The Prospects of Artificial Intelligence in Urban Planning

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Abstract

Due to the availability of big data and increased computing power, the presence of artificial intelligence (AI) has grown substantially over the last decade. Urban planning has been slow to recognize the benefits of these emerging technologies, and therefore, trail other disciplines that are innovating their decision-making and increasing productivity. While algorithms and automation are increasingly prevalent in urban processes, their applications within urban planning processes have been much less examined. We aim to better understand how urban planners can use AI effectively while at the same time being cautious about inequitable outcomes generated by past plans and decisions. Urban planning anticipates and guides and future physical and social conditions of communities, and therefore should benefit from improved analytical models enabled by AI. However, increased roles of AI have also appropriately elicited concerns that AI reproduces racial bias, further deepening "digital divides," infringes on privacy, and does little to address the "wicked problems" often at the heart of complex social issues. This paper describes a research approach that will be used to understand the prospects of AI in urban planning.

Introduction and Background

Over the past several decades, urban planning has considered a variety of advanced analysis methods with greater and lesser degrees of adoption and success. Geographic Information Systems (GIS) is probably the most notable, with others such as database management systems (DBMS), decision support systems (DSS), planning support systems (PSS), and expert systems (ES), having mixed levels of recognition and acceptance (Kontokosta, 2018; Yigitcanlar et al., 2020). The adoption of GIS, some will argue, has been primarily related to its cartographic capabilities and less for sophisticated spatial analysis techniques. Advances in information technologies have moved very slowly in the field of urban planning while revolutionizing other domains, such as financial services, healthcare, and consumer goods and services. Baidu, Amazon, Netflix, Google, and other companies have invested significantly in these technologies to gain insights on consumer behavior and characteristics and improve supply chains and

distribution. Likewise, urban planners should capitalize on these technologies to gain new insights into and efficiencies for the communities they serve.

This is an opportune time for planners to consider the application of AI-related methods given vast increases in data availability, increased processing speeds, and increased popularity and accessibility of AI methods. Research on these topics by urban planning scholars has been increasing over the past few years, however, there is little evidence to suggest that the results are making it into the hands of professional planners (Batty, 2018, 2021). Some academics propose that planners shorten the time frames at which they plan to better overlap with such advances in cybernetics and urban operations research (Batty, 2021). Others contend that planners should use the ubiquity of data and advances in computing to enhance redistributive justice in information resources and procedural justice in decision-making among marginalized communities (Goodspeed, 2015; Boeing et al, 2021).

This paper outlines our approach (i.e., research project) to understand the prospects for AI in urban planning. Our project will directly connect academic researchers and planning professionals to evaluate the balance between these futures of AI in planning and build frameworks for evaluating appropriate AI applications. We are organizing a multi-disciplinary network of expertise, both academic and professional to 1) identify the urban planning and decision-making processes with the greatest potential to utilize AI methods 2) design several pilot studies that will be used to develop and test these AI-related planning applications, and 3) pay special attention to the equitable deployment of these AI methods.

AI provides tools for making inferences about what people want or will choose to do. For example, recommender systems help to overcome human limits on attention. At the same time, however, AI tools are themselves limited by the data (predictors and choice outcomes), and by modeling assumptions. It is essential to identify both how AI tools can ameliorate attentional limits and behavioral biases in urban planning, and also recognize how AI tools are susceptible to incorporating these factors

into their design, resulting in similarly biased AI-based recommendations. Our approach will attempt to identify these factors through literature review, survey research, and interactions with professional planners from Arlington County, VA.

In urban planning applications, human expert planners bring significant domain experience to bear, while AI methods can bring computational power to consider big data and innumerable alternative plans. Human-AI interaction is necessary to combine both capabilities. However, two fundamental "black box" problems arise. First, artificial intelligence is relatively opaque from the perspective of human users. AI algorithms supply useful results, such as finding novel latent structure in otherwise difficult to comprehend data. However, the algorithms typically do not provide any justification or rationale for the results. Users of these algorithms are therefore faced with the decision of whether to accept the results at face value only, without the ability to question or understand the underlying process. Data gaps are also an issue. If the data being used does not represent the entire community, the outcomes and decisions will be biased. Transparency and traceability, while ensuring data privacy, are important. New "Explainable AI" methods are needed to enable analysts to peer inside the algorithms and gain some appreciation for how the analytical results were discovered by the algorithm, the process trail, analytical provenance, and data support.

