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Enhancing the quality and social impacts of urban planning through community-engaged operations research

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Abstract

While inquiry in operations research (OR) modeling of urban planning processes is long-standing, on the whole, the OR discipline has not influenced urban planning practice, teaching and scholarship at a level of other domains such as public policy and information technology. Urban planning presents contemporary challenges that are complex, multi-stakeholder, data-intensive, and ill structured. Could an OR approach which focuses on the complex, emergent nature of cities, the institutional environment in which urban planning strategies are designed and implemented and which puts citizen engagement and a critical approach at the center enable urban planning to better meet these challenges? Based on a review of research and practice in OR and urban planning, we argue that a prospective and prescriptive approach to planning that is inductive in nature and embraces "methodological pluralism" and mixed methods can enable researchers and practitioners develop effective interventions that are equitable and which reflect the concerns of community members and community serving organizations. We discuss recent work in transportation, housing, and community development that illustrates the benefits of embracing an enhanced OR modeling approach both in the framing of the model and in its implementation, while bringing to the fore three cautionary themes. First, a mechanistic application of decision modeling principles rooted in stylized representations of institutions and systems using mathematics and computational methods may not adequately capture the central role that human actors play in developing neighborhoods and communities. Second, as innovations such as the mass adoption of automobiles decades ago led to auto-centric city design show, technological innovations can have unanticipated negative social impacts. Third, the current COVID pandemic shows that approaches based on science and technology alone are inadequate to improving community lives. Therefore, we emphasize the

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important role of critical approaches, community engagement and diversity, equity, and inclusion in planning approaches that incorporate decision modeling.

Keywords
Smart cities, urban planning, community-engaged operations research, problem structuring methods, systems thinking

Introduction

Operations research (OR) is a multi-disciplinary field devoted to the science and practice of improved decision-making through modeling and analytics. OR has its roots in economics, industrial engineering, mathematics, and computer science, among other fields, and has traditionally found its academic home in engineering and management. There is a long tradition of OR applications to diverse public sector areas and urban affairs and services (see, e.g., Larson and Odoni, 2007; Pollock et al. 1994). However, the OR discipline has not influenced urban planning practice, teaching and scholarship at the level of other domains such as public policy and information technology. Could an OR approach which focuses on the complex, emergent nature of cities and the institutional environments in which urban planning models are implemented enable urban planning to better meet challenges that are complex, multi-stakeholder, data-intensive, and stochastic in nature?

This question is particularly relevant and topical given the ubiquity of urban data (Batty, 2013), the complexity inherent in the urban environment (Portugali, 2012), the proliferation of technological innovation in cities and the lackluster improvement in the urban quality of life attributed to these innovations (Komninos et al., 2016). While OR has been applied to a variety of urban issues, such as transportation, housing, education, land use, and human services, as a methodology and collection of analytic methods OR is not as widely used in urban planning, or present in urban planning curricula as its impacts on operations, management and strategy might suggest. For example, a well-known textbook on OR in urban affairs (Larson and Odoni, 2007), focuses on applications that are straightforward extensions of OR domains such as routing and scheduling, dispatching and facility location, rather than applications that address core concerns of urban planning: housing and community development, transportation and mobility systems and environmental sustainability. In addition, it is less common for OR to be applied to urban problems using more qualitative methods such as action research or community-based participatory research which are common in contemporary planning. We propose that some principles of best OR practices, augmented by a commitment to community-engaged operations research, could enhance the quality and social impacts of urban planning practice and research. Our use of the term "OR" refers to a diversity of application domains, analytic methods and world-views which posit that a host of problems in diverse areas can be understood as platforms to apply a systems approach based primarily upon mathematical modeling.

Scholars such as Kaplan (2008) have recognized that OR's social impact can be magnified if the profession embraces a mindset rooted in a systems view of the world and open to a more robust approach of examining and responding to real-life challenges. However, long-standing critiques within OR that the field is incapable of addressing social issues in a fundamental and critical way (Ackoff, 1979, 1987; Rosenhead, 1981) have not in our view been adequately addressed. We argue that a narrow, restrictive view of OR that is overly mechanistic has created a mismatch between what is required to address the ill-structured nature of urban issues and what OR offers. For example, even Kaplan's championing of OR applications that can have social impact is limited by his focus on

quantitative modeling and a limited appreciation of the importance of equity and social justice in decision modeling.

