Collaboration-based Urban Planning Platform: Modeling Cognition to Co-create Cities

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***Abstract*—Given the need to strengthen citizen participation in urban planning processes, related research is aimed at considering citizens as "sensors" in order to use their *collective intelligence*. In other words, people who interact as active members through the use of collaborative and social platforms generate valuable data that is used as input for intelligent systems. The stagnation of the construction sector in large cities and the resulting housing situation have led researchers to seek new technological answers where participation from people, together with policies established by the government, jointly create new environments and solutions of housing. This study aims to present the design of a social Web application that promotes collaborative-based urban planning within the context of *cognitive cities*. Specifically, after studying the theoretical bases and analyzing data collected in two Ecuadorian cities, we propose a non-functional prototype. The proposed methods approach to what will be a Web application that embeds a model of cognitive urban planning, and were evaluated by local government collaborators. The prototype was built depending on the requirements specification and the intelligent components that will allow citizens to collaborate and interact in a smarter way. We conclude that involving people in the co-creation of their cities (by collaborative computer-mediated means) may improve their living conditions and place urban resilience as a challenge that can be overcome.**

I. Introduction

In discussions that took place during the Habitat III Conference, one of the most overwhelming challenges was the provision of adequate and affordable housing [1]. Considering this issue, the strengthening of the nexus between housing and urban planning was the main subject matter. Besides, the incorporation of cooperative processes in planning as catalysts for access to housing was a relevant conclusion. In this sense, smart cities, under promises of efficiency and sustainability, have so far not responded to the demands of the future city, or the so-called cognitive city. Indeed, cognitive cities are understood as complex socio-technical systems, where the most latent challenges are related to make cities more inclusive and *resilient* [2], [3]. Therefore, *the cities of learning* in turn are framed in the smart city, and complement it. The involved collaborative urban planning requires cognitive (mental) processes that include individual and/or collective decisions, problem solving and learning, but also behaviors and relationships in the environment in which the decisions are made. Hence, these procedures, according to Thagard, have an important emotional component: the cognitive human factor [4]. Interaction between people thanks to new computer-mediated ways has proven to be a trigger for data generation with an intelligent and emotional human perspective behind. In fact, such information systems are fed and able to adapt themselves after learning from users' collective intelligence.

Taking into account the current situation of housing in Ecuador, the weak participation in urban planning processes, the stagnation of the construction sector [5], and the related literature analyzed, we may say that the relationship between *urban planning* and *housing* is still unconnected [6]). While evaluating the literature review results [7], a dispersed epistemology was evident, as well as a lack of a theoretical horizon that effectively relates collaborative urban planning to housing challenges. After comparisons, we identified the relationships *a)* Urban Planning – Cognition and *b)* Cognition – Social Behavior, highlighting the role of governance, as well.

The still abstract model on the road to a collaborative urban planning is expected to make concepts such as urban planning, collective intelligence, and cognitive computing work together. The proposed non-functional prototype detailed in this paper

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presents an alternative of such information system. In summary, we find as motivation the generation of a cognitive urban planning model based on the collection and trans-disciplinary analysis of data provided by citizens and local government authorities. For this purpose, we have been working with data gathered in Quito and Portoviejo since their authorities have shown support (in terms of meetings for discussion and workshops for validation of phases) and interest in the research outcomes. Our findings are thought to be used in a Collaborative Urban Planning platform where citizens may be able to create, acquire, and transfer knowledge.

This paper aims to present the primal results of our research which was conducted in different phases: *i)* people's expectations about what an optimal neighbourhood to live means are collected in two different cities of Ecuador[1]; *ii)* the housing needs of citizens are analyzed, as well as the problems related to urban planning from the local government side. In this phase, we defined the functional requirements of the intended platform; *iii)* the requirements are mapped in the mock-ups design; then, the first evaluated user interfaces are presented; and *iv)* the cognitive computing element of the platform is studied during the prototype evaluation; however, in this phase, we formalize the different *intelligent* models to be implemented.

The motivation of these series of studies is to obtain the bases towards the generation of a citizen-oriented system that can be embedded in a platform for collaborative urban planning. The outcomes of the first phases of our research will be further used to address various problems, to be extended and applied during the implementation of a Web-based platform. Our main contributions are:

- The functional requirements specification after a survey results analysis and from the urbanism view.
- The definition of a non-functional prototype based on the specified requirements.
- The formal introduction of the intelligent components that will be implemented in certain prototype scenarios.