This research is a partnership between Virginia Tech, the American Planning Association (APA), and Arlington County, Virginia's Departments of Community Planning, Housing and Development (DCPHD Planning Division) and Technology Services (DTS). The research team consists of university researchers in the areas of urban planning, computer science, and behavioral economics (Virginia Tech), the national professional organization for urban planners (APA), and our community partner for the project, Arlington County DCPHD Planning and DTS. Each of these organizations is represented on the team and contributes expertise related to urban planning and artificial intelligence. Our approach is structured to draw upon a rich pool of planning expertise across the planning profession as well as local

expertise. This includes drawing upon the knowledge of APA members as a source of ideas to be explored with our community partner. The objective is to work with planning experts to identify the human processes that may lend themselves to artificial intelligence in a variety of forms.

Methodology

While most discussions on AI suggest that (at least for now), AI will mainly serve to assist with specific tasks and processes instead of completely replacing the human role, the market for advanced tools that automate traditional planning tasks and processes (such as development review and zoning revision or administration) is expected to grow rapidly. Planners will need to adjust their skillsets and learn how to work with these emerging AI tools and applications. We expect that the planner will be an irreplaceable expert given the complexity of urban and regional spaces. Therefore, our primary research questions are 1) what urban planning functions are most suitable for augmentation with AI-related technologies and 2) how can these technologies be applied for more efficient and equitable outcomes? Candidate functions will be identified through a process discussed later in this paper and prototype AI approaches will be developed, implemented, and tested for a selected set of urban planning functions in the following phase.

Our process contains six steps to gather a range of background information that will guide our interactions with professional planners (referred to as "customer discovery"). By doing this we are better able to anticipate areas of AI application and use this information to prompt planning experts as we document their processes. Figure 1 shows the six activities that will be used to gather and synthesize data on both planning needs and AI methods. Prioritization refers to the final identification and selection process for the planning tasks targetted for AI application design.

Figure 1. Elements of "Customer Discovery"

LITERATURE REVIEW   APA AI FORESIGHT   SURVEY OF APA
                      GROUP   MEMBERSHIP

WORKSHOPS AND   INDIVIDUAL   SYNTHESIS AND
FOCUS GROUP   INTERVIEWS   PRIORITIZATION
DISCUSSIONS   (ARLINGTON
(ARLINGTON   COUNTY STAFF)
COUNTY)

In our case, "customer discovery" consists of hypotheses about problems faced by urban planners, features and solutions that might address those problems, and the processes and rules that a new solution would need to follow to be accepted. These hypotheses will first be tested through interviews with professional planners. Through these interviews, we will build a base of "facts" about planning functions and the workings that support or oppose their hypotheses. Those consistently opposed will be discarded, replaced, and retested in an iterative process.

We will be implementing a "Design Thinking" approach to catalyze AI innovation in the urban planning sector by facilitating customer discovery. In the first phase, the literature review concerning AI and urban planning highlights the state of the practice and identifies the most promising areas for investigation. These will be formulated into several candidate applications following the customer development framework. A survey of urban planners (APA membership) will address our research questions and identify planners willing to participate in more intensive focus groups and interviews (see

Appendix 1). In this phase, interviews will also be conducted with staff in the Arlington County Planning Department, our community partner on the project. These interviews and the information extracted from them are critical to this project. This information will be synthesized with survey results to identify the specific urban planning tasks to "match" with appropriate AI methods. Ultimately, one objective is to make the outcomes transferable and scalable to planners and planning organizations across the country.

The first part of our preparatory research includes a systematic review of the literature that will provide an overview of scholarship pertinent to our research questions. Through a comprehensive search, we will identify and critically appraise publications on the topics of "urban planning," "planning support systems," "knowledge-based systems," "decision-support systems," "artificial intelligence," "machine learning", and "automation." Publications will be targeted from disciplines allied with urban planning, however, some may be on general topics of information technologies, information processing, big data, data analytics, and automation and AI ethics due to the limited literature specifically on AI for urban planning practices. The goal is to deliberately document, critically evaluate, and summarize all of the scholarship identifying planning functions with potential artificial intelligence approaches.

