Transforming US urban green infrastructure planning to address equity

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Transforming US urban green infrastructure planning to address equity

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HIGHLIGHTS

- Current US urban Green Infrastructure planning requires transformation to address equity.
- Only 11% of plans define equity and 14% define justice.
- Current planning practices manufacture consent with limited inclusion.
- GI planning intends to significantly transform urban environments.
- Municipal, state, and federal policy must build inclusive planning capacity with communities.

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ABSTRACT

Cities across the Unites States have embraced green infrastructure (GI) in official planning efforts. The plans conceptualize GI as providing multiple functions and benefits for urban residents, and form part of complex responses to intersectional urban challenges of social injustice and inequity, climate change, aging and expensive infrastructure, and socio-economic change. To date, it is unclear whether official city GI programs address systemic racism and urban inequality. To fill this knowledge gap, we coded and analyzed 122 formal plans from 20 US cities to examine if and how they address equity and justice in three domains: visions, processes, and distributions. We find a widespread failure of plans to conceptualize and operationalize equity planning principles. Only 13% of plans define equity or justice. Only 30% of cities recognize that they are on Native land. Over 90% of plans do not utilize inclusive processes to plan, design, implement, or evaluate GI, and so target many communities for green improvements without their consent. Although 80% of plans use GI to manage hazards and provide multiple benefits with GI, less than 10% identify the causes of uneven distributions and vulnerability. Even fewer recognize related issues of houselessness and gentrification. Very few plans have mechanisms to build community wealth through new GI jobs. We find promising seeds of best practices in some cities and plan types, but no plan exemplified best practices across all equity dimensions. If formal GI planning in US cities does not explicitly and comprehensively address equity concerns, it may reproduce the inequalities that GI is meant to alleviate. Based on our results, we identify-three key needs to improve current GI planning practices for green infrastructure and equity. First, clear definitions of equity and justice are needed, second, planning must engage with causes of inequality and displacement, and third, urban GI planning needs to be transformed through a focus on inclusion.

1. Introduction to equity and urban greening in the U.S.

Historical and ongoing racist and colonial policies, planning, and cultural norms have created the numerous intersecting inequalities and justices in American cities (Laws, 1994; Gotham, 2000; Rothstein, 2017) fundamentally structuring urban landscapes and ecosystems (Schell et al., 2020). City planning remains a key site of contestation for achieving social and environmental justice (Hess & McKane, 2021). Green infrastructure (GI) has emerged as a major strategy for urban sustainability transitions globally and in the United States (U.S.) (Cilliers

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et al. 2019; Grădinaru & Hersperger, 2019; Pauleit, Ambrose-Oji, & Andersson, 2019; Silva et al. 2019; Cortinovis & Geneletti, 2018; Bartesaghi-Koc, Osmond, & Peters, 2017; Mell, 2016; Mascarenhas *et al.* 2015; Hansen, Frantzeskaki, & McPhearson, 2015). In the U.S., cities use the GI concept in diverse types of plans to integrate ecological systems with technological infrastructures to provide multiple functions and benefits (Grabowski, McPhearson, Matsler, Groffman, & Pickett, 2022). GI promises to add value to the urban environment by improving recreational opportunities, aesthetics, active transit, and social gathering spaces (among others), and manage urban hazards such as flooding, stormwater, excessive heat, and extreme weather (Keeler et al., 2019). Creating healthy and sustainable urban systems with GI continues to gain policy salience in urban contexts especially in response to COVID-19 (Lopez, Kennedy, Field, & McPhearson, 2022). In US cities, these efforts operate in the context of long running structural inequalities driven by racist and classist planning practices and prior efforts for urban improvement and renewal (Rothstein, 2017). We argue that to confront systemic inequalities in the United States plans must explicitly seek to transform inequitable urban landscapes and the planning processes that created them.

Transforming planning requires clearly articulating what is meant by equity and justice, and more broadly understanding the causes of current conditions of inequality. This includes understanding how plans specify procedures for the design, implementation, and evaluation of GI. We must also consider how GI changes the distributions of value and hazards in the urban landscape. And - as with any infrastructural intervention - we must also examine the distribution of labor required to realize and maintain GI. Here, we propose a conceptual framework to jointly examine these aspects of equity (Fig. 1), which we apply to evaluate the equity of plans through an equity screen (Table 1). We situate this conceptual framework in an overview of current urban GI planning efforts in the U.S. and their intersection with legacies of urban greening and inequality. Using methods for plan quality evaluation and discourse analysis we apply our framework to analyze if - and how - current city led planning efforts from 20 US cities in the United States conceptualize and operationalize equity principles. Our analysis focuses on plans produced by - or in direct supervision by - city governments to understand the current role of formal governance of GI, which we distinguish from non-profit organization led planning which often has an inclusive community focus (Buijs et al., 2016). Here, we present the most comprehensive plan review to date of formal city led GI planning efforts in the U.S.

2. Current approaches for green infrastructure planning in the U.S.

GI means different things to different academic and practitioner communities (Wright, 2011; Matsler et al., 2021b). In practice GI planning often focuses on either improving ecological landscape connectivity, sustainably managing storm water, or more broadly integrating ecological and engineered systems (Szulczewska, Giedych, & Maksymiuk, 2017). In the U.S., most cities use GI to comply with Clean Water Act regulations with stormwater focused approaches (Grabowski et al., 2022). These stormwater focused approaches can operate alongside landscape conservation approaches for connecting diverse green spaces to provide multiple functions and benefits (e.g. Benedict & McMahon, 2012). Some cities use GI to integrate the planning of diverse built infrastructures (e.g., transportation, energy, storm, and sewer systems) with urban ecosystems to deliver multiple services for urban residents (Grabowski et al., 2022).

Previous analyses examining specific plan types, such as sustainability (Benton-Short, Keeley, & Rowland, 2019) or comprehensive plans (Kim & Tran, 2018) find that GI concepts are often inconsistently conceptualized, and their role in improving social well-being requires further elaboration. For example, Benton-Short et al. (2019) call for greater scholarly attention on GI's relationship with social equity. These calls intersect with a relatively limited scholarship examining how GI plans target specific communities with different types of GI (Meerow, 2020; Hoover, Meerow, Grabowski, & McPhearson, 2021), or the inherently political processes of planning for GI interventions

