Universitat de Girona

SMARTER URBAN PLANNING THROUGH A CITIZEN-BASED APPROACH. THE SMART URBAN PLANNING METHOD

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Dipòsit legal: Gi. 188-2015
http://hdl.handle.net/10803/285384

Universitat de Girona

DOCTORAL THESIS

Smarter Urban Planning through a citizen-based approach

The Smart Urban Planning Method

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2013

DOCTORAL PROGRAM IN TECHNOLOGY

Advisor: Beatriz López-Ibáñez

Thesis submitted for the Degree of Doctor of Philosophy at the University of Girona

LIST OF PUBLICATIONS

MLl. Marsal, JLl. De la Rosa, The Representation for All Model: An Agent-Based Collaborative Method for More Meaningful Citizen Participation in Urban Planning, Lecture Notes in Computer Science, LNCS 7973 (III) (2013) 324–339

MLl. Marsal, I. Boada, 3D-VUPID: 3D Visual Urban Planning Integrated Data, Lecture Notes in Computer Science, LNCS 7974 (iV) (2013) 17-32

The following papers have been sent for publication:

MLl. Marsal, J. Meléndez, J. Colomer, Lessons in Urban Monitoring taken from Sustainable and Liveable Cities to better address the Smart Cities Initiative: The need for Intelligent Indices. Sent to Technological Forecasting & Social Change (Elsevier) 2012 Impact Factor: 2,106 (1Q)

MLl. Marsal, B. López, Smarter Urban Planning: Designing Urban Land Use from Urban Time Use. Sent to Social Indicators Research (Springer) 2012 Impact factor: 1,264 (2Q)

MLl. Marsal, R. Fabregat, Modelling Citizens' Urban Time Use using an Adaptive Hypermedia Survey to obtain an Urban Planning, Citizen-Centered, Methodological Reinvention. Sent to Time and Society (Sage) 2012 Impact factor: 0,528 (3Q)

NOTE :

On July 2013, the Method Smarter Urban Planning has been submitted to the United States Patent Office to apply for a US patent.

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ACKNOWLEDGMENTS

Special thanks to my thesis director, Beatriz López. It has been a long and fruitful collaboration. Besides the thesis, we worked together in the preparation of an article about the Method presented in this thesis which has been sent for publication. More importantly, the Method Smart Urban Planning disclosed here is being submitted for a patent in the United States. Regarding the patent, on behalf of Bea and myself, we want to thank the University of Girona, and more specially the Research Vice-Rectorate, and the Research and Technology Transfer Office, for their economic support and technical assistance, respectively.

Before this doctorate, I received a Master of Science in Applied Informatics, Automatics and Systems Computation at the University of Girona. I want to thank the professors for the advice and support given during the preparation of content that has now become parts of this thesis. Special thanks to Joaquim Meléndez and Joan Colomer, who helped me in the preparation of the Background Art, more precisely in the use of PCA to elaborate a summarizing index. I am grateful to Ramon Fabregat, who provided me with substantial material to prepare the adaptive hypermedia survey model. Thanks to Imma Boada, who carefully corrected and provided valuable suggestions on the model for integrated visualization and representation of urban planning data. And to Josep Lluís de la Rosa, who gave me interesting suggestions and ideas during the preparation of the agent-based collaborative model. Additional thanks to Josep Lluís de la Rosa and Imma Boada for their economic support in the participation at ICCSA 2013 (International Conference in Computational Science and its Applications), we presented two papers related to the research on agents and visualization, respectively; also published in two issues of Lecture Notes in Computer Science.

Finally, it is important to mention my research group, eXIT, Research Group on Intelligent Systems, who welcomed an architect and doctor in urban planning who was extremely thirsty to learn about intelligent systems, with the desire to contribute to making smarter urban systems.