Planner as Expert

The following literature review represents the first dimension of research we are exploring, that of the planner as an expert. For this, we searched for publications on the topic of artificial intelligence applications to six major topics in planning: zoning, permitting, sustainability, transportation, water and waste, and urban design. As part of our customer discovery process, we were interested in the role of the domain expert (i.e., professional planners) and found that it varied considerably among the articles we reviewed. The continuum includes, 1) research that serves as primarily as high-level technical thought leadership for practitioners, 2) research in which the authors at least tacitly state the study's benefits for planning experts, 3) research in which the authors demonstrate an understanding of

planning expert workflows and tailor their inquiry and solutions based on that knowledge, 4) research that employs experts directly to validate methodologies, and 5) research in which the authors engage in iterative collaboration with planners.

The first set of studies is the least in tune with practitioners' needs and workflows. While the authors focus on topics that are in the same domain and theoretically relevant to planning experts, this research tends to be highly technical, highlighting the best ways to optimize planning-relevant processes like protected area zoning, energy consumption monitoring, and designing transportation networks without much acknowledgment of how the innovative proposals would be implemented in typical planning departments (Li et al, 2011; Nosratabadi et al, 2019; Chui et al, 2018; Król, 2016). Li et al (2011), for example, propose a method for zoning protected natural areas using ant colony optimization, along with single-year coupling and merging-year coupling strategies to incorporate urban cellular automata. While this is a planning-relevant project, the authors make little mention of planning experts except to say that for the suitability analysis, "The weights for each variable should be decided according to expert experiences and domain knowledge" (Li et al, 2011 p. 585). Similarly, Chui et al's (2018) paper that proposes a "hybrid genetic algorithm support vector machine multiple kernel learning approach (GA-SVM-MKL)" to carry out non-intrusive load monitoring (NILM) for 20 different kinds of electric appliances does not make any significant mention of practitioners who are involved in energy sustainability planning (p. 1). The authors note that "more attention needs to be devoted to the work in progress undertaken by key stakeholders involved in efforts geared toward optimizing electricity consumption" (Chui et al, 2018, p. 16). In general, this group of studies is so focused on identifying state-of-the-art techniques for planning applications that they fail to develop any discernible relationship with experts or delineate concrete ways to translate everyday experts' processes to technological solutions.

The second common type of research on artificial intelligence applications for urban planning are studies in which the authors take care to be slightly more aware of experts, and particularly aware of the need for the outcomes of their research to benefit practicing planners. Several articles on artificial intelligence in zoning exemplify this approach, as the authors write that their research attempts to reconcile the differences between the functional zones (i.e. how people use space) and the required or legal zones in a particular area (Shen et al, 2009; Soto & Frías-Martínez, 2011; Hao et al, 2020; Feng et al, 2018). With that said, many articles, in the urban zoning field and otherwise, primarily mention benefits of their research to practitioners or what expert knowledge can add to their analysis in the framing sections (e.g., introduction and conclusion), without much other explanation in the remainder of their study design and discussion (Shen et al, 2009; Soto & Frías-Martínez, 2011; Hao et al, 2020; Feng et al, 2018, Nikitas et al, 2020; Faghri & Hua, 1992; Sousa et al, 2014; Karami & Kashef, 2020; Lučić & Teodorovic, 2002).

A third and perhaps the most common role for planning experts in the reviewed literature includes articles in which the authors display a detailed understanding of practitioner needs and goals but do not directly collaborate with practicing experts for their inquiry. Their reasons for grappling with planning expertise and workflows more directly are diverse, but some do so based on local knowledge of their case study regions (Lin & Li, 2019; Mrówczyńska et al, 2019; Quan et al, 2019), or because their methods derive from expert-based systems (Yeh et al, 1986; Ülengin & Topcu, 2000).

