljustice.
[24] NEJAC, "Recommendations for Integrating Environmental Justice into the EPA's Research Enterprise," 2014.

Transparency and accountability

A theory of change should include fundamental mechanisms of transparency and accountability. There should also be opportunities for frequent community feedback, input, and project course correction throughout the entire research or development process.

Acknowledgement and funding parity

There should be appropriate acknowledgement of expertise and contribution to solutions. Communities deserve authorship on all written documents and equitable compensation for their expert labor and consultation in helping to fulfill the government's responsibility of ensuring environmental justice for its people.

Regulation and warranty

There must be regulatory compliance and assurance that communities have appropriate, functioning, engineering infrastructure. Warranties and guarantees are needed such that if infrastructure is performing inadequately, systems can be quickly remedied. This includes ensuring initiatives yield equitable, safe, and affordable public health amenities for all.

Reparations

The 17 Principles of Environmental Justice, drafted at the First National People of Color Environmental Leadership Summit states: "Victims of environmental injustice [should] receive full compensation and reparations for damages" [25]. Reparations are needed and resources must be redistributed to those whose resources were taken or denied. This includes restitution, damage compensation, rehabilitation, satisfaction, and guarantees of non-repetition.

Collective Paradigm Across Engineering Sectors

Under an EJ framework, each engineering sector can be a part of an equitable solution that incorporates the aforementioned factors of importance. It's ultimately the government's responsibility to ensure that engineering initiatives result in societal equity. If the government has allowed for environmental injustices to manifest, it is responsible for taking active roles to rectify those injustices. In its responsibilities to define problems, appropriate solutions, and appropriate strategies and action plans, government entities should build the capacity of communities and community-based organizations to co-determine these items. Communities need to drive each process and have the information, resources, and power to do so. This is an essential component of needed reparations and allows for self-determination.

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[25] Sacoby M. Wilson, "Environmental Justice Movement: A Review of History, Research, and Public Health Issues," *Journal of Public Management & Social Policy* 16, no. 1 (2010): 19–50, http://content.ebscohost.com.ezp.waldenulibrary.org/ContentServer.asp?T=P&P=AN&K=51444641&S=R &D=poh&EbscoContent=dGJyMNLr40Sep7E4wtvhOLCmr0mep7FSrqu4SraWxWXS&ContentCustomer= dGJyMPGss0q1qK5IuePfgeyx44Dt6fIA%5Cnhttp://ezp.waldenulibrary.org/login?url=http:

Only after defining what the problems are and co-developing a strategic action plan should other sectors then be solicited to contribute to the determined strategy. For example, if it's co-determined that infrastructure needs to be developed and the private sector has the capacity to fulfill such a task more effectively and efficiently than other sectors, then it could be appropriate to solicit the private sector for novel technology development. If it's co-determined that more information is needed to better understand problems that communities face, then it might be appropriate to solicit the academic sector to conduct research that aligns with the community's needs and recognizes their contributions with authorship and funding parity. If there is a funding gap that is identified within available government resources that result in the inadequate support of solutions that were co-determined by communities, then philanthropy could be useful in this context. Regardless of sector, communities need to be an included, integral part of the diverse leadership of every initiative, partnership, and collaboration.

Case Study: The Center for Rural Enterprise & Environmental Justice (CREEJ)

CREEJ is a national community-based, non-profit organization based in Alabama. za significant motivation for its establishment is to increase the capacity of communities to advocate, organize, strategize, and mobilize to realize environmental justice. One of CREEJ's goals has been to make sure marginalized communities have access to safe, affordable, effective, and resilient sanitation infrastructure.