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ABSTRACT

In this dissertation we propose an objective method for updating traditional urban planning methodologies based on input from citizens regarding their current and future urban requirements. Specifically, our methodology is based on citizen web – based surveys regarding urban time use allocation and opinions concerning how to cover urban needs, and on the use of data mining tools to process the collected data. The Smart Urban Planning Method allows to obtain new planning values for urban land use design using an innovative conversion rule which transforms the daily distribution of urban time use into quantities of urban land use.

The Smart Urban Planning Method presented here is accompanied by different insights which provide methodological extensions. These extensions aim to identify difficulties and problems associated with the research topic and bring to light potential solutions. These insights are developed in the form of models. Precisely, we provide a first model that uses a hypermedia adaptive survey to gain voluntary participation from citizens. A second model covers the very much needed integrated representation and visualization of urban data. The final model is based on agent technology for more meaningful public participation in urban planning.

We test our Method by experimenting with a case study on the specific urban sub-system of public facilities and services, and use Girona Province as a pilot area. Our novel Method obtains new, objective, and more accurate design values for the planning of facilities and services using citizens' satisfaction thresholds. In addition, as an example of further application of the Method, we develop a municipal classification on self sufficiency in the services and facilities subsystem according to citizens' satisfaction values.

RESUM

En la present dissertació proposem un mètode objectiu per a l'actualització de les metodologies tradicionals de planificació urbanística basat en l'opinió dels ciutadans al respecte dels seus requeriments urbans presents i futurs. Específicament, la nostra metodologia està basada en enquestes web a la ciutadania per conèixer com distribueixen el seu temps urbà i en la opinió de com cobrir les seves necessitats urbanes. S'utilitzen eines de mineria de dades per al processat de les dades recollides. El Mètode Smart Urban Planning permet obtenir nous valors de planificació urbanística per al disseny dels usos del sòl amb la utilització d'una innovadora regla de conversió que transforma la distribució diària del temps urbà en quantitats d'usos del sòl urbà.

El Mètode Smart Urban Planning presentat en la tesi s'acompanya de diferents introspeccions que proporcionen extensions metodològiques. Aquestes extensions (anomenades "insights") pretenen identificar dificultats i problemes associats amb el tema de la recerca alhora que aportar llum o fins i tot una possible solució. Aquestes introspeccions s'elaboren com a models. Concretament, aportem un primer model que utilitza enquestes hipermèdia adaptatives per a guanyar participació voluntària del ciutadà. Un segon model per la més que necessària representació i visualització integrada de les dades urbanes. I finalment, un model basat en tecnologia agent per a una participació ciutadana en la planificació urbanística més representativa.

Provem el nostre Mètode experimentant amb un cas d'estudi en el subsistema urbà dels equipaments i serveis públics, i emprem la província de Girona com a àrea pilot. El nostre Mètode innovador obté nous valors de disseny per a la planificació urbanística dels equipaments i serveis més objectius i acurats a partir d'índexs de satisfacció ciutadana. Addicionalment, com a exemple d'altra aplicació del Mètode, desenvolupem una classificació municipal en termes de autosuficiència d'acord amb els valors de satisfacció ciutadana per al subsistema dels equipaments i serveis.

RESUMEN

En la presente disertación proponemos un método objetivo para la actualización de las metodologías tradicionales de planificación urbanística basado en la opinión de los ciudadanos al respecto de sus requerimientos urbanos presentes y futuros. Específicamente, nuestra metodología esta basada en encuestas web a la ciudadanía para conocer cómo distribuyen su tiempo urbano y en la opinión en cómo cubrir sus necesidades urbanas. Se utilizan herramientas de minería de datos para el procesado de los datos recogidos. El Método Smart Urban Planning permite obtener nuevos valores de planificación urbanística para el diseño de los usos del suelo con la utilización de una innovadora regla de conversión que transforma la distribución diaria del tiempo urbano en cantidades de usos del suelo urbano.