That said, a significant contingent of these articles was funded by regional or national government bodies with planning or planning-adjacent functions, like the Korean Ministry of Land, Infrastructure, and Transport, the Spanish Ministry of Economy, Industry, and Competitiveness, the Algarve Regional Coordination and Development Commission (Portugal), and government-owned Australian water utilities (Kim et al, 2020; Bienvenido-Huertas et al, 2020; Ortega-Fernández et al, 2020; Hadjimichael et al, 2016; Nguyen et al, 2018). In most cases, this funding mechanism creates some sort

of deliverable relationship between researchers and planning experts such that the researchers describe the needs and contributions of planners in more depth. For instance, Kim et al (2020) focus on how Korean planners are working to integrate BIM into their permitting process. With the stated goal of increasing the adoption of BIM-based permitting systems, they propose a prototype system, which includes modules for performing code checking, submission, pre-checking, and automated rule-making. In the modules, the authors aim to address common problems in the traditional permitting process with various automation tasks and unified document management (Kim et al, 2020). These researchers still do not collaborate directly with planners, but their research is much more closely aligned with experts' considerations.

While research that focuses on pure technical innovation or only tacitly acknowledges planning experts is often funded by national sources, like different national scientific foundations, none of the articles we reviewed that fell into the categories of lower expert collaboration (see above) were funded by government organizations with urban planning functions.

The last two groups consist of a small number of researchers who directly collaborate with practicing experts for their studies. In the case of Shao et al (2015), the authors work with several stakeholders, including regional authorities, citizens, and conservation agencies, to help define an evaluation scheme (leaving room for changing weights based on different viewpoints in practice). They then implement a novel, "improved" version of the Artificial Bee Colony optimization algorithm for complex zoning in an area known for ecotourism. Zhang et al (2020) take a slightly different tack, engaging with 'operators' (who are outside experts) to test and validate their methodology after it has already been developed. In both of these articles, the relationship between expert and researcher is a transactional one, of "definition" or "validation" at either end of the research process, not an iterative process.

In Shahi et al (2019) and Messaoudi et al (2019), though, more back-and-forth collaboration between researcher and expert exists. In Shahi et al (2019), the authors first validated their methodology with a panel of experts coordinated by the Residential Construction Council of Ontario (RESCON), the organization that largely funded the research project. The panel reviewed the proposed framework, provided feedback, and accepted a revised version as a "roadmap" for Ontario municipalities. In Messaoudi et al (2019), the authors directly interface with planners and other permitting practitioners by surveying those who work in municipal building departments. They regard this as the best way to find out about the current permitting processes across Florida, and it precedes any design and execution of new processes. In Messaoudi et al (2020), the authors then use the framework that came out of the survey as their baseline and develop a proof-of-concept for virtual permitting that they then validate using expert knowledge about the permitting process from survey responses in a single case city, Gainesville, FL. Notably, even in these situations, where researchers worked collaboratively with experts, no articles explicitly mentioned the opportunity for experts to give feedback regarding mitigating potential bias or taking into account algorithmic transparency in the proposed artificial intelligence solutions. In that way, the collaboration between experts and researchers is still limited in scope.

In this inquiry, we hope to build on the approaches of Shahi et al (2019) and Messaoudi et al (2019) by gaining an understanding of what it is that planners do on a day-to-day basis and how their work might be changed or enhanced by artificial intelligence, seeking feedback from experts and allowing their experience to guide our research, and bringing algorithmic transparency and bias to the forefront in conversations about planning applications of artificial intelligence.

Our complete literature review will incorporate research topics related to artificial intelligence more generally as well as the process by which knowledge is acquired from experts and translated into computerized processes.

As a first step, the literature review represents one part of background research that will be followed by a survey of APA members. APA has approximately 40,000 members that encompass a broad range of expertise and planning sub-disciplines. The survey serves a similar purpose to the literature review, where we expect to derive perspectives and planning thought about how (or if) artificial intelligence can augment planning functions. While the survey results will be useful in identifying specific areas of planning for further study, it will also help us to gauge overall knowledge, interest, and experience with artificial intelligence-related methods. This is a secondary benefit of the survey that will also potentially identify demographic and professional characteristics of planners and their varying levels of familiarity with AI.

Information extracted from the literature review and survey will be synthesized to identify both the types of planning tasks and AI methods seen as having the highest potential for tool development and implementation. A summary of these findings will be used by the research team and community partner as background for interviews and data collection that will occur in the "community engagement" phase of the project where the focus is on planning experts, their workflow, and work products. It should be noted that this synthesis will be used to inform our process, but will not limit what we are looking for as we analyze Arlington County planning practices. In other words, we expect to find instances of suitable AI applications that have not been documented in the literature or previously considered by practicing planners.