Drawing from the insights obtained from the review of literature at the intersection of OR and urban planning, and taking a cue from Kaplan's insights, we make the case for a framework that broadens and enriches the conventional OR toolkit to capture the subtleties inherent in many complex systems in the urban domain. The emphasis of our treatise is not on soft OR[1] (Kotiadis and Mingers, 2006; Mingers, 2000, 2011) or a hybrid form of soft and the mechanistic form of OR (subsequently referred to as hard OR). Rather, it is on a notion of "community-engaged OR" that embraces complementary approaches known as "community operational research" (Bowen, 1995; Midgley and Ochoa-Arias, 2004; Midgley et al., 2018; Ritchie, 1994) and "community-based operations research" (Johnson, 2012; Johnson et al., 2015b, 2018) that recognizes the importance of decision modeling and model-based problem solving that privileges the perspectives and values of diverse stakeholders. The acronym "COR" will be generally used to refer to the literature denoted variously as "community-based operations research" and "community operational research."

Our paper incorporates a brief discussion of inquiries that have attempted to integrate OR and urban planning to acknowledge certain missteps in applications of OR and decision science to urban planning. We also highlight recent work in planning whose embrace of data and complexity can be quite appealing to scholars and practitioners in the decision sciences and argue that a broader, forward-looking OR mindset that embraces multi- and transdisciplinary thinking could work in concert with urban planning to support innovative theory-building and intervention design in cities. A core area of interest is creating an effective vehicle for designing solutions to complex, data-rich problems that are seen by many researchers and practitioners as representative of the promise of the smart city and big data movements. Our primary scholarly contribution is support for problem structuring, authentic community engagement, transdisciplinary approach, and acknowledgment of diversity, equity and inclusion and racial and social justice in problem formulation and solution in research and practice in order to amplify the impact of OR and decision science within urban planning.

The balance of the paper is organized as follows: *Urban planning and operations research interface* characterizes the interface of urban planning and OR with an emphasis on the value-added by OR in the urban planning profession. *New realities* reiterates the need for an OR approach that relaxes traditional modeling assumptions and enriches the OR toolkit with an emphasis on a broader, more robust menu of solution options and enhanced participation by stakeholders and communities who may not be regarded by OR researchers as central to the problem-solving process. *Conclusion* concludes.

Urban planning and operations research interface

At the turn of the 20th century, the focus of urban planning was largely physical. This typically took the form of city masterplans that encompassed the whole city—an example is Frank Lloyd Wright's Broadacre city (Wright, 1935). This mindset was the norm even after WWII, a trend accelerated by government mandated plans that were often used as a precondition for receiving tax payer dollars (Rosenhead, 2009) and by the U.S. Housing Act of 1949 that saw federal government dollars directed at urban renewal projects (Lang and Sohmer, 2000). In instances when these plans have strong OR flavor, they have typically emphasized top-down models that are heavy on the mathematics—an example is the widely referenced San Francisco community renewal simulation project (Arthur, 1966; Ernst, 1966; Greenberger et al., 1976; Robinson et al., 1965). Such an approach precludes residents from having a voice in the process. It also prevents the agencies with direct responsibility from taking ownership of the process once the consultant's contract ends.

The success of these plans and developments were however mixed at best (Hall and Tewdwr-Jones, 2010; Lee, 1973). These assessments informed the recognition that hard OR may not be robust enough to address urban planning issues which fall under the category Churchman (Churchman, 1967) labeled *wicked problems* or in Ackoff's word, *messes* (Ackoff, 1979). Rosenhead (1981) put it succinctly when he argued that the less than stellar impact of OR in urban planning could well be attributable to the mismatch between hard OR and the complex nature of urban planning issues. The shortcomings of hard OR in urban planning are even more noticeable in recent times as urban planning processes strive to explicitly address the contextual realities of the environment. This may have caused a negative perception of OR within the urban planning profession (Goodchild, 2010), a distorted view that could be addressed by embracing a more robust set of tools and approaches as advocated by Rosenhead (Rosenhead, 1981).

In addition, metropolitan planning organizations (MPOs) are known to typically have 20–25 years planning horizons, even though most of these long-term plans have not been shown to achieve their objectives. Rosenhead (Rosenhead, 1981) has forcefully argued against these long-term planning horizons on the grounds that there is very little utility to such master plans, and that a more adaptive process that could be responsive to the certainty of change over time may be more beneficial—a viewpoint shared by a number of authors (Cooper et al., 1971; Elmqvist et al., 2018). Recent work on scenario planning (Goodspeed, 2020) argues that approaches that recognize the complexity of cities, the importance of collaborative planning, the distinction between societies that are presumed to be built based on predefined plans rather than those that respond in a dynamic way to current circumstances can enable planners to creatively incorporate uncertainty and long planning horizons.