El Método Smart Urban Planning presentado aquí se acompaña de distintas introspecciones que proporcionan extensiones metodológicas. Estas extensiones (llamadas “insights”) pretenden identificar dificultades y problemas asociados con el tema de la investigación a la vez que aportar luz o incluso una posible solución. Éstas introspecciones se desarrollan cómo modelos. Concretamente, aportamos un primer modelo que utiliza encuestas hipermedia adaptativas para ganar participación voluntaria del ciudadano. Un segundo modelo para la más que necesaria representación y visualización integrada de los datos urbanos. Y finalmente, un modelo basado en tecnología agente para una participación ciudadana en la planificación urbanística más representativa.

Probamos nuestro Método experimentando con un caso de estudio en el subsistema urbano de los equipamientos y servicios públicos, y utilizamos la provincia de Girona cómo área piloto. Nuestro Método innovador obtiene nuevos valores de diseño para la planificación urbanística, más objetivos y precisos a partir de índices de satisfacción ciudadana. Adicionalmente, cómo ejemplo de otra aplicación del Método, desarrollamos una clasificación municipal en términos de autosuficiencia de acuerdo con los valores de satisfacción ciudadana para el subsistema de los equipamientos y servicios.

1. INTRODUCTION

In the context of the Smart City initiative we present the Smart Urban Planning Concept. The concept stands for the need to reformulate the planning values used for designing and establishing the distribution and use of urban land. Depending on the legal system in a particular country, planning values can be either recommendations or mandatory standards. In many countries, planning values have not been updated since their creation, commonly during the 1970's, and they are based on the subjective thinking of planners.

Nowadays, ICT opens new opportunities to tackle urban planning. In this thesis, we propose the Smart Urban Planning Method, a methodology that takes advantage of ICT to obtain planning values according to citizens' needs. The Method is based on how citizens use and want to use their city. The Method uses a survey to learn about the current and desired urban time use distribution of citizens. Next, the Method transforms urban time use results into urban land use amounts, a pioneering and objective approach to reformulate urban planning values.

1.1. Problem: the obsolescence of urban planning design values and disillusion with the urban planning approval process

The main purpose of the urban planning discipline is to meet the urban needs of citizens. These are for the most part focused on decent and affordable housing, convenient public transport, accessible and sufficient public services placed in public facilities, and safe and livable public spaces. All of these basic urban planning purposes are in crisis, due to:

a) Obsolescence of the planning values (and thus rules and procedures) used by urban planners, and

b) The impoverished role of citizens in the overall planning process

Each of these problems is discussed in turn, below.

1.2. Traditional Urban Planning methods are based on obsolete and subjective planning values. Urgent updating and revision are needed

Traditional urban planning methods consist of rules and procedures which are based on planning values, which are in large part derived from the experience of urban planners. Therefore, traditional planning proposals are not only subjective, but sometimes even biased, due to political and other influences. Urban Planning Acts generally provide recommended values and/or planning standards for the amount of urban lands and their allocated uses (such as public spaces, facilities, housing, roads, commercial, etc.). Many of these recommended values and planning standards were created during the urban planning exercises of the 1970's, or even earlier. Since this foundational era, most countries have failed to update their urban planning design values, and still use them as the basis for city master plans. Even updated and recent city master plans are often based on antiquated planning design values. This situation must be addressed now. Cities are completely different, and the needs of citizens have changed dramatically.

New data for the revision of urban planning design values must come from the actual experience of citizens, and be based upon their opinions and desires concerning their urban needs and how they want to use their cities.

1.3. Traditional urban planning participatory processes are merely validation tools, which do not improve urban design. A more citizen-centered participatory model based on public opinion is required

Traditional public participation in the urban planning approval process consists mainly of citizen validation of proposed master plans. It is normally organized as a three-step approval process, requiring a public vote before passing to the next step. First of all, the basic city design schema is submitted for the so-called *master plan initial approval*, which is binding at the municipal level. At this point, citizens can only express whether or not they like the first initial layout. The second step, which is called the *master plan provisional approval,* involves a more detailed proposal, which is binding at the regional level and involves the regional administration (if it has jurisdiction under national law). Once again, citizens are only empowered to accept or decline the master plan. The third and last step, the *master plan final approval,* corresponds to the regional or even national administration, and the role of citizens is still restricted to validation.