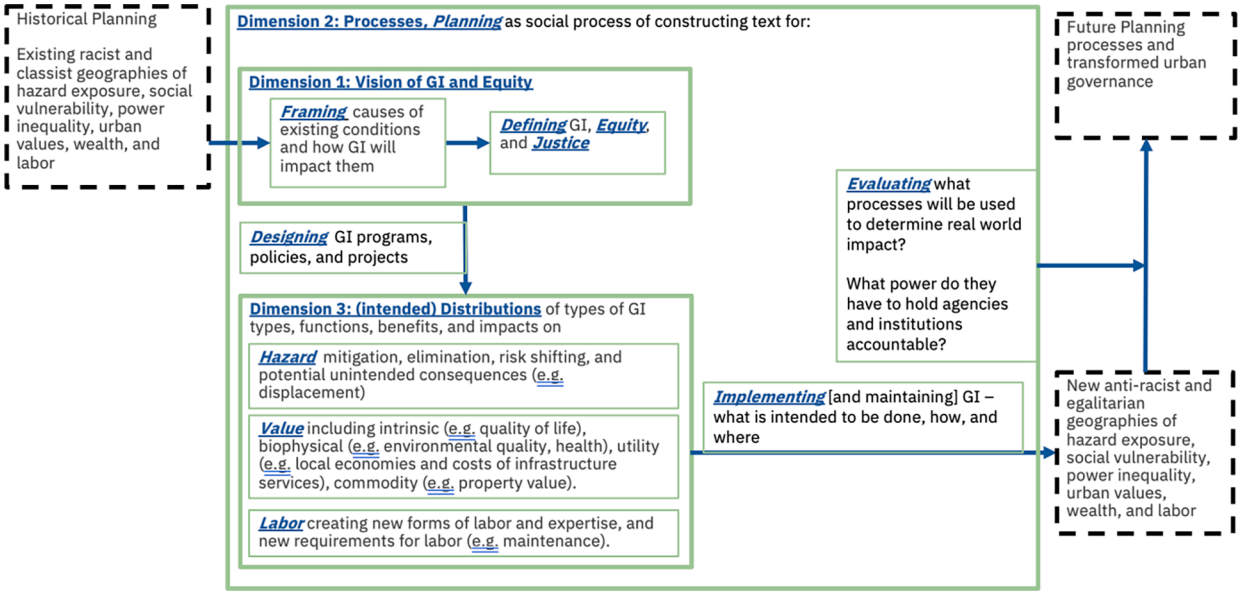


Fig. 1. General Framework for examining the equity of urban planning applied to Green Infrastructure (GI) planning. Dimensions analyzed are in bold, with their associated categories in italics. The dimension of **Vision** refers to how current urban inequalities and relationships between GI, equity, and justice are ***framed*** and ***defined***. The dimension of **Procedural equity** includes the categories of how the ***plan*** itself is constructed, how GI is ***designed,*** how it will be ***implemented***, and how its real-world impacts will be ***evaluated***. The dimension of **Distributional equity** examines the intended impacts in the categories of ***hazards***, ***value***, and ***labor***. In this conceptualization GI planning can create new desirable urban geographies if all of these elements are addressed, which in turn can contribute to creating even more just future planning processes by transforming urban governance. Solid outline boxes represent items present in this analysis. Dashed lines represent aspects of urban inequality beyond the scope of this work, but which can be included in empirically investigating the equity of GI planning. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

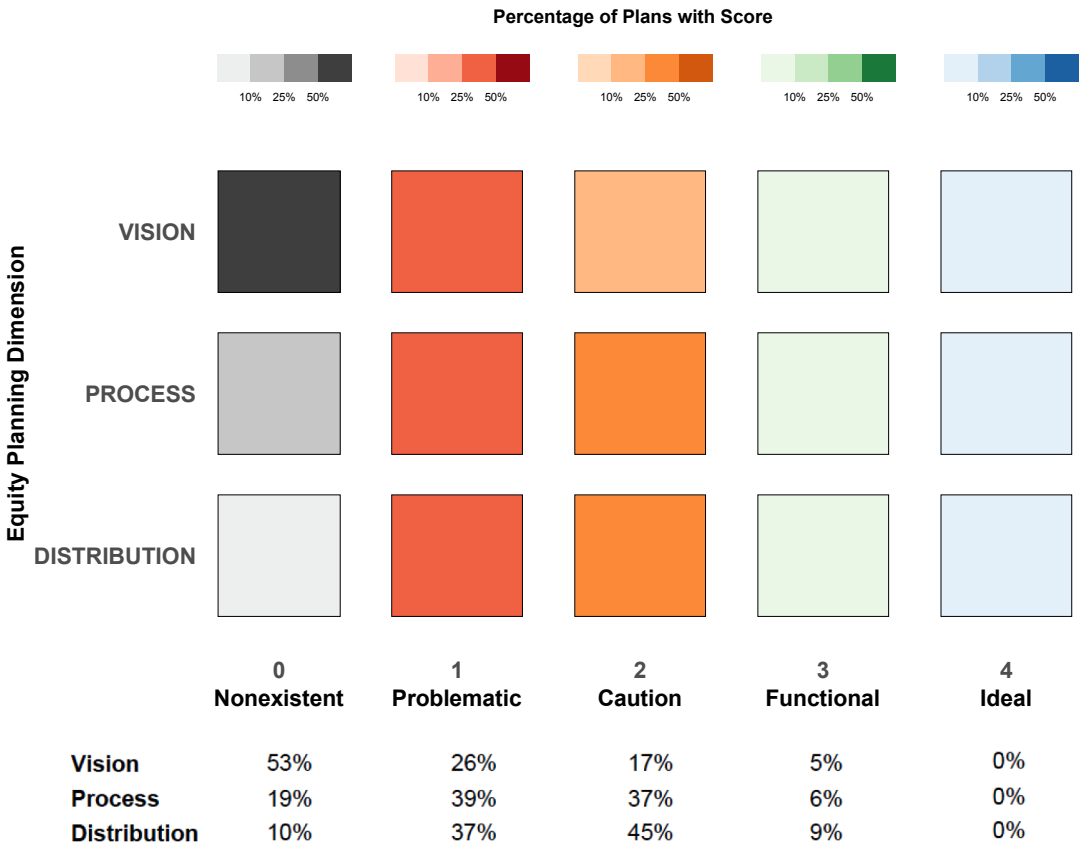


Fig. 2. Percentage of each plan with scores in each dimension. Score levels correspond to evaluation criteria in Table 1. The darker the color the more plans scored at that level in their respective categories. No plans achieved equity planning ideals (score 4). Rows represent each equity dimension. Columns represent the number of plans receiving each score.