The remainder of the paper is organized as follows: Section II summarizes the literature relevant for our research. Section III details the context of the present work. Section IV describes the applied methods and the different phases that conform our research; in Section V we present the results obtained after the evaluation of the prototype (relevant screens); finally, in Section VI, we conclude our work.

II. Related Work

Nowadays, cities are implementing interactive technologies and sensors in the environment. Often, technologies are integrated into the ubiquitous infrastructure of the smart city and personal tools; therefore, people and things are more connected than ever before [8]–[10]. The conception of the "smart city" tries to apply Internet and Information Technologies (ICT) tools in order to face challenges of effectiveness and optimization. On the other hand, "cognitive cities" demand effectiveness and resilience of new action plans for urban governance. Such approaches should include knowledge, cognition, and creativity. In other words, they rely on the human factor, along with the capacity to learn to confront those big changes and to attain problem-solving abilities [2].

In [11], the authors presented an eGovernment framework aimed at eEmpowerment of citizens, which can be achieved via the promotion of citizen participation focus on the interaction between administrations and citizens. In [8], the authors emphasize the extent to which the smart social city combines the best of two environments: first, a social city centered on people; and second, an intelligent city that takes advantage of the opportunity given by future Internet and technological innovations. Such innovations like living labs, Internet of Things (IoT), and big data are accessible to everyone. Next-generation technologies, such as the Internet of Everything and, more especially, artificial intelligence (AI), allow the realization of the promise of a cognitive city as a new paradigm.

Cities are currently growing within technologies. This growth is driving urban planning towards integration with ICTs in practice, which explains the possibilities that these technologies offer the community for consultation and creation of places [12]. Understanding the limits and specificities of the algorithms offers the possibility of making the analysis more significantly related to the integrated technological systems in urban environments [13]. Nowadays, the emergence of the digital age has introduced new actors [14]. Thus, every sensor (human or machine) can become a stakeholder [15], [16]. These changes introduce new challenges into the field of urban governance addressed from cognitive city approaches.

The cities are the scenarios where stakeholder behaviors emerge. Stakeholders may be government actors, infrastructure-service providers, as well as individual and corporate citizens [17]. However, several government institutions are not aware of the citizen-centered government advantage. Some works have been presented regarding governance and cognitive or smart city concepts [18]–[22]. The reports analyzed addressed some problems related to the governance of smart or cognitive cities. In [18], the authors indicate that providing services to the mega-cities of the future requires a fundamental rethinking of urban governance. Leveraging information technology and integrated intelligence, together with the provision of innovative services and government structures, can allow cities to deal with the complexities of fundamental change from a nation-state mentality to cities as global centers of social cooperation and local empowerment. Additionally, in [19], the authors deal with complex, large-scale, interconnected, open, socio-technological (*CLIOS*) systems, such as the national power grid, regional transportation systems, the world wide web, or the air traffic control system as well as other systems with wide-ranging social and environmental impact. They are presented in a 12-step framework designed to allow concurrent analysis, design, and management of coupled complex technological and institutional systems in the face of uncertainty.

The concepts mentioned above allow the emergence of an approach to urban planning in a cognitive city environment. This document seeks to establish the urban functional requirements of the cognitive urban planning model for the development of a prototype based on collaboration. This

[1]The data was collected by applying a survey in Quito and Portoviejo, in Ecuador. This analysis presents the comparison of the view of the population living in a big city, as it is Quito, the capital of Ecuador, against the perspective of people living in a small city. It is worth mentioning that Portoviejo is in the process of reconstruction of its infrastructure after an earthquake.

cognitive design approach is intended to provide access to housing and collaborative urbanism, as driving practices for renewed urban planning in the Ecuadorian cities of Quito and Portoviejo. Next, details about the context of our research are presented.