Public participation in the urban planning approval processes can no longer be a mere formality, limited to the validation of master plan proposals. Societies and municipalities are much more "social" than forty years ago. Citizens want cities and their governing bodies to serve them in the most optimal fashion. Using new technology, social media, and enhanced access to information, citizens want to be acknowledged, empowered, engaged, informed, and given multiple avenues to contribute to the design of their cites and the ways that their lives unfold. Citizens will not accept public participation which is structured as a formality, completing an administrative approval process that took place behind closed doors. Therefore, urban planning processes should expand the role of citizens and integrate their opinions in the earliest stages. Citizens are and need to be treated as the source of the most important and up-to-date data that must form the basis of urban planning values and standards.

To revise and update planning values, and make them correspond to the needs of citizens, we propose a more citizen-centered approach and expanded public participation as part of a Smart Urban Planning Method. Our methodology, set forth below, utilizes web-based opinion surveys and data mining tools to establish new values and rules for urban planning. Proof of concept is presented through a Study Case on public services and facilities urban sub-system in Girona Province (Catalunya, Spain).

1.4. Concept and main objective: Smart Urban Planning

The main objective of this work is to update urban planning values to better meet the needs of citizens through the use of ICT tools that reinvent public participation in urban planning. The Smart Urban Planning Method is designed for this purpose.

The proposed Smart Urban Planning Method consists on an objective approach that reinvents obsolete traditional urban planning. It uses a rule of correspondence and indicators of equivalence between urban time use and urban land use as innovative and pioneering tools for updating urban planning design values.

To develop the Smart Urban Planning Method we use the inverse engineering concept, under which the initial parameters are unknown and must be determined in relation to the desired target. In other words, this determines the causal parameters for an observed or desired effect. Solving a problem using inverse engineering techniques usually requires two computational tasks: first, simulating the problem, and second, selecting the optimal solution. In the context of the Smart City Initiative, the Smart Urban Planning Method addresses the problem of obsolete urban planning design techniques. It does so by meeting the urban needs of citizens (target) through an ICT-based citizen-centered method (solution), collecting data regarding the desired use of the city (simulation) for establishing the new urban planning design values (initial parameters).

1.5. Thesis overview and additional objectives

The Smart Urban Planning dissertation follows the classical presentation of a scientific experiment:

1. Introduction
2. Background and state of the art
3. Methodology
4. Applications of the Methodology
4. Results and Discussion
5. Conclusions and Further Research

In addition to describing the experiment through the different chapters, methodological insights are provided in order to explore further aspects of the Smart Urban Planning Method. These additional insights and explorations are presented as subchapters of the Methodology chapter. These *insights* have a technological nature, presenting a problem or a difficulty and attempting to provide a technical solution. Therefore, this thesis has additional sub-objectives and achievements, which are the following:

In chapter 2, Background and state of the art, a problem relating to the need for intelligent indices is presented. In an attempt to solve the problem, we analyze two ideas for monitoring the Smart Cities initiative in a better way. In developing the first idea, we study past and on-going initiatives in the field of Sustainable Cities and Livable

Cities and their respective monitoring indicators to demonstrate that not only is a set of indicators needed for efficient monitoring, but also a final synthetic or aggregative index to visualize the initiative's achievements. Specifically, we essay the construction of synthetic indices using principal component analysis (PCA). The second idea attempts to anticipate the changes needed, especially with regard to data collection, to be introduced in current monitoring practices to assess a city's "smartness" accurately. We test the use of real-time data instead of historical statistics as the basic information with which to construct a set of indicators to explain the initiative. A final index summarizing Smart Cities' real-time set of indicators is presented in the summary.

