Making Sense of the Urban Future: Recommendation Systems in Smart Cities

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ABSTRACT

A large variety of Recommender Systems today can help users to understand and make sense of certain aspects of their cities, for example events, restaurants, government services, or transport. With the rise of the Smart Cities concept, more city operations and services will be made available by integrating multiple information systems from all types of city systems. The development of Smart Cities solutions will open up an exciting space for urban recommendations on a new and complex scale, which is the topic of this position paper. Most work today focuses on individual services, such as recommendations for places, routes, or activities, but nothing yet makes use of the vast and complex available information and service space. Recommendations in smart cities can be a fruitful area to explore in order to drive recommendations away from single-item or single-domain systems and towards multi-source, multi-faceted, multi-stakeholder, multi-level, multi-dimensional, and integrated recommendations that explore and combine the rich data and services that cities have to offer. Apart from giving recommendations, suggestions, and decision support for daily life of citizens, such systems can also be a main building block towards smart cities, making cities and their citizens more green, sustainable, climate-aware, and ultimately, more liveable. The ambition we are sketching here shows integrated recommender systems in smart cities to be a highly complex and multidisciplinary challenge, with considerable input and output data and algorithmic complexity within a complex domain.

CCS CONCEPTS

• **Information systems** → **Recommender systems**; • **Human-centered computing** → **Social recommendation**.

KEYWORDS

Smart City, Recommendation, Urban Environment, Urban Interactions, Urban Computing, Information Access, Civic Tech, User Interaction, Complex Systems

1 INTRODUCTION

Cities are highly complex, dynamic, and interesting environments. Growing worldwide urbanisation puts cities under pressure to adapt to changing circumstances. There is not only a need for planning and operation of cities and city systems, but also interest in the huge and growing amount of data that is produced continuously 24/7 through cities and citizens for a variety of use cases, including navigating these data sources and provide information access to citizens and stakeholders. Researchers should take the opportunity to use the growing infrastructure and data availability to build exciting systems on top of this new city infrastructures to generate insights and provide new services and systems to people.

Recommendation systems have already been implicitly or explicitly catering to users in cities, often through specific domains such as location-based recommenders [8, 13, 15] or citizen services [11, 44]. Current and future work will continue this trend from both academic and industry perspectives. This is exemplified by workshops such as RecSys workshops on Location-Aware Recommendations[1], Tourism Recommender Systems[2], the CitRec2017 workshop on urban recommender systems for citizens [44], as well as other work we discuss later, that continue to encourage researchers to identify challenges and opportunities in this area.

On the other hand, the concept of Smart Cities [6, 9, 35, 41] is getting more traction in research, industry, and city development. For RecSys purposes, the Smart City concept can be understood as a convergence of digital information and physical environment along with social factors within a city. The 'smartness' from the ICT view is usually provided by information systems and concerns certain key areas: governance, people, living, mobility, economy, environment. Thus, Smart Cities provide a new digital infrastructure for cities. However, we take a broader view here to get to a better understanding of the full potential. A Smart City should be a city that not only provides smart data and services itself, but should also be able to make smart use and allow its citizens to make smart use of these and external data that is relevant and available in open datasets, crowdsourced data, or social networks; to find new ways of operation, living, and creation. On the one side are city systems, such as energy, transportation, infrastructure, sustainability, housing, traffic, control systems, urban data analytics, and additional sensors. On the other side are external services and data sources that can be used to make the city smarter. These include crowdsourced data, mapping, social networks, volunteered data, external systems and services running within the city, news, and also open data, both structured and unstructured.

The main innovations for a citizen are the availability of *data*, easy *access* to data and services, and resulting, a higher number of *options* to use and *participate* in a city that turns into a connected smart urban environment. The research question we want to explore in this context is,

> *'What will change from a RecSys perspective once we have a Smart City surrounding us?'*

We see many challenges and opportunities that not only make this an valuable and challenging application domain, but also a possible driver for further development of the recommender systems field. These cover most important fields such as applications

[1] https://recsys.acm.org/recsys15/localrec/
[2] https://recsys.acm.org/recsys19/rectour/

domains, user scenarios and information needs, data integration, methods and algorithms, and the general applicability of recommendations in both reactive and proactive situations as well as decision support and behaviour changes at multiple, complex levels. We especially see a necessary move away from single-domain single-item recommendation towards more complex and cross-domain approaches.