III. Case Study: Towards Cognitive Urban Planning in Ecuador

According to the Habitat III conference [23], urbanization processes have to deal with some problems and most of them are the responsibility of governments. Indeed, the main challenges have implications for territorial management, including the appropriate ways of mobilizing the community and monitoring of human settlements (at all levels, such as small rural communities, towns, villages, intermediate cities and metropolises). Multiple actors that include citizens, government, financial and construction institutions, as well as information control institutions for decision making should be part of the search for an adequate housing system. In Ecuador, 45% of the 3.8 million Ecuadorian households live in inadequate housing. This accounts for 36% of households suffering from qualitative deficits, and 9% of households suffering quantitative deficits. According to data provided by the Ministry of Urban Development and Housing (MIDUVI, from Spanish 'Ministerio de Desarrollo Urbano y Vivivienda'), 1.37 million homes with qualitative deficit reside in homes whose tenure is unsafe, built with inadequate materials, lacking basic health services, or with overcrowding problems. On the other hand, 342,000 households with quantitative deficits share their home with one or more families, or live in makeshift housing units [5].

While in urban areas 37% of households live in inadequate housing, this number reaches 60% in rural areas. According to MIDUVI, the main cause of the housing deficit in Ecuador is its affordability. This is explained by the disparity between household income and housing costs. Each year, 111,000 households join the national population, of which more than half are in inadequate housing. As it is known, inadequate urban planning processes carried out in Ecuador had unfortunate consequences after the earthquake in the coastal region of the country in April 2016 (being Portoviejo one of the affected cities). As a result of poor planning, there were many human and material losses. We could cite Rafael Correa, the President of Ecuador at that time, who pointed out "... the number of deaths could be less if there had been better constructions" [24]. Moreover, the disaster presented is not an isolated event, and the same problem could have occurred in any other location in Ecuador due to its geological, topographic and climatic characteristics.

The state of the art and empirical evidence confirm the need to explore the incorporation of new urban planning models, which lead to the formulation of the *Scientific Problem*: how could collaborative urban planning, collective intelligence and cognitive systems improve decision making for inclusive urban planning that addresses the challenges proposed by Habitat III? We started the study of housing issues with the aim of analyzing the expectations of an optimal living environment according to the people living in two different cities (which have their own characteristics). Information about the area covered by the cities, their population and their elevation

Table I: Characteristics of the analyzed cities

City	Area (km2)	Population	Elevation (m)
Quito	372.39	1,978,376	2,850
Portoviejo	418.06	223,086	53

above sea level are detailed in Table I. More details are provided in [25]. The local governments of both cities agreed to collaborate with information, data and time to continue with future work on our research. Given this, and the contrast of people's perception and housing needs that can be found in their citizens, we applied a survey to explore preliminary urban requirements. Next section presents the decisions made concerning the survey application and how its results have been used to generate the functional requirements of the intended platform.

IV. Method

In this section, we provide details about the strategies and techniques that guide the development of the four mentioned phases. The decisions made about data processing and analysis are explained. Moreover, we present a characterization of the intelligent components that will allow the platform to handle its cognitive feature.

A. Survey Applied: The Big Picture

Once the related literature was analyzed, a survey aimed at gathering the citizens' opinions regarding housing and neighbourhood and their associated expectations was prepared. The strategy implemented in the survey design was going beyond the quantitative and qualitative concept of basic needs of a population group, towards the understanding of the wishes and behavior of the citizens in relation to their environment, and their creativity within a cognitive-cultural economy.

In Quito, the survey was applied to 1606 citizens. In Portoviejo, 1248 filled in the survey. In both cases, we made sure that the people meet the age in the range of 25 to 60 years old. The research team decided to select four essential profiles for the design of the survey: i) those who demand a housing solution; ii) people who do not require housing and are only considered neighbors; iii) homeowners who have a home for sale or lease; and iv) construction professionals. Associated with these profiles, a specific number of questions were raised. Thus, the survey consisted of 65 open questions, twelve of which are general questions for all participants (mainly to collect demographic data), and between 4 and 11 specific questions depending on the profile of the respondent.

The results indicate that the sample is gender balanced with the percentage of men around 52% versus 48% of women. 71.85% of the people in Quito and 61.70% in Portoviejo have family incomes of up to USD 1,000. Among users who require a housing solution, about 38.5% want to make improvements to their homes, followed by those who want to build or buy. Finally, most of the people surveyed are satisfied with their place of residence and they want their neighborhoods to be safe, have basic services, equipment, quality public spaces, and a good location in the city. As for those identified as *neighbors*, around 83% of them would be willing to collaborate and organize in their neighborhoods to encourage the inclusion of new residents, as well as participate in collaborative urban planning processes. The in-depth analysis is presented in [6].