The research team will validate the findings of the summary from the literature review and survey in a series of conversations with Arlington County planning staff. Participants may be subdivided into focus groups by subject area, seniority, technical ability, or other relevant characteristics. During these meetings, staff members will be asked to describe their "pain points" and be introduced to recent developments in AI. They will also provide feedback on the summary report and survey results to help identify the most promising directions for development. Finally, they may be asked to describe or

demonstrate their technique for fulfilling a given planning function, for example, through a hypothetical scenario or by recording a video of their computer screen. These findings will be consolidated into several "use cases" brief descriptions of problems experienced by planners and their potential AI solutions.

After validating and refining the findings of the summary report with front-line planning staff, the research team will review the use cases with county management with personnel and budgeting responsibilities. Consistent with software development, these stakeholders will prioritize the use cases in order of business value. They will also have the opportunity to reject use cases outright if they are deemed to be inappropriate in any way. Technical experts on the team will prepare an estimate of the relative level of effort for each use case in order of priority. The research team will then reorganize the use cases in order of payoff by dividing the business value estimate by the level of effort required.

The research team will document and summarize the information gained through the workshops, focus groups, management meetings, and estimation process. It will then recommend several AI projects for development. The first draft will be shared with partners (Arlington County and APA) for comment. The final draft will be disseminated to APA membership through educational materials such as conference presentations, webinars, whitepapers, or newsletter articles. It will also be shared with smart city accelerators, incubators, and venture capital funds, and with the research community through journal publication. We intend to use any feedback from these communications to improve our process and build our knowledge networks.

Next Phase

After completion of the tasks previously discussed, this research will focus on direct "community engagement" working with professional planners to understand their workflow and work products. The objective will be to examine where and how AI methods can augment specific points within a planning

effort. This process includes the elements shown in Figure 2. As suggested by the Figure, we expect the process to be iterative starting with obtaining information from experts, designing and developing solutions, followed by implementation, testing, and evaluation.

Figure 2. Community Engagement Phase
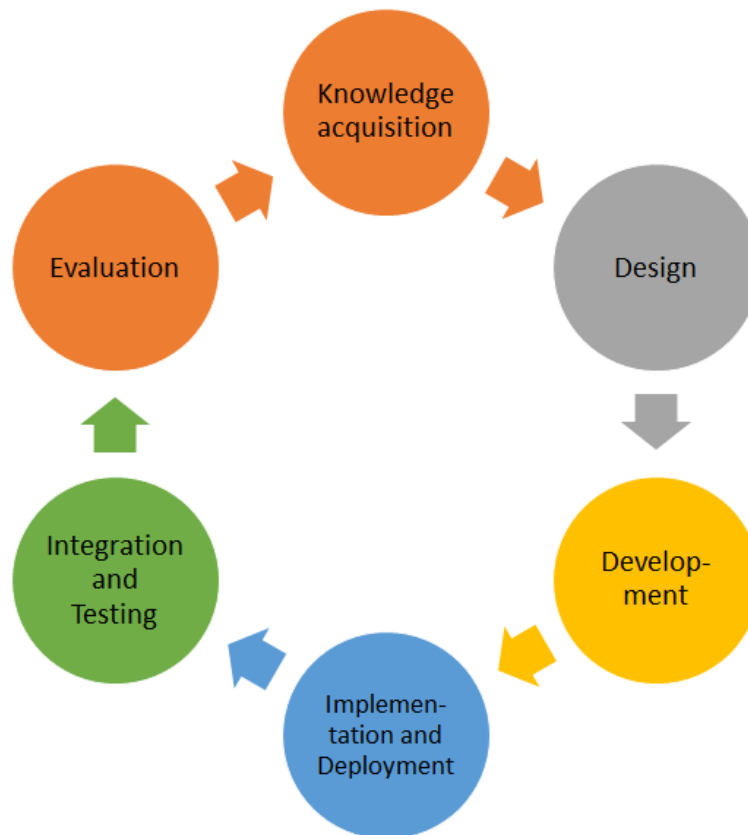
Summary