To better support our case for integrated Smart Cities as a valuable new research area for Recommendation Systems, we will first explore some related work to understand the current state of the art and then sketch a future path.

2 RELATED WORK

Recommendation Systems are a way to filter through an abundance of data, add personalization, and create a valuable selection tailored to user preferences and context. With growing amounts of data and options in data-intensive Smart Cities, such tasks becomes increasingly important as a means to facilitate *information access* to a vast range of options. Recommendation Systems assume a choice of the user from a selection that usually is triggered by context or activities. It is different from pure control systems or on-demand search. These other fields will also need to adapt to the new Smart City urban environments, but in this paper, we are especially interested in the ramifications for recommenders.

Research related to recommendation systems in the overall and integrated Smart City context is still in very early stages. It is noteworthy that we could not find any papers that deal with the Smart City concept as a whole. The closest would be the workshop approach of citizen recommendation [44], though not necessarily the individual contributions. Other available theoretical and practical papers usually address rather limited and focused aspects without discussing the role of recommenders in the overall smart city context.

2.1 A Definition of Smart Cities

A city as an organism comprises the buildings, roads, sub- ways, and other built environment, its natural environment in terms of topology, water, flora (and some fauna) together with machinery and finally, citizens and inhabitants. Seen on this level, a city is a highly complex organism with a multitude of dimensions that can be understood from a variety of viewpoints [2, 6, 9, 24]. This is reflected in recent literature that is understanding cities not only in terms of place and space, but also in terms of systems, structure, networks, flows, and processes [9]. Work from a more computational perspective [33] understands cities as sites of ubiquitous information and communication technology and data that people use to connect to people, places, and services. For example, cities have previously been ideally designed to be legible [32], and to give people the ability to form a mental model and mental map, and that this is now changing towards cities being transparent or understandable also from a data side [22]. This need is based on the observation that media interfaces are becoming the dominant interfaces to the city. Additional work concerns sustainable [27], liveable [35], or [5] hackable cities and ways to engage citizens [24] or communities [20].

For our definition of a Smart City, we broaden the usual technical definition of a computationally-augmented and sensor-enhanced to that of the *sustainable participatory liveable smart city* [2].

On the infrastructure side, we acknowledge that a real-life smart city is build up of many separate systems that are not all centrally controlled by a municipality, as there are many separate services that can make a city smarter. As such, we see a smart city as an open ecosystem [3] that facilitates technical integration and collaborative open innovation where necessary. In combination, this allows us to also focus on inhabitants and participation/co-creation activities in addition to technology and infrastructure. The users can be citizens, defined as people living in the city, as well as travellers coming from elsewhere to visit the city physically or also use some city systems remotely, as well as a range of other stakeholders.

2.2 Related Recommenders

Longer discussed features for the evolution of recommendation systems include extensions of older methods, mostly based on limitations of content-based, collaborative, and hybrid approaches. Suggestions [1] include an improvement of the understanding of users and items, the integration of context, multicriteria ratings, more flexible and less intrusive recommendations, and broader evaluations based on usefulness or quality. Further discussions [16] include the use of knowledge-based and group-based approaches and the exploration of additional applications domains, such as software engineering, knowledge engineering, product configuration, and, especially important here, persuasive technologies and smart homes (both for design and for control to improve quality of life). The latter show a stronger relation to our topic, but still stay within smaller niche tasks.

Understanding recommender limitations from a human point of view can help to look at recommenders untied from current technology [36]. This view is close to our ambition here, to look into what would be an ideal system from a human life perspective, and what options for future work can be derived.

The area that currently has the strongest city relation is location-aware recommendation systems [13] and recommendations in LBSNs [8], often with a focus on venues and places [15]. LBSNs with their locations and user interactions can also be used to get insights into a city's internal life and processes [12].