The need for a different mindset

Beyond the planning horizon are the inherent systems properties of cities. Cities typically contend with a multitude of projects running simultaneously that individually can result in better-quality housing, more jobs, and improved infrastructure. However, these initiatives can destabilize communities and result in increased inequality and reduced quality of life especially for less-advantaged community members. There is not a common understanding or mechanism by which a "portfolio" of interventions might be designed to improve quality of life for the broadest diversity of community residents. Of equal relevance to this discourse is the uncritical acceptance of "scientific," "data-driven" approaches that do not acknowledge the political economy by which those with power and privilege set the terms of engagement will result in solutions that reproduce systems of inequality and "dis-empowerment." The next two subsections address these issues.

City as a complex system. "Big data" and "smart cities" have often been proposed, and marketed, as "magic bullet"-type solutions (see popular press treatments such as Lindsay, 2010, Maddox, 2018 and Ellsmoor, 2019). Indeed, Lemoy believes, as we do, that urban models alone cannot solve these problems, and that "the main challenge is actually a question of social and political consciousness and will" (Lemoy, 2011). In addressing this issue, we do not propose a formal model or taxonomy of urban environments or believe that there is one solution or approach that can tackle all of these problems. However, we explicitly recognize the complexity of the city as a system and the difficulties of engaging the diversity of city residents and of the communities they comprise.

Contemporary discussions of "smart cities" and "big data" recognize that a technology-focused approach to city design and renovation are impoverished due to a lack of appreciation of the implications of pervasive technologies for persistent social and economic inequality. Brannon (2017) shows that databases of criminal offending can encode spaces as dangerous or not, or commercially lucrative or not, without regard to understandings of individuals as actors with their

own motivations, social context that has produced different kinds of neighborhoods, or a range of interventions that can satisfy social welfare. Amin (2016) argues that narratives of cities as vulnerable to disruption support technology-enabled risk-mitigation experiments that can disadvantage vulnerable and marginalized populations. This narrative relies on the notion of cities as essentially static and mechanistic.

An alternative view, rooted in policy flexibility and improvisation, and of dynamic relationships among various actors, can better leverage technology for urban improvement. Rogan (2019) critiques the extravagant promises of smart cities under design or development, including Hudson Yards in New York City and Quayside in Toronto (see also Lindsay (2010) description of South Korea's New Songdo), emphasizing the lack of clarity on what smart cities are, or what they will do to improve the quality of lives for the broad diversity of individuals and communities. Broussard (2018) coined the term "technochauvinism" to represent the notion that technology has all the answers to urban problems, asserting instead that technology that is poorly designed, immature, and mis-used is far more prevalent than tech evangelists assert. O'Brien (2018), in his examination of the use of 311 data based on citizen requests for services to address a wide variety of urban problems, advocates for the use of real-time data to support civic stewardship, while acknowledging spatial disparities in use of 311 and widely varying levels of understanding of the use of data for urban service delivery across multiple municipalities in Massachusetts.

Toward a people-centric planning approach. The phrase "civic stewardship" underscores the need to actively engage with community residents in finding solutions to urban problems. The past few decades have seen a movement in this direction given the increased citizen involvement in urban planning (Wilson et al., 2017). This push to include citizens in the deliberation process is not new (Arnstein, 1969). Cooper et al. (1971), for example, advocated a similar approach approximately 50 years ago, where they emphasized the centrality of a bottom-up process anchored on a citizen information system. Our interest in this approach is in an active, engaged citizenry—shaping, influencing, and driving not only the implementation of the planning process but more importantly its conceptualization.

The key word here is "engaged" given its relevance in a democratic process. Though seldom used in the same sentence, we contend that democracy and urban planning have much in common given the functional definition of democracy—striking a balance among the competing needs of different groups of individuals within a society. This necessarily implies a multi-stakeholder situation. This situation begs the question as to the effectiveness of hard OR and how to ensure that voices relevant to the discourse are not drowned out. Consequently, a value-free OR that recognizes only the primacy of efficiency and/or effectiveness at the cost of other salient factors such as equitable representation will fare poorly in addressing urban planning problems. An analogy that comes to mind is a greedy algorithm that naively uses a narrowly defined search criterion in the optimization process.