B. Functional Requirements Specification

Potential users of the application provided the data during workshops with public institutions collaborators, and through surveys conducted in community spaces in the two cities mentioned before. The results allowed us to know in a general way what the main housing needs of citizens in the respective cities are. After several work sessions between the the research groups (Cognitive Urbanism, Software Factory and Intelligent Systems) it was decided to start with the stage of specification of *functional requirements* for the Web platform, which will be our final deliverable. The Cognitive Urbanism team was trained to be able to make the specification of functional requirements, since they are the ones who know in depth the domain of Urban Planning, its problematic, the modern perspective of including citizens in the co-creation of their cities and the vision of the benefits of accompanying these planning processes with technological tools. Therefore, their training included topics such as: creation of user stories, recognition of actors or types of end users and use cases for functional requirements specification.

The use cases are used to obtain requirements considering what users must achieve in the system [26]. They describe the functions for the software prototype which are based on the findings of the analysis of the collected information. The use scenarios and their deployment in urban functional requirements are classified in three general dimensions of the conceptual model of cognitive urban planning: *i)* access to housing (supply and demand); *ii)* collaborative urban planning; and *iii)* decision making on urban planning and housing. The functional requirements enable the next stage of cognitive architecture related to the design of the prototype and each use case scenario has been designed for real-time interaction between users and the prototype. The 11 scenarios of use within the Collaboration-based Urban Planning Platform dimensions are presented as follows.

The dimension of access to housing refers to the interactions through which various types of housing solutions are demanded and to the supply of goods or services that supply these demands, establishing five scenarios:

1) The citizen who wishes to improve his home is presented with a list of construction technicians to perform the renovation work.
2) The citizen who aspires to build his house, is presented with a recommendation list of professionals to do the work.
3) Professionals and construction technicians receive an evaluation by way of rating after completing their work.
4) The citizens who need to buy or rent a home receive a recommendation based on the desired characteristics of the house/apartment (number of rooms, price, location, etc.) and the neighborhood (safe, near to workplace, etc.)
5) The owner who wants to sell or rent his home receives a recommendation based on the reliability of the user that requires buying or renting.

The central dimension of collaborative urban planning contemplates two usage scenarios. Here, we pretend to relate citizens who wish to participate in the co-creation of their urban living, with those who wish to attend to new residents in their neighborhoods:

6) The citizen who wishes to cooperate in the urban development of his neighborhood or with the technical team of the municipality. For its compliance, the user could report an incident or event or present proposals for the improvement of the urban environment.
7) The citizen who wishes to assist the new neighbors is contacted with them, in order to establish a type of collaboration. Participation, and appropriation of urban space are encouraged.

The third dimension for the prototype design includes decision-making around urban planning and housing; in it the municipal managers and technicians interact with the citizens, and it contains four usage scenarios:

8) The municipality may review, systematize and process the problems of the city associated with an urban area, by type, location, intensity, magnitude, among others.
9) The municipality might make decisions about land use and occupation guidelines. They are provided with reports about housing and collaborative urban planning associated with citizen socio-economic profiles.
10) The municipality might generate participatory programs to implement urban projects of common interest. Citizen participation is proposed for collective construction of proposals.
11) The municipality might make decisions about property structure, urban development financing, and land market regulation. Real transaction value in the purchase-sale and rental of housing operations are reported.

In conclusion, each use scenario associated with its urban functional requirement has allowed the intelligent systems team to advance with the intelligent requirements of the model, which are translated into the first prototype designs, along with the cognitive algorithms based on Machine Learning processes, Text Mining and Natural Language Processing.

C. Intelligent Components Characterization

The intention of creating intelligent computer systems in the field of Urban Planning is to make cities smarter. The algorithms embedded in those systems learn from the data to improve the way cities work. In this paper, we have proposed the design of a software prototype that reflects the functional requirements of the platform, which, at the specification stage, were recognized and classified. Among these requirements, there are several that allow the user to enter information into the system (Figure 1), others that extract reports for users in the context of decision-making (Figure 2), other functions enable communication between various system actors (computer-mediated Human-Human interaction, Figure 3), but we have identified a list of requirements that need intelligent algorithms to meet their information processing and delivery objectives. These requirements and their algorithms are detailed next.