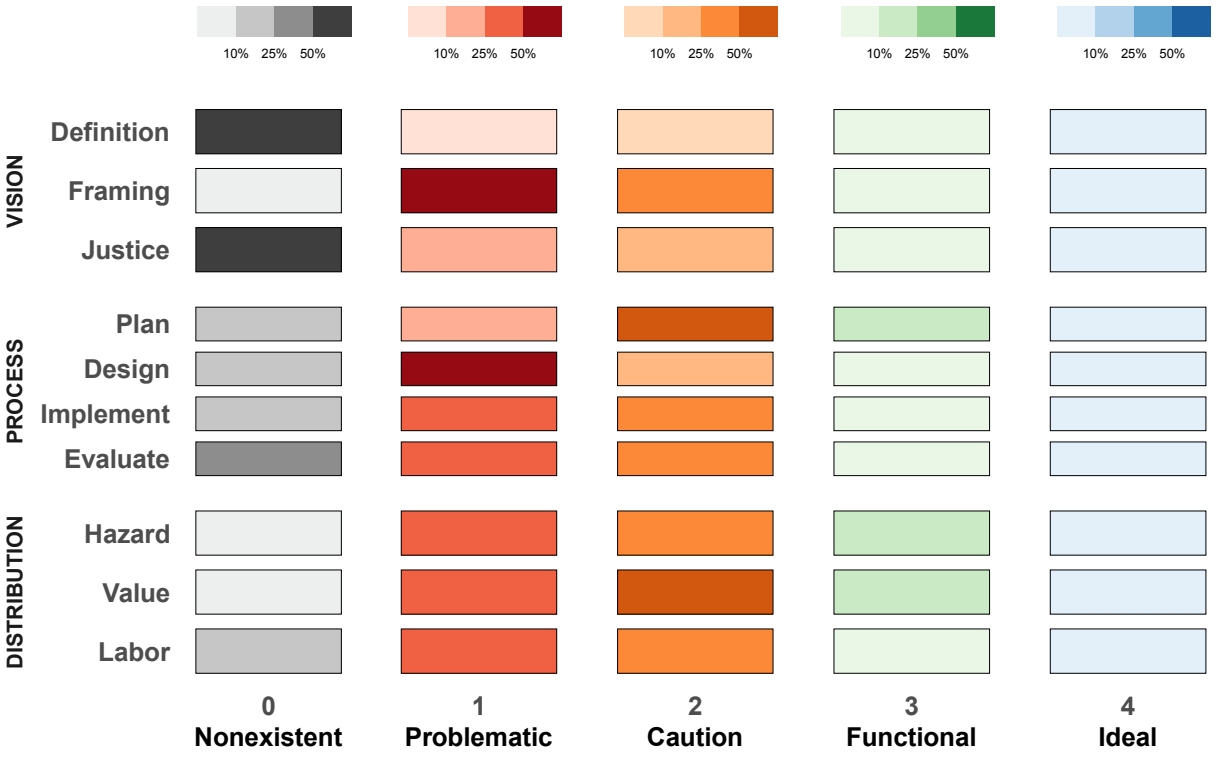
(Finewood, Matsler, & Zivkovich, 2019), both of which need to be understood to evaluate the role of GI in addressing urban inequalities. Although GI is inherently multi-scalar (Shi, 2020), cities operate as discrete units of governance with tremendous power to reshape their social-ecological-technological systems (Kirsop-Taylor, Russel, & Jensen, 2021; Branny et al. 2022). City GI programs also make significant investments in urban systems, such as New York City's $1.5 + billion urban tree planting program and Washington DC's $2.7 billion Clean Rivers Project. Despite efforts to understand the equity implications of climate and resilience plans around the U.S. (Shi, 2020; Chu & Cannon, 2021; Shi & Moser, 2021), empirical studies of the diverse planning instruments used to implement green infrastructure remain rare.

3. How GI planning in the U.S. intersects with urban inequalities

As cities increase investment in GI they must grapple with embedded, multifaceted, and intersectional equity issues (Matsler et al. 2021a). Cities vary in their level of development of GI (Young, Zanders, Lieberknecht, & Fassman-Beck, 2014), and should be expected to vary in how they address equity concerns. Major equity concerns identified by affected communities and in the literature include intensifying unequal exposure to environmental hazards, exacerbating inequalities in access to environmental amenities, and contributing to housing displacement (Gould & Lewis, 2016; Pearsall & Anguelovski, 2016; Anguelovski, Connolly, Garcia-Lamarca, Cole, & Pearsall, 2019). In U.S. cities, these issues cannot be separated from the legacies of prior planning efforts and structured inequalities in American society.

Fundamentally, structural inequality in the U.S. is rooted in the inception of America as a settler colonial and capitalist state requiring enslaved labor and seizure of Native lands (Horne, 2019). Addressing these structures of oppression requires transforming the systems that continue to perpetuate harm (Coulthard, 2014; Rothstein, 2017; Gilio-Whitaker, 2019; Schell et al., 2020), including planning systems (Yiftachel, 1998; Brownill & Inch, 2019). Planning makes socially constructed racial hierarchies tangible through designing physical and social systems apportioning opportunity, critical public services, and (de)valuing different human lives and types of land (Lord & Norquist, 2010; Fields & Fields, 2014). Planning is also a contested arena in which the rules governing urban systems can be rewritten in collaboration with marginalized communities to achieve equitable transformations (Reece, 2018). Doing so however depends on how plans envision equitable transformations, the processes used to create and implement them, and the resultant distributions of goods, hazards, and labor in the urban environment.

U.S. cities utilize GI for mitigating diverse hazards including water pollution, urban heat, flooding, traffic accidents, and air pollution, all of which have uneven distributions documented by environmental (Pellow, 2017) and climate justice scholars (White, 2020). Inequalities in hazard distributions have been caused by explicitly colonialist and racist policies including land theft (Gilio-Whitaker, 2019), redlining and housing covenants (Rothstein, 2017), uneven infrastructure investments (Trounstine, 2018), and discrimination in the institutions managing and responding to disasters (Breen, 2021). Distributions of GI such as tree canopy (Locke et al., 2021; Zhou et al., 2021), and parks (Rigolon, Browning, & Jennings, 2018) have strong relationships with hazards such as heat exposure (Hoffman et al. 2021), and the impacts of Covid-19 (Spotswood et al. 2022). These patterns of inequitable distributions of hazard exposure are reinforced by inequalities in access to GI providing environmental amenities and other ecosystem services (Nowak, Ellis, & Greenfield, 2022).



	0 Nonexistent	1 Problematic	2 Caution	3 Functional	4 Ideal
Definition	84%	2%	9%	5%	0%
Framing	8%	54%	30%	8%	0%
Justice	66%	20%	12%	1%	0%
Plan	11%	20%	52%	16%	0%
Design	20%	61%	16%	2%	0%
Implement	16%	38%	46%	1%	0%
Evaluate	27%	36%	33%	4%	0%
Hazard	6%	34%	49%	11%	0%
Value	2%	28%	58%	12%	0%
Labor	22%	48%	26%	4%	0%

Fig. 3. Tallies of equity scores per equity category across all cities and plans. The darker the color the more plans received that score in each category. The majority of plans did not define equity or justice and had problematic framings of GI-equity relationships. Procedurally, plans showed some promise in inclusion in plan writing, though generally only in surveying public opinion prior to planning. This was reflected in the higher percentages of problematic and cautionary scores in design, implementation, and evaluation. Plans were more consistent in attempting to address unequal distributions of hazards and value with GI, though approaches towards building labor equity were largely problematic.

The benefits of GI, which we define here as the 'value' of GI, include recreation opportunities, gathering spaces, habitat, alternative transit options, and educational opportunities (Grabowski et al., 2022), intersect with deeply uneven geographies of the value of urban land (Fields & Raymond, 2021; Heynen, Perkins, & Roy, 2006; Smith 1982). Increasing investments in GI as an urban environmental amenity can disproportionately benefit more privileged communities by increasing amenity value in wealthy neighborhoods (Pearsall & Anguelovski, 2016). Environmental amenities - such as parks - have also been used by predominantly white urban elites to dispossess minoritized communities, as in the case of Central Park in NYC (Conservancy, 2020), and in several instances in the Washington D.C. (Flanagan 2017, Chase, 2020). Given legacies of uneven investment and tactical dispossession in U.S. Cities, selective and piecemeal investments in greening have given rise to 'green gentrification' (Gould & Lewis, 2016), and subsequent resistance to some local greening efforts (Rigolon & Németh, 2018). Housing displacement can exacerbate houselessness (Pearsall, 2018), and cause communities to relocate to more hazardous areas (Gould & Lewis, 2016), as has already been observed in coastal cities such as Miami (Keenan, Hill, & Gumber, 2018), New Orleans (Aune, Gesch, & Smith, 2020), and across the U.S. (De Koning & Filatova, 2020). Green interventions for improving parks access and the exchange values of adjacent areas often omit the lived experience of houseless people and displace them in the process (Speer & Goldfischer, 2020). These concerns must be addressed, especially as many cities - recognizing distributional inequalities in access to green amenities - have begun to use 'equity lenses' to promote the installation of GI in marginalized and underserved communities (Hoover et al., 2021).