Subscribing to a people-centric process is particularly relevant to housing and community development problems. These challenges, from the perspective of operations research, are multifaceted, technically demanding, and require action in the face of limited information and/or resources (Killemsetty et al., 2021). As described by Johnson (2012), decision modeling approaches to housing and community development include descriptive models to learn more about policies, systems and phenomena, prescriptive models to generate recommendations for interventions that measurably improve on the status quo, and decision support systems that incorporate databases, decision analytics, and spatial data to augment human decision-making. Essential to each of these approaches is a commitment to go beyond economic efficiency as a primary decision criterion to include social impacts of housing interventions through adaptations of social benefit-cost analysis, to include objectives that quantify notions of equity, to ground decision models in

formal value structures, and to ensure that decision models reflect the needs of less-advantaged stakeholders.

Broadening the operations research toolkit

Operations research is commonly taught and practiced in a way that reflects its identity as an applied engineering discipline that privileges quantitative analytic methods and that does not provide an explicit role for community members as co-creators. The discipline is typically presented from a positivist perspective that reifies objectivity and scientific precision and a technocratic, top-down approach to problem identification, formulation, solution, and implementation. This would seem to run counter to planning's contemporary emphasis on community engagement, social justice and mixed methods as ways to enlarge a traditional focus on design and prescription for physical land uses and the social interactions and perspectives that generate social value for diverse groups.

While a number of OR projects with tangible benefits to disadvantaged or marginalized populations have been documented Kaplan (2008), failures of urban planning in theory, concept, and practice (Nussbaum and Spessot, 2017) are many. These include fragmented municipal governance, plans that accommodate and reinforce racial and economic segregation, abandonment of fully-funded visions of mass transit, urban housing, and social policy programs (Gerckens, 2000), and limited technical expertise of public planners, poor understanding of planning fundamentals by key stakeholders, and interference in the planning process by decision-makers (Nussbaum and Spessot, 2017). To address these issues, we make the case that some *principles of best OR practices*, augmented by a *commitment to community-engaged operations research*, could enhance the quality and social impacts of urban planning practice and research. By "community-engaged operations research" (Johnson, 2019; Johnson et al., 2019), we mean an amalgam of "US-style" community-based operations research (Johnson, 2011; Johnson et al., 2015b) and "UK-style" community operational research (Midgley and Ochoa-Arias, 2004; Midgley et al., 2018). This approach enriches conventional notions of problem identification, modeling, analysis, solution, and implementation that reflects the centrality of community stakeholders and that ensures a commitment to meaningfully engaging with these communities.

Integral to this approach is the values concept. To determine the best use of physical and social infrastructure, capital and resources to enable the ideal built environment, urban planners must articulate the values by which competing priorities may be balanced and develop prescriptions by which numerous uses can be prioritized and developed to improve social objectives. OR can assist planners in making transparent and quantifiable values that are inherent in the political planning process. It provides a new way to understand how values are negotiated. This can be done through problem structuring methods, value-based decision modeling and meaningful community engagement. Problem structuring methods (Smith and Shaw, 2019) are responses to problems that are messy, ill-defined, subject to substantial uncertainty, and even disagreement as to what the "real" problem is. PSMs build models of situations, reject simplifying assumptions, and explore systemic or foundational issues that can confront historical barriers and inequities.

Finally, PSMs recognize that problems may be understood differently by different people. Value-based decision modeling is an approach to OR that spans the problem formulation, modeling, and solution process and puts values of diverse stakeholders at the center of the problem-solving process, in the spirit of Keeney's value-focused thinking (Keeney, 1992, 1996). This ensures a congruence between the needs and perspectives of those who want to solve a problem—who may have deep knowledge of the problem context but not of analytic methods—and those who seek to devise solutions—who may have deep knowledge of analytic methods but not of the problem context. Meaningful community engagement (Ufua et al., 2018) can be defined as "enabling people from local communities to have a substantial input into framing both the issues to be discussed and

potential actions to address them," in this way ensuring that the needs of community members—a particular type of stakeholder not always at the center of empirical problem-solving in the tradition of public-sector OR—receive appropriate attention.

This way of thinking was demonstrated in Johnson et al., 2015b work on the post 2008 Great Recession that triggered a housing crisis in the United States. Elements of the study include a systems approach to modeling, an explicit connection between values and objectives, policy "levers" (decision variables and decision alternatives) and quantities that characterize these levers (coefficients of decision variables and constraint values; attributes of decision alternatives), and a deep and subtle understanding of "optimization" in a multi-objective, multi-stakeholder environment. The authors also emphasized the importance of diverse approaches to decision modeling represented that can bridge the gap between theory and practice: the largely qualitative problem structuring methods approach to make sense of messy problems including, for example, value-focused thinking, as argued by Keisler (2012), and the largely quantitative analytics approach to connect data with insights for practice (Raynard et al., 2015).