Partnership between CREEJ and the government sector led to determination of what the problems and their root issues are, definitions of successful outcomes, mapping of available resources and constraints, and strategic planning. With community leaders and the academic sector, CREEJ co-conducted a scientific study of exposure to biohazards from untreated wastewater that aligned with community goals and adequately credits community members with authorship and funding parity. While policy was being drafted to expand governmental resources, CREEJ partnered with the philanthropic MacAurthur Foundation to increase their capacity to raise awareness and disseminate information to the public, supplement governmental funding gaps of engineering solution support, and provide CREEJ access to resources and networks. CREEJ is also currently exploring appropriate collaborations with entities in the engineering private sector to develop innovative treatment technologies that address the needs of their community. Each collaborative effort was community-led and integrated mechanisms of transparency, and accountability. Under an EJ framework, all sectors of government, community-based organizations, academia, philanthropy, and private sector effectively engaged to address environmental injustices while incorporating fundamental aspects of diversity, inclusion, equity, self-determination, acknowledgement and funding parity, transparency and accountability, regulation, warranty, capacity building, and reparations.

Theory of Change Execution Tools

COMR & MOU/MOA

It is vital that communities are centered at the forefront of engineering process development and execution. The West End Revitalization Association (WERA) of Mebane, NC (Alamance County and Orange County) has established a framework to conduct equitable research and development called The Community Owned and Managed Research (COMR) Model [26]. WERA's COMR model includes pillars of funding equity, management parity, science for compliance, legal leverage for corrective actions, compliance and enforcement using research results, and more. This creates a framework of transparency and accountability which addresses inequitable power dynamics between collaborating parties. It is considered to be the gold standard by the National Institute of Environmental Health Sciences for how to conduct EJ research with communities and has been successfully integrated into state and federal policy and legislation. COMR is an established best practice framework for how to develop and execute community-led action research to combat environmental injustices and should serve as a standard rubric as to how the action plans of Justice 40 initiatives are conducted. The national Citizen Science Association's board recently adopted the WERA Model's core MOU/MOA (Memorandum of Understanding and Memorandum of Agreement) when collaborating and partnering with other sectors in order to protect "community science" data and research that fosters measurable outcomes at ground level (see Appendix).

Trainings

Engineers' interest to conduct EJ research and development does not mean that they are adequately trained or have the skills required to do so. Conducting equitable EJ work requires holistic, multi-dimensional, interdisciplinary approaches that are very different from paradigms of how engineers are traditionally trained. Pro-social and translational engineering is necessary for grassroots organizations representing the interests of adversely impacted communities. All sectors should co-develop workshops and modules with communities to train engineers how to holistically design, execute, and evaluate infrastructure research and development. For example, the Center for Diverse Leadership in Science asks graduate students who are working with tribal communities to take coursework from UCLA's American Indian Studies Center and participate in workshops.

Evaluation & Stakeholder Analysis

Evaluation of engineering operational theories of change is an important aspect of ensuring that efforts simultaneously cause no harm and further build the capacity of communities to combat injustices [27] [28]. Communities should be centered in how engineering research and development is evaluated, regardless of sector. Diversity, inclusion, equity, self-determination, acknowledgement and funding parity, transparency and accountability, regulation

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[26] Wilson, Sacoby M., Omega Wilson, Christopher D. Heaney, and John Cooper. 2008. "The Use of Community-Owned and Managed Research (COMR) to Address Public Health Issues and Empower and Revitalize Disadvantaged Communities."

[27] NEJAC, "Recommendations for Integrating Environmental Justice into the EPA's Research Enterprise." 2014

[28] U.S. EPA, "Environmental Justice Research Roadmap," no. December (2016), https://doi.org/10.4324/9781315764788.

and warranty, capacity building, and reparations metrics should be used to assess theories of change to evaluate aspects such as funding parity, level of community ownership and management, feelings of inclusivity, levels of transparency and accountability, effectiveness of an engineering effort to address environmental injustice, and more. A comprehensive comparative analysis should be performed for all stakeholders to evaluate whether the processes and outcomes of the engineering work were equitable. Supplemental stakeholder analysis and evaluation questions can be found in the Appendix. Institutional standards of what defines successful engineering research and development need to evolve to incorporate these crucial aspects.