In chapter 3, the Methodology of the Smart Urban Planning Method is presented. Our methodology is based on citizen web-based surveys regarding urban time use allocation and opinions concerning how to cover urban needs, and on the use of data mining tools to process the collected data. The new planning values for urban design are obtained from an innovative conversion rule which transforms the daily distribution of urban time use into quantities of urban land use. The opinions of citizens concerning how to cover their urban needs and associated time use allocation are used to establish equivalence results, and re-calibrate and improve current urban land use.

Also in chapter 3, methodological insights are presented. We propose a more sophisticated survey which uses adaptive hypermedia techniques to gain voluntary participation from citizens to ensure good representation of all ages and social groups. The adaptive hypermedia techniques we propose combine stereotype and feature-based models, which we explore in order to include them in the survey. The combination of stereotype and feature-based models has different advantages, among others: stereotype techniques avoid initiating survey profiles from scratch and feature-based techniques allow a personalized questionnaire to be employed. Moreover, personalization, in combination with user profiles, allows prediction which is of great interest for this project due to its planning purposes.

A second insight related to the visualization and representation of the new urban planning values obtained from the Smart Urban Planning Method is presented. The new urban planning values are part of the urban information used during the elaboration of master plans. Urban information is integrated (technically called "represented") by statistics, indicators and indices. Urban planning values are mandatory (in some countries recommended) indicators and/or indices. The overall set of urban information can be visualized in graphics, maps, Geographic Information Systems (GIS), 3D images, and simulations. Cities use urban information portfolios for planning purposes but, unfortunately, these are usually represented separately and visualized in independent tools. This leads to complex and time-consuming information management requirements and data redundancies. To the best of our knowledge, there have never been any attempts to represent and visualize the urban information portfolio of a city in a single or unitary piece of software. Our proposal is a Model which integrates information representation and visualization in urban planning. The Model is designed to converge, organize, and map all urban information related to the urban planning activity in a common framework and to depict it in a simple, understandable way. Additionally, our proposed Model provides customized updates and gathers available open data and mobile internet anonymous data.

A final insight presenting the problem of participation in urban planning is provided in chapter 3. An agent-based collaborative model for more meaningful public participation in urban planning is presented. The Model is designed to greatly increase public participation in urban planning and make it more citizen-friendly, to automate data collection processes, and to ease the verification of results. We use an agent technology consisting of a pair of opinion-miner recommender agents which, through mining of the opinions of citizens, make recommendations to planners on the design of the master plan. The advantages of using recommender agent technology in our DSS

Model are that it accelerates acceptance of planning proposals and creates more participatory urban planning. A particularly innovative feature of our Model is that public participation occurs both before and during the development of the master plan, and in a citizen-friendly way. With our Model, planners come up with citizen-sensitive proposals and are able to more accurately predict the reaction of citizens to them. The case of the redesign of the Diagonal Avenue in Barcelona is provided as a concluding example.

In chapter 4, as an example of further application of the Method, we analyze how rules for self-sufficiency classification and sub-classification of municipalities can be generated through the land-uses values obtained with our method. We use the corrected values of the conversion rule to classify the municipalities into those which satisfy the needs of citizens and those which do not. To refine the classification, more data from municipalities is required, which is often unknown. Therefore, we analyze and discuss how missing data can be treated in this context to enable classification.

In chapter 5, results of the implementation of the Smart Urban Planning Method in the case study of the Girona area are presented. The outcome is new urban planning values for urban land uses which are citizens' satisfaction thresholds for the corresponding urban activities.

Finally, in chapter 6, conclusions and recommendations for further research are presented. The conclusions highlight the need for updating urban planning standards and the value of our ICT-based citizen-centered Method, since it is proven to be successful in the Girona case study. Our novel Method makes it possible to obtain new, objective, and more accurate design values for urban planning. In addition, it stimulates and inspires public participation in the urban planning approval process, changing citizens from passive valuators to active partners and designers. The next research steps will investigate what needs to be done to integrate the urban planning values obtained with our Method in an Intelligent Index which would monitor the Smart Cities initiative.