New realities

In this section, we discuss innovations in urban data science and analytics that are broadening the potential of operations research and urban planning to improve the quality of life in urban communities and how these innovations can become part of mainstream practice.

Recent developments

Perhaps the most significant development in urban analytics has been *data ubiquity*. As a result of sensors and monitors in public and private spaces throughout cities, routine storage of data associated with traditional services (e.g., public transport) and e-government services (e.g., 311) and data associated with internet and communications technologies, huge volumes of data are available for practitioners and researchers who wish to learn more about how and why people in urban spaces make the residential, employment, traveling, consumption, and leisure choices they do. These data may be available through municipal data portals (e.g., Analyze Boston; https://data.boston.gov/), nonprofit and university data portals (e.g., Boston Data Portal; https://www.northeastern.edu/csshresearch/bostonarearesearchinitiative/boston-data-portal/), open APIs to social media (e.g., Twitter, https://developer.twitter.com/en/docs) and by request to private firms.

These data, whose potential has been recognized for more than two decades, had led some to declare that the internet, and the data contained in it and services enabled by it, were independent of government control (Barlow, 1996) and made possible innovations in data science and data-driven internet products and services that were not reliant on traditional norms and processes of science (Anderson, 2008). Recent controversies with unauthorized acquisition by Cambridge Analytics of Facebook data used for analysis that likely influenced the outcome of the 2016 U.S. presidential election (Kaiser, 2019) and improved understanding of how data and algorithms can be misunderstood and misused (O'Neil, 2016), especially in ways that hurt disadvantaged and marginalized groups, especially communities of color (Abebe et al., 2020) have been well-covered in the academic and popular press. Johnson (2015) has in addition cautioned that mission-based and community-focused nonprofits are less likely to take advantage of large datasets and widely available analytic methods and software and that these community-based organizations have specialized needs for data analytics and information technology that are not always well-served by data and service providers and universities that train community-focused practitioners.

Nowhere is this data proliferation more prevalent than in transportation. Geotagged data, for example, reveal a wealth of information including satellite enabled global positioning system (GPS)

traces that provide rich breadcrumbs on travel patterns and on the locations people frequently visit. The three biggest ridesharing companies—Uber, Lyft, and Didi Chuxing—each generates hundreds of terabytes of data daily. These content-rich data, given their spatial-temporal nature provide detailed information at the level of individuals that could subsequently be used to provide insights on aggregated travel behavior pattern.

Use cases

Given this data deluge, can OR, specifically COR, be used to resolve the virtually intractable nature of urban issues? We respond by discussing three projects, one to formulate localized responses to the housing foreclosure crisis, the second to assist economic development professionals choose appropriate community-level initiatives and success metrics, and the third, to manage community revitalizations challenges specific to shrinking cities. These projects use principles of community-engaged operations research to identify stakeholder values, formulate decision models, and generate solutions in consultation with stakeholders.

Foreclosure crisis. One response to the housing foreclosure crisis of 2007–2010 was to use federal funds from the Neighborhood Stabilization Program to support community development corporations' (CDC) efforts to acquire residential properties at risk of foreclosure or at various stages of foreclosure. These properties, if successfully purchased, could be rehabilitated and re-purposed for re-sale to owner-occupants, or managed by the CDCs themselves as rental properties. While CDCs often have great capacity to identify, secure funding for, acquire and redevelop properties, they have less experience in choosing from a wide range of acquisition alternatives which subset of properties to pursue, the scheduling of these acquisition efforts, as securing funding and resources can be time-consuming, and choosing what portions of their service areas to concentrate on, all to optimize social impacts. Working with four CDCs in the Boston metropolitan area, a team of researchers applied a variety of analytic methods to formulate and solve decision problems related to community-based foreclosure response. In one project (Keisler et al., 2014), researchers engaged with CDC staff to determine what organization values were associated with their strategic goals, and how these fundamental values could be linked, in a causal way, with a range of potential community-level interventions. The resulting structures, based on Keeney (1992, 1996) value-focused thinking process, generated a number of insights. First, the configuration of the values structures—the nature of the fundamental objectives, means-ends objectives, and decision alternatives—differed greatly across CDCs and reflected their specific local housing markets and community priorities. Second, values structures could be used for simulation exercises, in conjunction with CDC professionals, to show how different understandings of stakeholder priorities could be used to identify most-preferred development scenarios. Third, learnings from values structures could be aggregated across CDCs to understand what types of objectives are most salient to various CDCs and how these objectives relate to CDC business models and theories of change.