AI's wide-ranging applications can help improve government responsiveness, compensate for limited capacity, increase resource efficiency, and reduce the burden of repetitive labor-intensive tasks. In addition to automation, we are seeking creative solutions to urban planning processes that have relied

on traditional, analog approaches. We anticipate detecting synergies between public and private sectors

based on the widespread adoption of AI technologies. This points to the need for an agile, equitable, and

thoughtful response to potential challenges. Our contributions will be specifically in the areas of

research discovery, advances in practice, and education through the development of case study

materials suitable for urban planning coursework and training. We also hope that the results of this

research will catalyze AI startup activity in the urban planning field.

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Information Technologies in Planning Survey

The objective of this survey is to measure planners' experience with and perceptions of artificial intelligence (AI) as emerging information technology. We are interested in getting feedback from a broad range of planners, whether actively engaged in using these technologies or not. Your responses will help us to characterize the degree to which information technologies, particularly artificial intelligence, are currently being used by planners or have anticipated uses in the near future. The results of this survey will be made available by APA and the research team on the APA website. The survey is anonymous and should take no more than 10-12 minutes of your time. All responses, regardless of your level of experience or interest in AI are important to us. If you have any questions, please contact Tom Sanchez at Virginia Tech (tom.sanchez@vt.edu).

About You
The following questions are asked so that we can gauge the representativeness of responses we obtain from this survey. [those with options will have pull-down]

> *Position/title: [open text]*

> *Years of experience: [pull down choices from below]*

> *Age: [pull down choices from below]*

> *Gender: [pull down choices from below]*

> *Ethnic origin: [pull down choices from below]*

> *Highest degree attained: [pull down choices from below]*

> *Name of degree (highest degree held): [open text]*

> *Organization type: [pull down choices from below]*

Questions

1. On a scale of 0 to 5, how would you rate your level of interest and experience with data analytics and digital applications as applied to planning? (0 signifying no interest or experience and 5 signifying that you consider yourself an expert). [0 to 5 scale]

2. On a scale of 0 to 5, how would you rate your level of interest or experience with artificial intelligence related to planning? (0 signifying no interest or experience and 5 signifying that you consider yourself an expert). [0 to 5 scale]

3. Briefly, based on your current understanding, how would you define "artificial intelligence"?

   [open text box]

4. On a scale of 0 to 5, how significant will the impact of AI be on the planning profession and how planners work? (0 signifying no significance and 5 signifying dramatic impacts). [0 to 5 scale]

   a. If the response to No.4 is >0, then No.5
   b. If the response to No.4 = 0, then No.8

5. For each of the areas listed, please rate its potential for employing some type of artificial intelligence. This response can also reflect your level of optimism.

0 = No potential, 5= Highest potential	0	1	2	3	4	5	Currently using*	Don't know
Comprehensive Planning	X						Yes/No	X
Community Development								
Demographics								
Housing Planning								
Economic Planning								

Environmental Planning									
Community Facilities and Services									
Transportation Planning									
Land-Use Planning									
Community Involvement									
Plan Review									
Zoning									
Other _____									
Other _____									
Other _____									

Note: "Using currently" means that you or your organization are using an AI application at this time.

6. If you indicated that you or your organization are currently using an AI technology in Question 5, please briefly describe the specific application(s).

[open text]

7. Are there any specific areas of planning that you feel are **most suitable** for the application of AI? [Yes, No, Don't know options]

If Yes, please list or describe.

[open text if Yes]

8. Are there any specific areas of planning that you feel are **unsuitable** for the application of AI? [Yes, No, Don't know options]

If Yes, please list or describe.

[open text if Yes]

9. Are you or your planning organization expecting to adopt any AI technologies in the near future (i.e, next couple of years)? [Yes, No, Not Sure options]

    If Yes, briefly describe the specific application.

[open text if Yes]

10. If you answered **Yes** to No.7, 8, or 9, would you be willing to meet for a 20-30 minute interview to describe your experiences? [Yes, No options]
    If Yes, please provide the following information so that we may contact you.

Name: [open text]

Email: [email format only]

THANK YOU FOR YOUR ASSISTANCE