Adapting cities to climate change while providing a high quality of life for burgeoning urban populations offers numerous opportunities for well-paying jobs (White, 2020). Recognizing this, some U.S. cities explicitly use GI investments to create economic opportunities, primarily through creating new jobs and employment sectors (Grabowski et al., 2022). These initiatives are encouraged by national policies to create new jobs in marginalized communities (Agency, 2022), as well as target particular communities for environmental justice interventions in the name of climate action (Executive Order 14008; Agency, 2020). Addressing wealth inequality through green jobs creation is an

Table 1

Plan Equity Evaluation Screen. Using principles of plan evaluation (Lyles & Stevens, 2014) and equity planning (Reece, 2018), plans were evaluated in three dimensions of equity in terms of their visions, processes, and expected distributional impacts. Within each of these, specific categories were evaluated on score of 0 to 4, using coded items grouped according to our codebook (Supplemental Table 2). Scores strongly correlated with the quantitative groundedness of the number of coded units pertaining to each category (Supplemental Figs. 1 and 2). References explaining the rationale behind each category are described in methods and materials.

	Dimension Definition	Category name and description	Level 0 absent	Level 1 - problematic	Level 2 - caution needed	Level 3 - functional	Level 4 - ideal
VISION	Quality of the definition of equity, use of concept in framing vision and goals of the plan, if and how the plan addresses social and environmental (in) justice	**Definition**: How Equity is Defined (Brand, 2015)	not present	universal, general, or partial 'flat' definitions	addresses inequitable outcomes but not causal processes	articulated as core principle, addresses legacies, outcomes, and process	all domains covered and specified within city context
		Framing: how equity is more broadly framed and discussed (Brownill & Inch, 2019	not present	equity as keyword with no content	focuses on improving outcomes but not underlying conditions	articulated as core principle applying across all elements and programs	truly visionary in terms of social transformations required to achieve equity and justice in city
		Justice: addresses ongoing and historical injustice (Fraser 2009; Pellow, 2017; Gilio-Whitaker, 2019)	not present	justice as keyword with no content	some discussion of how historical and current injustices influence current conditions and appetite for planning	(in)justice defined by oppressed communities, includes recognition, restoration, and transformation	commitments of resources to be used in community led deliberative processes for reparations as defined by injured communities
PROCESS	How affected individuals and communities have influence on processes throughout the planning lifecycle	**Planning**: how those affected are involved in the planning process (Hopkins, 2010)	not present	superficial engagement	formulaic engagement, obscured/ manufactured consent	numerous avenues for input, transparent documentation, demonstrated inclusion	deliberative and pluralistic democratic process
		Design: how affected communities have input and control over design of GI (Nesbitt et al., 2018)	not present	superficial/post design consultation	formulaic/bounded engagement e.g., menu of predetermined options	co-produced designs	design in service of community needs
		Implementation: how those affected are involved during enactment of GI programs (Quick & Feldman, 2011)	not present	basic notification	limited coordination	substantive mechanisms with documentation of addressing concerns	implementation shaped by community needs
		Evaluation: how those affected evaluate the impacts of GI (Oliveira & Pinho, 2010)	not present	documentation of complaints	commitment to periodic check ins	concrete avenues for adaptive management of planned activities	mechanisms allowing for transformation of decision-making procedures
DISTRIBUTIONS	The relationship between proposed social and spatial distributions of GI and their influence on rearranging urban value, hazards, and labor required over the GI lifecycle	**Hazard**: use of GI to influence social and spatial distributions of hazards (Nesbitt et al., 2018)	not present	intention to use GI to mitigate hazards	formulaic and context independent methods of estimating hazard reduction	analysis of causality of uneven hazard and vulnerability	pluralistic elucidation of hazard distribution, causality, and systemic impacts of GI
		Value: use of GI to influence value of urban space for affected individuals and communities (Nesbitt et al., 2018)	not present	intention to use GI to add value to urban landscape	some acknowledgement of disparities in perceived value of urban landscape, value framed using limited means	acknowledging differential perception and need of value of GI	plural framing of GI values and relationship to other social objectives and systems of managing infrastructures and lands
		Labor: Acknowledgement of labor required by GI, inclusive of planning, design, construction, maintenance. (e.g., Finewood et al., 2019, Gulsrud et al., 2018)	not present	acknowledgement of labor needs but no discussion of equity	acknowledgement of labor required throughout GI lifecycle but clear inequities present	specified pathways and mechanisms to distribute lifecycle labor benefits and address labor burdens	Addressing intersectional labor issues throughout GI lifecycle, commitment to community wealth building

important goal (Bozuwa, 2020). Structural inequalities in labor markets, however, have historically caused racialized individuals to be underrepresented in managerial professions and overrepresented in the maintenance sector (Bonilla-Silva, 1997). For GI, many have noted that GI maintenance often falls upon unpaid volunteers, reinforcing urban labor inequalities (Riedman, 2021). Urban planning in turn has a long history of labor market interventions (Scott, 1988) and has potential to influence who performs specific types of labor required by GI systems, how, and for what compensation.

The unequal distributions of urban hazards and values cannot be

separated from the racist and classist decision-making processes driving the social distribution of polluting technologies, labor, and property value (Pellow, 2017). While the distributional inequities that GI explicitly interacts with are well documented, the range of formal city led plans seeking to implement GI have not been systematically examined. Existing work has found that while some plans may have explicit goals of addressing urban inequalities with GI, they lack mechanisms to evaluate their own implementation, such as in Detroit's equity forward green roof programs (Sanchez & Reames, 2019). Thus, GI planning may be failing to positively influence the distributional equity of environmental hazards and amenities either through accelerating displacement, or through a failure to implement equity focused approaches. Efforts to mitigate or improve unequal urban conditions with GI, either through adding amenity value, or managing urban hazards, must therefore confront the systems of decision making that influence what makes places valuable, desirable, and risky to diverse and marginalized communities (Laws, 1994).

City planning has reinforced residential segregation, as well as siting undesirable land uses and facilities in minoritized neighborhoods (Trounstine 2018; Pellow, 2017), serving as a key instrument of repression of minoritized communities (Yiftachel, 1998). However, planning can also be a key site of organizing for diverse publics, seeking to equitably transform urban futures, especially with the rise of climate adaptation (Shi, 2020, Shi & Moser, 2021; Chu & Cannon, 2021) and sustainability planning (Hess & McKane, 2021). These plans often borrow from participatory planning approaches attempting to create inclusive planning processes (Lovell & Taylor, 2013). Participation alone however is insufficient to create inclusive planning, as power differentials between participants cannot be resolved through the participatory paradigm (Hopkins, 2010). In many ways planners face a paradox of urban formation – that of resolving 'top down' and 'bottom up' processes of urban formation (Batty & Marshall, 2017), which requires greater attention to the specific mechanisms used to not only produce plans, but through which plans are implemented and ultimately evaluated.