In another project (Johnson, 2012), researchers addressed a conundrum often observed in CDCs: CDCs may express a desire to act "strategically," without conveying, in quantitative terms, its meaning, or an ability to assess the policy and planning tradeoffs associated with this concept. Working closely with a CDC in the city of Chelsea, MA, they quantified the notion of "strategic value" in acquisition and redevelopment of foreclosed properties, using principles from facility location models and multi-attribute choice functions. The resulting strategic value functions reflect, alternatively, the viewpoint of residents, who value proximity to local amenities and distance from local dis-amenities, and viewpoint of CDCs, who take a more strategic view of local development and thus value all amenities and dis-amenities. A primary finding from this modeling effort was that, in the absence of decision modeling, current CDC practice represented a social loss of up to 69% as

compared to potential acquisitions that optimize strategic value. These projects and other parts of the same research effort, summarized in Johnson et al., 2015b, embody the notion that decision science-based responses, if formulated in conjunction with community stakeholders who might not have specific training in data or decision analytics, could generate important insights regarding how to deploy limited funds and expertise to support community change.

A similar approach was inspired by the work of local community economic development professionals in Main Streets organizations to choose specific local interventions, such as community fairs, or sidewalk sales, or building renovations, to make their communities more attractive to local businesses and welcoming to residents and visitors. The motivation is that, while Main Street professionals are excellent at implementing specific local projects and evaluating the impacts of their work, they are less-experienced at using a systems-type approach to identify a wide range of potential community interventions—including ones never before pursued—from which to select a few for focused efforts, and similarly to identify a wide range of performance metrics from which to select projects that balance tractability and analytic insight. Using problem structuring methods, Johnson and Jani, 2016 have employed a novel cross-case analysis to identify most-preferred local economic development alternatives and performance metrics that provide local Main Streets managers, and administrators and the city local economic development agency, with flexibility to determine what supports to provide local businesses and what performance metrics to report to their city funders to assess local economic development success.

Community revitalization for shrinking cities. Johnson et al. (2021) research on revitalizing communities in shrinking cities was inspired by the special challenges of communities, cities and regions facing decline, shrinkage, and physical distress. Traditionally, planners use a variety of tools and incentives to encourage land uses that accommodate changes in populations, infrastructure, and activities to maximize quality of life and social and environmental sustainability. These are generally designed for growing cities and politically and socially active communities. Since many regions face significant disparities in social supports, financial resources and quality of life, use of these tools is thus problematic. This work describes a new approach to citizen-engaged, community-focused planning methods and technologies rooted in operations research and spatial decision support. Examples of this approach include the development of neighborhood-level investment strategies that reflect the varying ability of communities to respond to infrastructure investments (Johnson et al., 2014), and parcel-level strategies for creative re-use of vacant land for stormwater mitigation, urban farming, potential development, and blight elimination that balance objectives that measure the land area devoted to these competing land uses (Johnson et al., 2015a). This project is motivated by a desire to provide planners with analytic tools for local interventions that augment their abilities to solve challenging problems in community revitalization using methods commonly provided in graduate training in urban planning.

Taking stock

The discussion of community OR by Johnson et al. (2018) is appropriate at this point. The authors asked: "is there something that differentiates Community OR from other forms of OR, beyond the broad idea that it involves applications to community development?" They subsequently answered the question in the affirmative and made the case that meaningfully engaging with the community is central to community OR while acknowledging the subjectivity of the word "meaningful" or in the definition of a community. The authors posit that two key features are needed for an approach to pass muster for being classified as community OR: intervention for desired change and the use of modeling with the modeling seen as a trait, passed on to, community OR by its parent—OR. In addition, the authors deliberated on four salient areas of continuing controversies in the field, three

of which have particular relevance to the present discourse—whether COR should be political; whether it should be grounded in systems thinking and if it offers an enhanced understanding of practice that could be useful to the broader OR field. With regards to the first, the authors contend that COR is inherently political in nature given the interwoven nature of political and methodological concerns. On the second, they assert that OR and systems thinking represent two overlapping communities that can benefit from learning from each other. We believe that an affirmative answer to the third is relevant to fields outside of OR, including urban planning.

The descriptions of the authors' previous studies and the examination of principles of community OR, provided above, show that innovations in OR that are salient to urban planning are less about the physical domain (innovations in technology and data and decision analytics) but more about communities' contextual realities. These innovations also embrace learning across disciplinary boundaries—not just diverse analytic methods that may be combined in a project with no real integration (multidisciplinarity), but multiple approaches that are integrated across all stages of a project (Max-Neef, 2005). Finally, this approach may embrace data ubiquity, though without a somewhat uncritical acceptance of solution approaches rooted in quantitative data analysis observed in much contemporary data analytics.