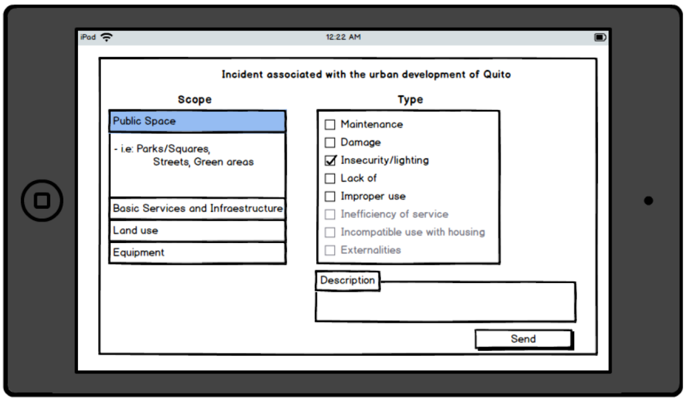

Figure 1: Form for event entry by the citizen.

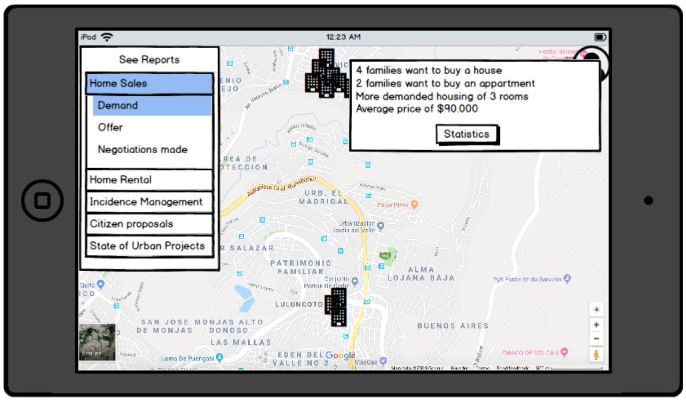

Figure 2: Information report for government collaborators.

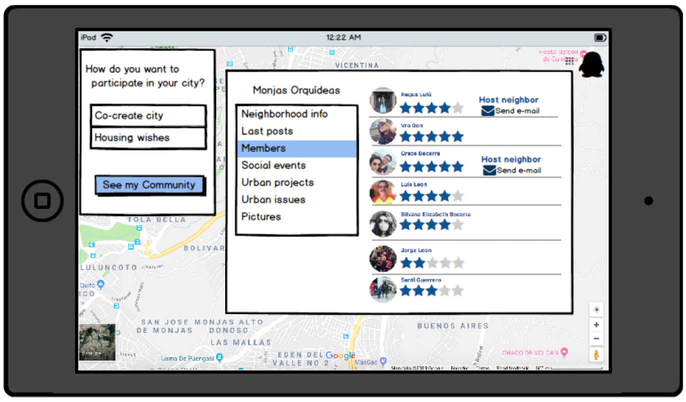

Figure 3: Ease of contact between members of a community.

1) Classification of event reported by the user: The user has the possibility to report an incident or event. This event must be visible to at least one of the "citizen care groups" of the municipality. For example, if someone reports a robbery, the metropolitan police must receive that report for its proper management. If a citizen reports destruction of a park, the care group that must take action will be another. That assignment or classification of the event, according to the care group that should receive it, will be done automatically by this intelligent component.

2) Recommendation of urban proposal to citizen so that (s)he can support it: The user has the possibility of entering urban proposals in the system. Each proposal will be stored and, therefore, will be visible to users once they have logged into the platform. It is assumed that the more citizens support that proposal, the more relevant it will be for the local government to prioritize and give attention to it. But not all citizens will be interested in supporting the proposals. That is why, depending on the user's profile and the content of the proposals, this intelligent component will be in charge of identifying which user "most likely" would be glad to support a certain proposal.