4. Conceptualizing transformative planning processes

City planning is a formal social process defining the rules for how urban systems evolve over time. Plans shape what can go where and how, presenting visions for futures operationalized through constellations of other policies. No matter how one attempts to escape the technocratic aspects of 'modernity,' planning and associated zoning rules remain important drivers of urban evolution (Batty and Marshall 2017), whereby the explicitly unequal geographies of the past are transformed into (potentially) equitable geographies of the future. By focusing on equity, urban planning can have a profound impact on urban inequality, including the distributions of environmental amenities and hazards, and ideally, transforming exploitative political and economic systems (Reece, 2018).

Based on a synthesis of the literature reviewed above, we propose a conceptual framework for evaluating the equity of formal GI planning (Fig. 1). This framework includes three major dimensions of equity: 1) how equity is envisioned, 2) the processes of planning, and 3) distributional equity. We decompose each dimension into more specified categories of equity for analysis (Table 1). The dimension of vision is composed of categories of how plans frame current conditions, their causes, and relationship with GI, along with how they define equity and justice. The procedural dimension includes how the plan itself was written, and how it specifies processes for design, implementation, and evaluation of GI. The distributional dimension includes GI's intended impact on distributions of value, hazards, and labor. More details on these categories can be found in the methods and the equity screen analysis. Through this analysis we offer a clear conceptualization of how to evaluate the equity of planning processes, and lay a pathway for further analysis of the how different types of planning appear impacted by current urban inequalities, as well as how they may lead to urban change and transformed governance. Drawing upon a diverse set of plans from 20 different US cities, we analyze these three dimensions of equity within a plan quality evaluation framework (Table 1), which guides our synthesis.

5. Data and Methods: Equity of U.S. urban GI plans

5.1. City and document selection

To understand how U.S. formal urban GI planning addresses equity issues, we reviewed 122 current city-led plans from 20 cities across the country. This research expands from a recent study examining how city plans define the scope of GI planning across the U.S., including definitions of GI and its related functions and benefits (Grabowski et al., 2022). We sought a diverse group of cities that cover all major biomes and EPA regions in the U.S. We also sought a range of cities based on size and age, and purposefully included known early adopters of GI in their planning systems (such as Milwaukee, WI, Philadelphia, PA, Portland, OR, and Seattle, WA, see Hopkins, Grimm, & York, 2018). For more detail on city selection see Grabowski et al. (2022). Within these cities we used a reproducible and iterative document acquisition process to identify current plans written or endorsed by city agencies explicitly addressing GI. Our analysis does not include plans led by community groups or non-profit organizations, or those pertaining to metropolitan regions – as we focus on the formal policies that are tied to official city budgets and programs, and not voluntary or citizen led efforts. Out of over 360 documents reviewed, our plan selection and screening process yielded 122 plans across the 20 study cities. In contrast to existing approaches examining limited plan types such as sustainability plans or climate plans (e.g., Shi, 2020, Chu & Cannon, 2021, Meerow, Pajouhesh, & Miller, 2019, Keeler et al., 2019), we identified the diverse types of plans seeking to implement GI across multiple planning levels (Dong et al., 2020). Our analysis thus provides the most comprehensive review of formal GI planning in U.S. cities to date.

5.2. Plan equity evaluation screen

Building on concepts in plan evaluation (McGuire, 2020; Lyles & Stevens, 2014; Berke & Godschalk, 2009), we used content analysis methods in combination with a novel equity screen (Table 1) based on our conceptual framework (Fig. 1), to analyze the equity of GI plans. Plans were read and coded with a collaboratively and inductively derived codebook (Supplementary Table 1), in the software package Atlas.ti (Friese, 2019). Formative codes related to different aspects of equity were consolidated into 10 specific categories of equity nested within the three major dimension of equity – vision, process, and distributions (Table 1). Our evaluation expands upon existing methods in evaluating the equity of urban planning (MIT CoLAB, 2010; Reece, 2018), which focus on inclusion and distributions, which can limit an evaluation of the overall framing of plan goals and how affected communities define equity in the first place. By including an analysis of framing and definitions, our equity evaluation screen draws upon principles in plan quality evaluation to examine how plans connect goals with objectives, implementation strategies, metrics, and evaluative strategies (Berke & Godschalk, 2009). Our evaluation also expands upon the conceptual framework presented by Meerow et al. (2019), which applied widely accepted concepts and theories around equity and justice summarized by Schlosberg (2007).

Our equity screen was used to evaluate: 1) how well each plan *envisioned* equity and justice, which includes recognition of specific characteristics, prior and ongoing harms, and needs of diverse communities, 2) *procedurally included* affected communities in the formulation of the plan, strategies for the design of policies, projects, and programs, their implementation, and ultimately their evaluation (including metrics) and 3) how plans assessed and intended to influence

current *distributions* of value, hazards, and labor (Table 1, Materials and Methods).

Each category was scored on scale of 0 to 4 with 0 representing a complete omission of addressing that category (e.g., not having a definition of equity). Generalized scores were defined as follows. A score of 1 corresponded to the category being problematically addressed, such as a mention of the importance of community inclusion, but no specified mechanisms to do so. A score of 2 indicated that caution was needed in applying the plans current formulation of equity, e.g., a desire to bring benefits of GI to marginalized communities but no acknowledgement of the potential for housing displacement. A score of 3 represented functional best practices, such as the use of design charettes for project design. Given that current best practices often fall short of issues addressed in the planning literature (e.g., the pitfalls of the participatory ideal discussed above), we were also interested in whether plans incorporated concerns and methods present in the academic discourse on transformative planning, which was represented by a score of 4. For each category, qualitative scores were assigned based upon coded content and summarized in our overall plan scoring results (Supplemental Table 4). The 0–4 scores were also assessed for groundedness by tabulating the number of coded entries per equity score both globally (Supplementary Fig. 2) and for each individual category (Supplementary Fig. 3) (Friese, 2019). We found significant differences in the number of coded entries per evaluation score across all categories. Scores were also examined for correlations with plan types and cities (Goodman-Kruskall's two-way tau, Pearson, 2020). Although our analysis focuses on green infrastructure, this equity evaluation screen could be applied more generally to any planning process.

5.3. Envisioning equity and justice

For each plan we examined we searched for explicit definitions of equity and justice. The quality of definitions was scored from 0 to 4 depending on how well it addressed distributional, recognitional, procedural, and transformative elements (Brand, 2015; Lake 2016). A score of 0 was applied if no definition was found. A score of 1 corresponded with the problematic use of the word equity or justice without any corresponding textual substance (e.g., keyword approaches or 'equity washing'). A score of 2 was applied for definitions focused solely on distributions or outcomes, but did not include procedural elements. A score of 3 (functional best practices) was given if definitions included historical context and committed to inclusion of communities in the processes of addressing them. A score of 4 (ideal) was given if communities impacted by prior planning decisions were the ones who defined how planning systems should be transformed (Gready and Robins 2019; Pellow, 2017; Gilio-Whitaker, 2019). Given that many plans utilized the words equity and justice, but did not explicitly define them, we also evaluated their use within broader and more general framing statements regarding how plans characterized the causes of current conditions and how they were related to GI (Brownill & Inch, 2019; Zapata & Bates, 2017), using similar criteria as above.