This thought process is particularly relevant in addressing the issue of diversity, equity, and inclusion in the decision sciences, both from the perspective of the profession and the discipline (Johnson et al., 2019), with the dual goals of better understanding the current status of diversity among practitioners, and enlarging the range of models, analytic methods and interventions commonly used by researchers. For planners, the importance of this work is that it may extend planning's emphasis, in recent years, of reviews of past work and framing current initiatives in terms of social justice and anti-racism (ACSP, 2020a, 2020b), to address model-based interventions in urban domains where issues of equity and social impact are at the center. Such thinking could influence, for example, where and how retail stores for legal cannabis may be located, how response planning for disaster response can ensure that at-risk communities can ensure that they receive the same timely and high-quality services as communities often seen as more deserving or privileged, as well as issues of housing and community development described above. This broader way of thinking is useful in that it explicitly deals with the issue of boundary critique (Ulrich, 2000) and poses the question: what might decision modeling look like if people, social justice, and critical perspectives were at the center of the inquiry and practice? As the response by Black faculty in the Association of Collegiate Schools of Planning (ACSP) to the society's recent statement on social justice makes clear (ACSP, 2020b), there is no agreement on how seriously the planning discipline takes these concerns.

We would like to mention that this form of thinking is not restricted to the examples provided in the previous paragraph. Even seemingly innocuous problems such as finding parking spaces could quickly snowball into virtually intractable ones. Fabusuyi's research on designing and implementing a smart parking application provides a canonical example of such a situation (Fabusuyi and Hampshire, 2017; Fabusuyi et al., 2014). The parking study encountered two key challenges: problems related to data quality and interoperability created by the unique environment in which the smart parking application was deployed. More important than data interoperability issue was the need to address a conflict between the technology solution and the contextual realities of the environment in which that solution will be implemented (Fabusuyi et al., 2013). This observation underscores the perception that smart city solutions, particularly those touted as "one size fits all" tend to be value free and devoid of the contextual realities of the environment in which they are implemented. Individuals that subscribe to this reductionist mindset, described by Green (2019) as "tech googles," perceive cities as "complex, normative, and eternally agnostic political decisions as reducible to objective technical solutions." The quote supposedly attributed to Mark Twain—"To a man with a hammer, everything looks like a nail." is particularly apt in this instance.

Applying lessons learned: toward a richer operations research framework

Recent critiques of the big data and smart cities concept, in the popular media (Cecco, 2019), practitioner-focused media (Rogan, 2019), and scholarship (Brannon, 2017) have brought into question the inevitability and social benefits of private sector-led and tech-driven investments in urban areas. Komninos et al. (2016) echoed these concerns by arguing that despite the proliferation of technological deployments in the urban space, only incremental improvements in performance have been documented. To address these shortcomings, we endorse an emphasis on smart communities as distinct from smart cities (Azahara, 2017; Gurstein, 2014) and a commitment to community data analytics (Johnson, 2015) and community-engaged operations research. This is an explicit rejection of an inflexible notion of smart cities and big data that sees urban areas mostly as promising test-beds for tech-driven innovations that appear to demonstrate an unwillingness to explore social, spatial, economic context for interventions, that ignore the needs of diverse stakeholder groups, especially lower-income communities and communities of color, and do not accommodate or respond to the complex relationships between the built and social environment that determine quality of life for residents.

By designing theory-rich, model-based, and data-aware interventions with and for the benefit of localized communities, especially those comprising disadvantaged and marginalized populations, we can generate policy and planning principles, guidelines, and prescriptions that best leverage the strengths of OR and urban planning to transform urban spaces and living experiences to benefit the broadest diversity of urban residents. Thus, we argue for a robust hybrid framework that broadens and enriches conventional engineering design principles to capture the subtleties inherent in many complex systems in the urban domain.

We take the view that long term solutions to these challenges must address the needs and reflect the values of the communities of interest. Specifically, does a given solution reflect the needs of the community, or are we solving the wrong problem—colloquially referred to as the "Type III" error (Kimball, 1957)? Which stakeholders have tended to dominate conversations about services and needs? Which stakeholders have not traditionally had their voices heard? How can we design data- and technology-aware interventions and processes that reflect different priorities or versions of truth for each stakeholder? How can we move away from a reductionist mindset to an emergent one that is better suited to address the complex, interconnected nature of urban issues? These questions require a framework robust enough to conceptualize and design innovations that make explicit consideration of the context in which these innovations will be implemented.