Conclusion

Engineering research and development can be powerful tools to address environmental injustices and other infrastructure issues. However, tools must be utilized in an equitable manner for them to be effective. While Justice 40 is a step in the right direction, the federal initiative needs to ensure that engineering sectors do not further exacerbate inequities and operate under an environmental justice framework. Communities are the experts of their own context and should be leading every step of engineering processes to produce research and development which is equitable in nature, effective in addressing the community-defined questions of exploration, and actionable to build the capacity of communities in their efforts to achieve environmental justice. Engineering theories of change, regardless of sector, should be co-assessed by the government and impacted communities to determine what initiatives, programs, and projects are deemed worthy of receiving Justice 40 funds. Even Justice 40 itself should be evaluated. The concept of only allocating 40 percent of funds to combat environmental injustices, without guarantees that the other 60 percent majority investment will not perpetuate and exacerbate inequities, is in itself inequitable. Root issues of racism, colonialism, capitalism, and more must be adequately addressed and fundamental aspects of diversity, inclusion, equity, self-determination, acknowledgement and funding parity, transparency and accountability, regulation and warranty, capacity building, evaluation, and reparations must be incorporated into engineering theories of change. Only then will engineering research and development be effective at advancing environmental justice.

APPENDIX

WERA Notes
- WERA work also includes initiatives on new policies on the lack of "Oversight and Regulations on COVID-19, Medical, Heathcare, and Testing Waste" that disproportionally is dumped, incinerated, and landfilled in Black and Brown communities. All of this requires paid engineering to produce more disparities.
- The APHA (American Public Health Association) is currently review a policy statement that grow from WERA's work in Mebane, NC, Title: "*The Overlooked Public Health Crisis of Healthcare Waste: A Call for Oversight, Protections, & Tracking*" (see attachment/reference).
- WERA's digital archive can also be accessed at www.weranc.org.

Evaluation Questions
- Relationship Health & Dynamics
  - How were the partnerships and research formed/developed?
  - What were the incentives and intentions of each stakeholder?
  - How long has relationship with the community lasted? Were there any lags in the relationship?
  - Is there trust and reciprocity in the relationship with community?
  - Has there previously been or is there currently conflict with community? Were these issues holistically resolved?
  - Are communities being empowered?
- Step #1 – Problem identification
  - What are the problems the communities are facing?
  - What are the root issues that create and perpetuate the problems the communities are facing?
  - Is engineering research and development needed in the first place? If so, why?
- Step #2 – Method to develop solution (Theory of Change)
  - What is the theory as to how that change will be realized (i.e. theory of change)?
  - What change does the research aim to achieve?
  - What were the incentives and intentions of each stakeholder?
  - Specifically, is there funding equity; are communities equitably paid for their time, expertise, investment, inconvenience, etc. in the conception, design, implementation, and evaluation of a research project?
  - Is there management parity; are communities centered in every aspect of the research being conducted?
  - Do they have equitable control and management of every step of the project conception, design, and execution?
  - Was the community granted or denied the ability to own their own data?
  - Was science conducted for compliance; is the research being used to evaluate whether an environmental context adheres to local, state, regional, and/or federal regulations?

- ○ Regarding intellectual contribution, were original thoughts and ideas from the community valued and were they incorporated into the foundation of the research?
  - ○ Who is funding the research?
  - ○ Who is driving the research process?
  - ○ Who is conducting the research?
  - ○ Is the research being conducted solely to fuel the enterprise of knowledge production or will it be used and leveraged to result in tangible actionable change that benefits the community of interest?
  - ○ Do communities have "equal access to the decision-making process" in research projects?
- ● Step #3 – How solution will be executed (Action Plan)
  - ○ Is there an action plan at all?
  - ○ What will be done with the research?
  - ○ Are written and verbal products of the research equitably produced with community members?
  - ○ Are the research professionals taking credit for community expertise and taking control of the community's narrative?
  - ○ Are the research professionals uplifting the voices of the community and giving credit where credit is due?
- ● Step #4 – Assessment of Impact
  - ○ With respect to climate, are the communities being further subjected to disproportionate effects of climate change?
  - ○ What are all of the benefits from the research project that were realized for each stakeholder?
  - ○ When compared to each other, are the benefits equitable?

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