5.4. Evaluating procedural equity and inclusion

Procedural equity was evaluated based on how plans articulated mechanisms for including communities in the creation of the plan, the design of GI policies, programs, and projects, their implementation, and their evaluation (Reece, 2018; Meerow et al., 2019). Procedural categories were scored 0 if there was no evidence of inclusion. Plans were scored 1 if there was problematic superficial engagement, such as statements 'communities will be consulted' with no information as to how this consultation will take place or be documented. Plans were scored 2 if efforts were largely formulaic (e.g., telephone surveys), and partially documented (e.g., broad demographic information being presented about survey respondents), meriting caution in interpreting them as representative of the will of affected communities. Current best practices in inclusion (Score 3) include properly documented outreach to affected residents through multiple avenues, and adaptive planning, whereby community-based evaluation procedures are used to modify plans as they become implemented (Hopkins, 2010). Ideally – given that power differentials exist even in the most 'participatory' planning processes (Hopkins, 2010) – plans would go beyond participation to create inclusion that builds capacity for ongoing community leadership and the co-production of planning processes (Quick & Feldman, 2011) – which is Score 4 in our screen. Our procedural equity scores thus represent a continuum from planning 'for' to planning 'with' to planning 'by' – whereby, technical experts, planners, and city agencies go from making unilateral decisions on community needs, to becoming 'partners,' to ideally acting in the service of impacted communities.

5.5. Evaluating distributional equity of planning

Distributional equity refers to how plans address the existing and proposed *distributions* of the added value of GI (Vandermeulen, Verspecht, Vermeire, Van Huylenbroeck, & Gellynck, 2011; Nesbitt, Meitner, Sheppard, & Girling, 2018), the urban hazards managed by GI (Meerow & Newell, 2017), and the social distribution of labor required to realize and maintain GI (Finewood et al., 2019; Gulsrud et al., 2018). These categories go beyond the conceptual framework of Meerow et al. (2019), by explicitly examining the potential jobs provided by GI systems. A score of 0 was provided if there was no analysis of existing distributions and no intention to affect distributions. A score of 1 corresponded to problematic intentions to address distributions with GI without acknowledging existing distributional inequities. A score of 2 corresponded to approaches to characterizing existing and future distributions that merited caution and further analysis. A score of 3 acknowledged the contextual nature of value and hazards, as well as how they had been structured by social processes targeted by the plan. A score of 4 indicated that plans had examined the intersectional and interdependent nature of hazards, values, and labor of GI as a system affected by other infrastructure systems and planning decisions (Dong et al., 2020).

6. Results

We find systemic failure to operationalize equity principles in current US formal urban GI planning (Fig. 2). Despite the fact that GI has well documented connections to urban equity issues, city agencies and governments have generally not embedded equity or justice as a central concern of GI planning efforts in the 122 plans we studied. Over 80 % of GI plans analyzed were generally problematic or poorly operationalized in 7 out of 10 equity categories (Fig. 3). No plans achieved excellence (score 4) in any category, which refers to their utilization of using existing principles in equity planning scholarship (Reece, 2018). While some plans displayed best practices in one or more aspects of planning (~30 % of plans), no plans contained best practices across all equity categories (Supplemental Fig. 3). Plans that scored highly in some categories – e.g., plans with equity 'bright spots' – had generally weak positive correlations (Goodman Kruskall's two-way tau, Pearson, 2020) between equity categories. More robust framings of equity, did correlate with more inclusive mechanisms of community-based evaluation as well as greater sensitivity to the contextual nature of GI's value, but do not correlate with how plans address distributions of hazards or labor (Supplemental Table 3).

The vast majority of plans did not define equity or justice or use these concepts in their guiding visions and goals (Fig. 3). Although 45 % of plans examined used the word "equity", only 13 % of plans define it. Similarly, 44 % of all plans use the word "justice", but only 11 % of plans define it (Fig. 2). Portland's Climate Plan was unique in having a robust definition of justice drawing upon climate justice principles. Otherwise, the majority of mentions of justice occur within Combined Sewer Overflow plans stating they will address environmental justice without

specifying how (Fig. 3). This indicates a 'box checking' approach to meet EPA's Environmental Justice directive under Executive Order 12898, rather than a substantial vision for addressing injustice in urban planning. In a few instances, plans state that they would address the harms of prior planning decisions, but also do not say how. While some cities, including Denver, incorporate equity into the guiding visions of their plans, no cities incorporated equity into the visions of all their plans (Supplemental Fig. 3).

Best practices in procedural equity were rare across plans (6 %). 16 % of plans have functional best practices of committing to include affected communities in the early stages of planning, but these dropped off sharply in design (2 %), implementation (1 %), and evaluation (4 %). Procedural equity of creating plans did not correlate strongly with other procedural categories, indicating a substantial need for elaboration of what procedural equity means in planning GI (Supplemental Table 3).

GI Plans seek to equitably add value (70 % scoring 2 or higher) and rearrange hazards (60 % scoring 2 or higher) in urban systems. While they explicitly seek to improve urban hazard mitigation, almost no plan types besides climate plans consistently consider existing inequitable distributions of hazards (Supplemental Fig. 3). At the same time, over 70 % of plans failed or problematically addressed the relationship between GI and labor (Fig. 3). Plans that discussed labor issues, they often focused on low wage workforce development with limited opportunities for advancement in economically marginalized communities, reinforcing racist and classist hierarchies of labor. New York City, while being exceptional in specifying that its GI program will create 270 maintenance jobs, states that these will be minimum wage, non-union jobs with limited opportunities for advancement. This finding is in sharp contrast to the NYC energy efficiency jobs programs creating union positions with a clear mentorship structure and pathways to increasing certification concomitant with pay (OneNYC, pg. 63). A few cities exemplified current best practices for GI workforce development. Milwaukee GI planners sought to inclusively build wealth building by creating vertically integrated regional economic sectors around green infrastructure and water management through a 'water centric city' concept. (Fig. 3). Other cities discuss GI networks as leading to opportunities for inclusive economic growth (e.g., Denver and Baltimore in Supplementary Fig. 4). Aside from a few plans in Portland, Atlanta, and Denver, no cities discuss how increases in value may lead to undesirable outcomes, for example by leading to green gentrification or displacement, including that of houseless people.

7. Discussion: Implications for transforming urban GI planning

Despite a backdrop of systemic failure to address equity issues in US GI planning, we identified several best practices that build on existing equity planning principles (Reece, 2018). These included some plans with robust, place based, and collaboratively created definitions of equity and justice (e.g., the Portland Climate Plan) and related framings of how GI can address larger urban equity issues. There were also some plans (e.g., in Atlanta, Denver, Portland, and Seattle) that recognized the relationships between adding value and shifting risks, including the potential for housing displacement. However, no plans examined had anti-displacement strategies articulated at the time of this analysis. Lastly, some plans undertook inclusive approaches towards soliciting public input in the initial stages of planning, and these practices could be expanded to transform GI planning.

7.1. Recommendation 1: Explicitly define equity and justice

Despite decades of scholarship on the meaning of equity and justice, plans fail to explicitly define the terms. At a minimum, plans should integrate core principles of recognitional and transformative justice (Gready and Robins 2019). Recognitional justice requires recognizing the harms caused by prior planning decisions, especially those visited on groups because of their assigned identities, but is not sufficient to address issues around self-determination (Coulthard, 2014). Transformative justice requires transforming the decision-making systems (i.e., political systems) that cause harm, as those same planning systems cannot be relied upon to hold themselves accountable (Shi & Moser, 2021). Ideally, plans would undertake transformative work to address systemic environmental racism (Pellow, 2017), legacies and current practices of dispossession and uneven investment (Rothstein, 2017), and a fundamental need to address ecological genocide and Indigenous Environmental justice (Gilio-Whitaker, 2019).