There are some themes we have found useful as organizing concepts for a new perspective on operations research and urban planning, especially as they relate to contemporary interests in smart cities and big data. First, *values are essential*. We believe that if researchers and practitioners do not identify the goals they wish to achieve and if local stakeholders do not play a central role in identifying these goals and objectives, it is far less likely that any proposed intervention will be successful. Second, *we must distinguish means from ends*. Data are crucial to understanding diverse aspects of communities, and systems and technologies can broaden the range of services that can be provided to communities, but why might we make these investments in data, models, and technologies? Who will benefit, and how, and how are these benefits likely to be distributed across stakeholder groups and geographies? The most meaningful focus on data is not how "big" it is, but how we negotiate the tension between "data-driven" and "problem-driven" analysis. Third, any model driven intervention must be rooted in a commitment to *meaningful engagement of communities*. It is our belief that communities, more often the object of policies, plans and interventions than the primary actor, that must play a central role in agenda-setting, problem formulation, systems development and solution implementation to ensure successful outcomes. Fourth, interventions must confront *administrative and technological barriers* to application of decision analytics: cities

face real difficulties in the use of decision models and decision support systems to rigorously formulate, solve and evaluate decision models. Fifth, interventions that reflect the model-based systems approach typical of OR and decision science must center issues of *diversity, equity and inclusion and racial and social justice*. Finally, developing approaches that properly address the complexity of contemporary urban problems requires *integration of diverse disciplinary approaches*.

Without being unduly prescriptive, we now present a framework for smart cities problem-solving that adapts analytic approaches of operations research and embodies the three core principles of problem structuring methods, value-based decision modeling and meaningful community engagement that can be understood as comprised of five steps (Johnson et al., 2021). The first of these is community engagement for *problem identification*. This step includes identifying stakeholder groups, with an emphasis on disadvantaged, underserved, or marginalized communities, and initiating conversations that support a critical perspective on the problem to be solved, the social context within which the problem is situated, and the range of problem-solving approaches under consideration. The second step is *values elicitation*. Here, the goal is to better understand the relationship between problems that are presented to be solved, or alternatives from which a most-preferred course of action is to be selected (alternatives-focused thinking), and a more organic association between stakeholder values, alternative courses of action that are causally associated with values, and decision attributes that are logically associated with values. Values elicitation can result in the choice of a specific objectives and specific policy and planning instruments to be used, adapted or constructed.

Next, the *data collection and analysis* step encompass meaning-making from quantitative and qualitative data, primary and secondary data, and spatial as well as non-spatial data, and diverse analytic methods. This step should involve multiple stakeholders, especially those without traditional expertise on or exposure to data for planning and address descriptive and exploratory analysis using a variety of methods, and multiple analytic methods, embracing, for example, traditional parametric statistics as well as non-parametric approaches drawn from data science. The fourth step is *examination of the solution space*, using a variety of approaches to generate insights, policies and prescriptions. Such approaches may be rooted in classical prescriptive OR methods such as mathematical programming, decision analysis, stochastic processes or simulation, or newer methods rooted in data science, artificial intelligence or primarily qualitative "soft OR" methods.

The last step is *evaluation and impact assessment*, in which analysts, working with stakeholder groups, will attempt to determine if the modeling results—which may reflect multiple sets of values, assumptions and analytic approaches—represent potential Pareto improvements upon the status quo. Ideally, this step would incorporate implementation of model-based solutions in the field to determine the social impact of the solution process. In either case, it is likely that insights from this stage will motivate improvements to previous stages in the solution process and another round of problem-solving.

Conclusions

In this paper, we have assessed the history of operations research as it has been applied to problems in urban planning and we make the case that there are opportunities for operations research and urban planning professions to collaborate more closely. These opportunities are numerous, including instances where diverse communities and stakeholders stand to gain or lose through resource allocation decisions, where there are multiple competing objectives, where communities must play a central role in identifying, formulating and solving challenging problems that directly affect their well-being, and where uncertainty and a long planning horizon are central to the understanding of the problem to be solved. Such collaborations can have their greatest impact by

being grounded in community engagement, use of appropriate modeling and analytic methods, a thorough appreciation of the importance of diversity and social justice, and can result in new and innovative ways that need not sacrifice analytical rigor.

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Notes

1. John Mingers (Mingers, 2009) defines soft OR as structured but non-mathematical approaches including cognitive mapping, soft systems methodology (SSM), and strategic choice approach (SCA) that are well suited for tackling wicked problems.

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