Aspects of venue and event recommendation can be used to show the research opportunities that can arise with the use of the digital infrastructure of a Smart City [14]. To get around limitations with only using location-based social networks (LBSN), that work explores the use of social and physical sensors, for example analysing CCTV footage to detect interesting events. This is also described as a way to bridge different silos of closed LBSNs. Similarly, sensor metadata can be used for city event detection [4] or Twitter can be used as a set of social sensors to understand and summarise city events [34] in preparation for recommender steps.

A promising approach is to use parts of the sensor infrastructure of a smart city to improve quality of life, focusing on the features of personal health conditions coupled with real-time sensor-based route information [10]. Citizen services as a general topic [44] and e-government in particular [11] are further relevant domains.

For the sensor integration of the Internet of Things (IoT), some approaches deliver recommendation for analyses of data streams [42], while others already approach a smart home scenario [45] that recommends things based on relationship of users and RFID-tagged things, to for example support cooking or similar tasks.

Abstracting from individual locations, transportation and navigation can be considered an area where integration of recommendations is a bit further developed, either as multi-modality in the routing or in the data sources. Examples include trip recommendation [31] that includes places and events based on a rule- and preference-based approach or transportation systems that recommend both taxis and passengers to each other [46]. Other systems recommend routes specially adapted to electric vehicles [17]. A very different approach recommends beautiful or happy routes through a city based on maps and picture analysis of street-level photographs that derive additional dimensions for the city [38].

An interesting survey on smart communities [43] observes recommendations used for mobile social learning, event guides, and context-aware services. Similar to smart cities, it further makes the important definition of a smart community arising out of three factors: physical world, online world, and social world. A similar work examines the applications for context-aware recommenders in smart urban environments [21] and describes scenario contexts of restaurants, public transportation, shopping, being at home, or on a trip.

There are obvious differences in interest and needs for citizens on the one hand and city planners or operators on the other. Only a few systems approach smart cities from a city planning or organization perspective. Some frameworks exist that aim at recommendations for city planners, but often not with a computational approach [37]. Yet, some systems for city planners support smarter planning and management, often in the form of decision-support systems [28]. There are also some very specialised systems, such as recommendations for the position of air quality measurement stations [25].

Finally, towards sustainable cities and citizen involvement, initial work is exploring the use of recommendations as an offer to citizens to adapt their behaviour, for example in the choice of mobility with personalised options that provide easier access [30].

3 SMART CITY RECOMMENDER CHALLENGES

There are some initial promising approaches in the related literature. Smart City sensors are already initially included to broaden data sources [10, 14] and some work shows a positive vision towards more complex city level scenarios [21, 43, 44]. However, there is a strong need to broaden the scope of recommenders and to focus more strongly on wide integration of systems and more complex scenarios.

For the overall Smart City Recommendation System vision, we see a strong need to get away from single-item and single-domain recommendations. Development should be towards multi-criteria, multi-domain, multi-community, multi-source, multi-faceted, multi-level, and multi-dimensional recommendations. Further, set recommendation would be important where not a single item, but rather a set of items from multiple domains/systems is the suitable user support. This will also mean to re-examine and re-assess the purpose of these systems towards user needs [26].

To understand and utilise all services in and around the Smart City and to integrate them, Recommenders have to work at different levels and scales. A possible goal would be to move the city experience into a *Smart City Experience* that combines exploration of the city, service discovery, proactive recommendations, and more into a personal assistant to enable a personal sustainable liveable city (cf. [7]). Some of the identified challenges are:

Data integration: Recommendations spanning multiple data sources and systems, user scenarios, and user information needs. Integration into an open ecosystem of smart cities [3] to access for example municipal, local or national public and private, and worldwide systems, ranging from social media over vertical collections, down to individual municipal or local citizen services.

Improved context-awareness: approaches need to draw from more complex user and city environment context and need increased adaptability [23].