Equity in planning requires an allocation of resources based on need, including the resources required to meaningfully engage in planning. Without recognizing systemic barriers to collaboratively framing equity issues, planners and scholars documenting uneven outcomes of urban planning (e.g., distributional inequities) inadvertently perpetuate racist and classist norms of exclusion from decision-making processes (Pellow, 2017). While some cities make commitments to understanding specific historical wrongs and establishing new offices of racial equity and justice (e.g., Baltimore, Chicago, Denver, Louisville), it is unclear to what extent these initiatives will affect the implementation of existing plans with pre-defined priorities. On a more fundamental level, equity and justice in environmental planning in the United States must address the legacies of colonialism and dispossession affecting Indigenous peoples (Gilio-Whitaker, 2019). Only 30 % of the cities we examined acknowledged their presence on Native land, and only Portland recognized its treaty obligations. No city otherwise discussed the need to restore Native governance. Without clear and place specific definitions of equity and justice issues, especially those addressing transforming systems perpetuating harm, plans will only reproduce the logics that have led to current inequalities.

7.2. Recommendation 2: Confront uneven development and displacement

The uneven geographies of value and risk impacted by GI cannot be separated from ongoing processes of uneven development driven by speculative real estate investment (Stein 2019; Smith, 1982). In New York City for example, resilience policies have continued to promote luxury floodplain development in some parts of the city, while many other floodplains are home to minoritized communities (Herreros-Cantis & McPhearson, 2021), mirroring contradictory patterns across the country (Collins, Grineski, & Chakraborty, 2018). To address these complexities, we must acknowledge that the distributions of urban hazards and values are deeply interdependent. As discussed above, purposefully adding value through GI is often combined with hazard mitigation, which, in marginalized communities, has been found to cause housing displacement by dramatically increasing property values, taxes, and rents (Gould & Lewis, 2016; Pearsall & Anguelovski, 2016). While some cities acknowledge this phenomenon (e.g., Denver, Atlanta, and Portland), no cities had dedicated anti-displacement strategies, despite over a decade of implementing GI plans – Although Atlanta's newest GI Strategic GI Plan has committed to studying the issue.

Recent applied research projects have identified concrete strategies to countering housing displacement by 'greening in place,' (Gibbons, Liu, Malik, O'Grady, Perron, Palacio, & Trinh, 2020), however, these practices are not reflected in current plans. The combined effect of structural racism in housing markets (Rothstein, 2017), accelerating gentrification in many cities (National Community Reinvestment Coalition NCRC, 2020), rising exposure to climate extremes (Shi & Moser, 2021), and pandemic hazards (Spotswood et al. 2022) highlights the urgency of centering equity in transformative urban planning projects.

GI can add lasting value to communities by building community wealth (Bozuwa, 2020). A community wealth approach, however, relies on strategies attendant to context and subject to local control with built in measures for genuinely affordable housing and support for social programs and organizing (Gibson et al. 2020). Conversely, plans need to consider the historical production of differential vulnerability to the hazards to be managed by GI, something that climate plans have started

to examine, no doubt due to influence from the Climate Justice movement (White, 2020). Such an approach would seek to understand and provide redress for specific historical practices that have resulted in uneven exposure to hazards like redlining, targeted disinvestment, and other infrastructure and housing policies (Rothstein, 2017), and yet care must be taken so these targeted investments do not contribute to perverse outcomes. As the extensive literature on the distributional equity of urban GI suggests, explicitly attempting to increase the spatial equity of urban GI is likely required to make it biophysically effective (Xu et al., 2022; Herreros-Cantis & McPhearson, 2021; Meerow & Newell, 2017) – however, the social processes through which GI is planned and implemented are what drive the social and spatial distributions of GI.

Much of the social value generated by GI is strongly interdependent with social distributions of labor and expertise (Bozuwa, 2020). Yet most plans we examined were silent on labor issues. Some cities, like Milwaukee with its 'Water Centric City' concept, seek to create community wealth through vertical integration of different GI oriented skillsets in planning, design, engineering, and maintenance. Such democratization and diversification of the GI labor force can be a key part of a just transition for building community wealth (Bozuwa, 2020; White, 2020). Additionally, building community wealth in turn can have a positive impact on communities' desire and capacity to engage in planning efforts, potentially creating a virtuous circle of urban greening. As an immediate step, planners and city agencies can compensate communities for participating in the labor of planning.

7.3. Recommendation 3: Use inclusion to transform planning

We find that cities across the United States fail to meaningfully include communities in the implementation and evaluation of GI plans. Despite efforts to gather input and public opinion in the early stages of planning, our results indicate a failure to create genuine inclusion (Quick & Feldman, 2011; Chu & Cannon, 2021). This is troubling given that the participatory paradigm present in urban planning across the United States is insufficient to address the deep-seated injustices present in American cities (Lovell & Taylor, 2013). One limitation of our study was in our focus on official planning documents, which does not represent community or grassroots led efforts to construct more equitable urban GI systems. For example, in Detroit a multi-year community led process has resulted in target areas for planning efforts through Detroit Future City (DFC). However, while plans say these areas should be targeted for improvement, it was not clear how initiatives were binding upon city agencies, or designed, implemented, or evaluated by affected communities. Other work on green roofs in Detroit, found that equity forward planning efforts have not delivered the spatially equity they were supposed to (Sanchez & Reames, 2019). Given a lack of meaningful procedural equity, these findings are not surprising.

This plan analysis provides a replicable framework for examining the procedural equity of plan efforts beyond official city plans and could be useful for further work on the complex mosaic governance of urban GI (Buijs et al., 2016). Making official city planning efforts more inclusive can foster greater integration of community and non-profit led planning efforts. Inclusion in planning and governance is only desirable to the extent that individuals participating in those processes can transform the systems creating inequalities in the first place (Laws, 1994). Failure to foster inclusion over generations may be behind systemic failures to engage communities in existing city agency led planning processes, as a sort of intergenerational planning fatigue and entrenched mistrust of city government (Pløger, 2021). Overcoming the perceived futility of the participatory model, as well as addressing structural barriers to inclusive planning is required to transform planning systems to equitably plan for GI.

But what does transformation through genuine inclusion mean? At a minimum, existing principles such as the Jemez principles (https://www.ejnet.org/ej/jemez.pdf) lay out a framework for inclusion that is closely aligned with the idea of Free Prior and Informed Consent (FPIC) – which has set a basic standard for consultation with Indigenous Nations and communities affected by development proposals (Mahanty & McDermott, 2013). Despite over 40 years of planning for equity (Reece, 2018), we found little operationalization of these principles in urban GI planning, and exactly zero mentions of FPIC across all plans examined. Such an omission about meaning of consent and inclusion in planning is doubly troubling, as neither the Jemez Principles or FPIC deeply engage with structural barriers to inclusion, namely that affected communities, due to ongoing economic and political marginalization, may not have the resources or desire to participate in existing decision-making processes (Hopkins, 2010).