3) Classification of users who are detected as potential host neighbors: People residing in a given neighborhood can give support, welcome and induction to a new neighbor. The detection of potential host neighbors to be hosts is given automatically by this intelligent component, depending on their profile and interactions on the platform (reputation is calculated in the system).

4) Classification of neighborhoods according to level of habitability satisfaction: It is possible that the user who is looking to move home, looks for a neighborhood that has certain characteristics that (s)he considers necessary for the environment to live. If the user starts a search for housing on the platform and insists on customizing the characteristics of the neighborhood, (s)he will be asked to detail those values. Then, the platform will find the most similar neighborhoods to the user's search with the use of this component.

5) Price prediction of sale/lease of housing according to the market: Users who want to promote the sale or lease of their home on the platform will receive a notice of how fair the published offer price is. That value will be compared with the prediction made by the system, using this intelligent component.

6) Classification of users that are detected as potential citizens to include in consensus: The municipality must have the support of citizens to approve urban projects. The detection of potential citizens who probably want to participate in consensus convened by the municipality is automatically given by this intelligent component, depending on their profile and interactions on the platform.

7) Housing recommendation for user: The user looking for housing to buy or lease may filter the search by sector (and its characteristics, see intelligent component 4). Once the appropriate sector has been found, the system will search for housing offers that match the demographic profile of the citizen. This intelligent component implements the algorithm that is the main recommender system in the platform.

D. Low-level Prototype Design

Once the requirements and intelligent components were defined, the research team was able to elaborate the first prototype samples supported by cognitive algorithms design. When people say "software prototype", they usually think of a mock-up of a possible user interface. A mock-up simulates behavior without the need to implement it by showing user interface screens and some navigation between them. It contains little or no real functionality. A mock-up focuses on a part of the user interface and does not immerse itself in all architectural layers or in detailed functionality. This type of prototype allows to explore some specific behaviors of the intended system in order to refine the requirements. During evaluation, the mock-up helps users to judge whether a system based on the prototype will allow them to accomplish their job [26]. Therefore, as we had the opportunity to work with the potential users, during the (*qualitative*) evaluation meetings we improved the diverse designs bearing in mind not only the software requirements, but also characteristics such as cognition, collaboration and collective intelligence.

The mock-ups that we developed demonstrate the functional options that the users will have available. The functions and navigation structure represent the requirements detailed before. The particular screens where the intelligent components are going to be implemented were identified, as well. We tried to use real information on sample screens and outputs. The obtained prototype improved its validity as a model of the real cognitive urban planning system, because we evaluated it with the help of some of the expected end users. The evaluation workshops were planned to allow the users to be familiar with the prototype. Three important aspects were considered for the evaluation: accuracy and quality of the requirements (errors and omissions were recognized), understanding of the intelligent components that make the platform be conceived as cognitive, and collective intelligence options that are expected in collaborative-based systems.

To conclude, mock-ups were useful for confirming our understanding of the requirements, revealing ambiguities (especially concerning the intelligent models) and evaluating possible technical approaches.

V. Main Prototype Screens after Evaluation

To validate that the functional requirements of the system are correct, we created non-functional prototypes with the design strategy of mock-ups. We followed an evaluation process of these designs through three sessions with representatives of the Municipality of Quito. This local government team was made up of collaborators who work in the IT department and in the Urban Planning and Architecture department. These actors are considered relevant users of the developing system and have provided support in the mock-up validation process. After the analysis of the system requirements and the non-functional prototype, every session generated an improved version of the platform, including the algorithms' goals. The evaluators gave the project researchers their views according to their roles and experiences. Besides, all participants focused on the collaborative side of the platform to provide their validation.

We know that under the conventional system of access to housing, unsatisfied (minimum) needs could be met; however, these needs are normally mediated by public and mainly private agents. In practice, these intermediaries end up directing or restricting the real behavior of the population [27]. Then, the theoretical purpose of this model of cognitive urban planning is that the wishes of users who demand a housing solution are fulfilled under new rules of cooperation between actors integrated into a collaborative system of access to housing and urban planning. Consequently, if we were able to satisfy the aspirations of the user that finds a housing solution, we would