Scenario-based approaches: more complex, real-life oriented scenarios, including ensemble-based, task-based, or exploration-based recommendations, curated [29] from multiple streams. Complementary domains may be location, events, people, products, services, routes, transportation, schedules, fitness, jobs, or news.

Increased complexity: Complexity has to be handled inside the system, on the UI side, and also will require better explanations for users into how the system works and why certain recommendations are made [40]. Complexity occurs both on the input side with multiple connected systems and data sources, as well as on the output side with needs for results to span these systems and options and possibly combine them to satisfy user needs.

Cross-domain: recommendations may come from multiple domains of a smart city depending on user context, or set recommendations may be needed.

Integrated and new domains: Recommendations as a support tool to explore and experience and use the city, for both tourists and locals.

Stakeholders: Systems need to address the right users, which can range from citizens, visitors, tourists, commuters, students, homeowners, children, adults, elderly, municipality, service users, businesses, civic society, NGOs etc.

User involvement: How do we find relevant civic engagement opportunities? This can range from urban plans and consultations up to NGO engagement or concern the development of these systems themselves as civic tech or systems for the common good, for example by involving citizens and communities in development and use cases, requirements, or systems.

Individual vs. community targets: New challenges can occur for public services, where recommendations should be both for the common good and the individual needs [39], which may be achieved by more inclusion of participatory design and open data use.

Algorithms: new scenario-based approaches may require other recommendation algorithms, moving beyond item-based, collaborative, or knowledge-based paradigms.

Evaluation: Not just accuracy, but also diversity, serendipity, robustness, trust, security, privacy, usefulness, quality, unobtrusiveness.

Privacy and data ownership: Privacy issues in many forms can arise from the smart city concept [48], especially if it is seen implemented as the data-driven, surveillance-prone variant. But also the variation mostly described here would generate a lot of privacy-related data, that needs to be properly safeguarded. It is also not just about obvious CCTV blanket coverage; also the combination of less invasive data sources can lead to privacy leaks. Such issues are already necessary considerations in existing data collections and systems, and should be treated there initially. However, also systems only built on top of those even without own data gathering, have a responsibility and need to consider the use of such data, and for recommender systems to for example avoid data leakage [47]. Also data governance and ownership is an important issue, where larger systems make it harder to understand what is happening to user-provided or sensed data further downstream, who owns it and can decide on sharing or integration, and whether/how it may be used. But with the integration across systems discussed here, more critical privacy issues could arise and also need to be considered in building these aggregating systems. Privacy should be a guiding factor in such future systems. Surveillance of citizens and data abuses are not specifically to recommender systems. In the context of Smart Cities, it is a particular crucial aspect, when data collection systems are deployed city-wide, also opening up issues of ownership and anonymous use of public spaces and services and rights to the city [18]. However, this issue is also one of cultural background. Some countries place a much stronger focus on commercialisation and surveillance in the smart city concept, while others set a stronger counterpoint of municipal needs, appropriate governance approaches [19], and citizen focus [2]. It will require work to strengthen or maintain these democratic aspects throughout.

The initial discussion shows that a lot of work is already available, but that merely combining it would not be enough. Strong new research approaches are necessary.

4 CONCLUSION

> *The metropolitan region is now the functional unit of our environment, and it is desirable that this functional unit should be identified and structured by its inhabitants. The new means of communication which allow us to live and work in such a large interdependent region, could also allow us to make our images commensurate with our experiences. [32]*

The Smart City scenario is a challenging next frontier to explore. Improving cities and sustainability will be one of the major issues facing us in coming years. Cities can be made more liveable, sustainable, and understandable through a range of measures. Their growing complexity coupled with growing data, information access, and urban options opens huge pathways for development of innovation, citizen involvement, and data-intensive smart systems.

Recommendation Systems can and must help to shape this urban future towards important real-life recommendations. The multitude of open challenges coupled with interesting opportunities makes this a very valuable and rewarding area for research to drive recommendation systems towards their urban future.

In the breadth that we have presented our vision here, it is an as-yet underspecified problem. The ambitions sketched out here will have to be conceptualised and refined in more detail. In this paper, we made a small contribution towards this goal.

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