Since existing institutions structure environmental planning in US cities (Finewood et al., 2019), including communities in transformative planning requires overcoming administrative siloes and questions of whose knowledge (Miller et al., 2008), and whose experience (Grabowski, Klos, & Monfreda, 2019), counts when planning environmental interventions. Principles of FPIC are designed to address both issues by acknowledging that communities themselves set the terms for what counts as appropriate consultation and desired outcomes. Utilizing these ideas in practice requires communities to have material and political means to enforce their systems of governance, including effective boundaries around their territories (Coulthard, 2014), and the protection of jurisdiction in metropolitan regions (Shihadeh & Ousey, 1996).

In urban systems, community-determined boundaries and governance systems rarely exist; instead, multiple levels of alienated governance intersect with power differentials to create asymmetries even within participatory processes (Pløger, 2021). These deeper structural considerations contrast with best practices in the plans we examined, whereby demographic representativeness of participants served as a proxy for community buy-in to planning efforts. This type of shallow representativeness is problematic, as it relies on the idea that partial and socially constructed identities (e.g., 'Black,' 'low' or 'high' income, 'college educated') are somehow meaningfully consistent with the varied needs and desires of individuals and communities. Genuine inclusion requires going beyond consultative representativeness, and should include commitments to transferring wealth and resources to the communities being asked to participate in planning their own futures, a necessary requisite to genuine co-production of planning processes (Quick & Feldman, 2011). Other best practices in inclusive planning include providing compensation, childcare, and flexibility in scheduling of meetings (McCullough & van Stokkum, 2021). These simple logistical steps are guided by the larger goals not only enabling the participation of affected communities but granting control over the process for their own benefit. To be transformative, dedicated resources for participation should be made available alongside the creation of governance systems that correspond to specific communities, as has started to take shape in participatory budgeting processes (Sintomer, Herzberg, Allegretti, Röcke, & Alves, 2013).

Transformative inclusion may also benefit from incorporating principles of direct democracy (Purcell, 2013; Leach, 2013). While some authors pose that there is no equity 'ideal' in urban greening (Nesbitt et al., 2018), deep attention to democratic processes poses that 'ideal' processes are those which are continuously evolving in response to the needs of their participants (Purcell, 2013). Such an approach asks us to focus on the nature and quality of relationships between institutions, communities, and individuals, including traits like trust, communication, sense of purpose, identity, and values of actors involved in implementing and caring for GI. Deepening democratic engagement can happen by expanding and improving existing practices in participatory design (Leonard et al. 2021). Community-based evaluation practices, while in relative infancy compared to planning and design, may provide a framework for robust evaluation of GI's multi-dimensional impacts. Austin Texas for example, has committed to a process of community-based evaluation of its Urban Forestry Plan – an adaptation of community forestry principles – which themselves remain contested and in need of elaborating just what is meant by 'community' (Flint, Luloff, & Finley,

2008; Matarrita-Cascante, Trejos, Qin, Joo, & Debner, 2017). Making inclusive processes successful requires not reifying uneven power relationships in urban environments based upon social constructs, such as those represented in typical discourses of 'top down' vs 'bottom up' decision making. Additionally, while the development of participatory software platforms may foster greater inclusion (e.g., Leonard et al. 2021), a focus on technologies can obscure differential access to, and fluency in, digital tools (Dantec & DiSalvo, 2013). Innovations in democratic governance are not a panacea, but a vital avenue of building collective capacity to address place based urban issues (Agger, 2021). In this sense, inclusive planning can leverage the resources of public institutions to support community led GI initiatives at local to regional scales.

8. Conclusion

Cities across America struggle to address long standing issues of uneven development, environmental degradation, and systemic racism (Cai, 2020). Existing landscapes of urban inequality have been created through historical and ongoing planning practices, the intersection of national policies and real estate markets (Rothstein, 2017), and restructuring of economic and tax policy by socio-economic elites (Noah, 2012). Even though municipalities define and operationalize GI differently, federal regulations have directly motivated most urban GI planning efforts focused stormwater management. National policies have large influence how urban GI planning takes shape, including how local communities can influence the equity of GI planning. Existing legislative mandates created by the 1964 Civil Rights Act (CRA) and administrative directives such as Executive order 12898, require federal agencies to analyze the impacts of their decisions on environmental justice communities (Agency, 2020). Title VI of the CRA seeks to create fairness in the participation and distribution of benefits and burdens from programs receiving federal assistance due to race, religion, ethnicity, or socio-economic status. Given that many city infrastructure programs receive direct or indirect federal investment, we found it surprising that there is substantive failure to address equity and justice issues. It appears that existing federal regulations and provisions are not being adequately operationalized. One bright spot in our analysis is the finding that GI specific plans are much more concerned with equity than other broader storm and sewer plans. This indicates that plans entirely focused on GI are adopting different planning logics than traditional grey infrastructure planning. This conclusion is reinforced by recent work finding that stormwater agencies adopting GI approaches are more attendant to social concerns than their non GI implmenting peers (Matsler et al. 2021c). How GI plans are implemented to address the concerns above will likely require stronger federal leadership in the context of promulgating standards for appropriate inclusion, consultation, and subsequent evaluation of the impacts of GI on diverse urban populations.

Under the current federal administration, environmental justice has received increased attention through three new executive orders mandating federal agencies to consider environmental and climate justice in decision making (Review, 2022). However, these efforts appear to be omitting deep consideration of the procedural equity required for inclusion, instead focusing on prior mapping of those communities considered 'disadvantaged' based on census data of socio-economic conditions which continue to undercount marginalized groups (Census, 2020). As we and others have found (Gould & Lewis, 2016; Hoover et al. 2021), a focus on distributional equity without procedural equity and inclusion is insufficient to create equitable outcomes. To address this gap, federal investments in infrastructure should be accompanied by dedicated funding for inclusive planning processes to address place and community specific equity and justice issues.

The 122 plans we have analyzed here represent the current state of formal GI planning in diverse U.S. cities. Amidst a backdrop of systemic failures to address equity and justice issues relevant to green infrastructure planning efforts, we find that equity is an emergent concern of city agencies implementing GI through diverse types of planning efforts. Future efforts should explicitly, and contextually, define equity and justice and use these community generated definitions to build inclusion into GI projects from plans to evaluation. City planning departments, as well as state and federal agencies working in urban settings, can address these issues by dedicating funds from infrastructure programs to build inclusive community led planning. Doing so requires centering communities as experts in the necessary procedural and material interventions required to improve their lives, with researchers and practitioners acting in the service of those communities.

How planning evolves remains a function of the political, social, technical, and economic capacities of diverse urban communities. Current national initiatives to address environmental justice must go beyond a focus on defining community needs using a-priori justice criteria and support the creation of inclusive planning processes (e.g., EJ Screen 2.0 2022). Our analysis provides an empirical basis for understanding some current promising approaches and the numerous pitfalls facing current planning efforts in the U.S. While these insights are drawn from a purposefully limited sample of city-created GI plans in the United States, their implications have global relevance for cities seeking to use GI to improve urban resilience, sustainability, and equity. As part of this broader project, we created a website with city level recommendations at www.giequity.org.

GI planning can address equity if it is transformed for inclusive governance over the life cycle of GI systems. Ultimately research must be performed with affected communities in order to understand the impact of GI planning on distributional equity. And while many urban inequalities are driven by structural forces outside the scope of GI planning, GI planners can address a number of structural forces by explicitly addressing inequality and the need for urban environmental justice.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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