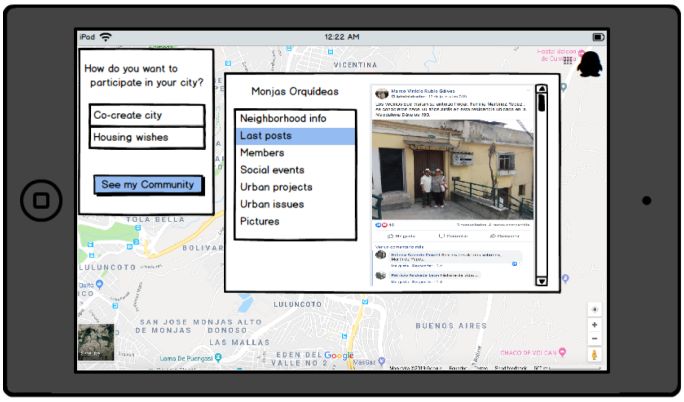

Figure 4: Social activity of the members of a neighborhood.

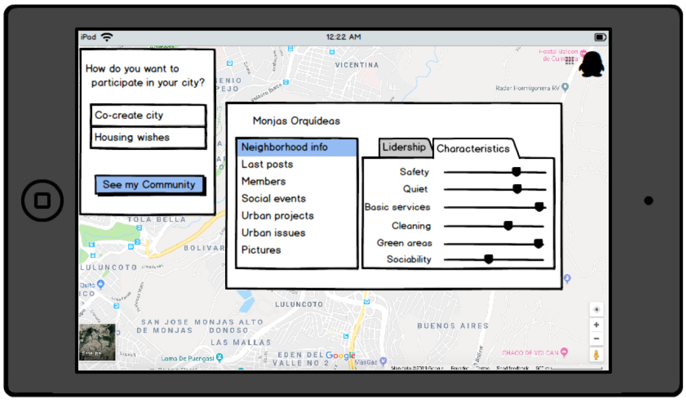

Figure 5: Neighborhood's characteristics quantified by the system.

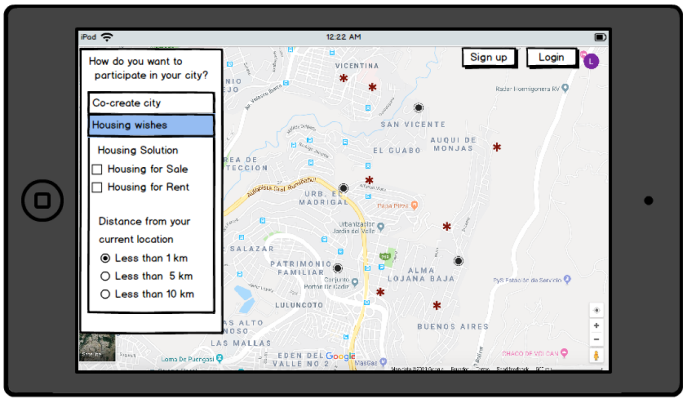

Figure 6: Recommendation of homes for sale or for rent.

contribute directly to the increase of the subjective well-being and quality of life of that segment of the population, added to the collective well-being of the host neighborhood.

The mock-ups that exemplify the collaboration-based interactions and support the collective well-being are presented in Figures 4, 5, 6.

VI. Conclusions and Future Work

Efficiency, sustainability and resilience influence the evolution of urban socio-technical systems. In this context, the collaborative work that integrates technology and people functioning as a whole emerges, giving rise to a process of collective intelligence. Cognitive characteristics are being studied in the field of Urban Planning with the objective of implementing environments in which citizens are active components of urban projects in all their phases.

Our proposal is aimed at creating a collaborative platform that makes the co-creation of neighborhoods possible. We have defined the functional requirements with the joint work of a trans-disciplinary research team and the commitment of several actors. Potential end users of the system (especially collaborators of the municipality of Quito) were involved in the qualitative evaluation of the non-functional prototype. The resulting mock-ups supported the task of understanding functional requirements as they are an early and effective means of communicating elements of what the system will do for the users. Learning communities, social and personal networks, use of collective knowledge, among others, are several of the alternatives presented by the design of the urban planning platform. The components that make the platform "intelligent" were also detailed. For future work we propose a quantitative evaluation of the in-progress high-level prototype. To validate functionality accomplishment, we plan to include tasks where citizens interact with the platform and to each other.

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