2. BACKGROUND AND STATE OF THE ART

Standards and recommended values, as part of indicators and indices in general, are indispensable, not only as a mechanism to ensure legal compliance with practices such as urban planning, but also to follow up the evolution of initiatives and actions. Urban planning standards, as a set of indicators which regulate urban land uses, are part of Smart Cities measurement. In this chapter we analyze different proposals for indices to measure and monitor the Smart City. In future developments of our Method, the new planning values should have the intelligent index features described in this chapter.

2.1. Introduction: on the need for a synthetic index to visualize the monitoring of urban strategies

It can be said that urban monitoring started with the Earth Summit of 1992, a pioneer event in promoting the role of cities on the road to sustainability. Out of the summit came the so-called Aalborg Charter, which began the assessment of the sustainability of cities. By 1995, more than 1,200 cities all over the world had ratified the charter. The main agreement reached by the signatories was to draw up their own Local Agenda 21, consisting of a set of indicators to monitor sustainability. From 1995 and over a period of approximately ten years a number of cities did this. Since 2006, however, sustainability monitoring has decreased considerably. In our opinion, the lack of a synthetic index summarizing the overall set of sustainability indicators is the reason behind LA 21's failure, a claim which is analyzed in the following section.

Concurrent with the start of the Local Agenda crisis, in 2005, a new set of global indicators appeared. Quality of Life indicators were proposed as a way of assessing a city's livability. The promoter of this new urban monitoring was a private corporation, Mercer, a human resources and related financial services consultancy, with its headquarters in New York City. Mercer is the world's largest human resources consultancy, operating in more than 40 countries. Prior to launching its livability monitoring indicators and index, the so called Mercer's Quality of Living Reports, the firm was well-known for its ranking of cities in terms of cost of living, and its list of the world's most expensive cities for expatriate employees. Mercer's quality of life reports are published on a yearly basis for 221 major cities all over the world. All its surveys are updated yearly. Besides Mercer's there is another measure of livability accepted world-wide: The Economist Intelligence Unit's quality-of-life index. Indicators and the final index were first calculated in 2005 and included data from 111 countries. Unlike Mercer's, The Economist index ranks both countries and cities, making use of Mercer's data for cities. The Intelligence Unit is an independent company within The Economist Group, a world leader in the field of financial information. The unit provides tailored advisory, management and analysis services to companies. It is known for its e-readiness index (concerning the effective use of ICT technologies to boost countries' economies and welfare provision) and democracy index (a measure of the level of democracy in both UN and non-UN countries).

Although both Mercer's and The Economist's sets of indicators and final indices have a shorter history, they look more promising than local agendas. Both summarize a combination of subjective life-satisfaction and objective quality of life indicators in an aggregated index which makes their well-known rankings of countries and cities possible. The need of synthetic indices is not only for comparison matters out of a certain ranking. In our opinion, in today's era of information excess it is crucial to synthesize the large amounts of available information in small but representative visualizations, and both Mercer's and The Economist Intelligence Unit seem aware of that when drawing up their indices. Proof that quality of life indices are successful is that middle-sized cities not included in these reports produce their own quality of life indicators and indices, and the number of them doing so is growing every year. This is exactly the opposite of what has occurred with local agendas that assess a city's sustainability. We take a deeper look at the success story of quality of life indices in the third section of this chapter.

In recent times the Smart Cities initiative has expanded all over the world. It was around 2009 when the concept began to be globally understood as the target for any city to achieve, no matter what its size. The initiative developed out of the previous experiences of environmentally friendly and livable cities, embracing the concepts of sustainability and quality of life but with the important and significant addition of technological and informational components. Reliable indicators do not yet exist to measure how “intelligent” cities are, and neither does a summarizing index, but interest in the initiative is growing and it will not be long before the worlds of academia, business and government start to take notice. Besides the analysis we make about the use of real-time data to develop a Smart Cities set of indicators - learning from the previous experiences of sustainable cities and livable cities - we study the goodness of the elaboration of a synthetic indicator to summarize a city’s “intelligence” or “smartness”. In the fourth section of this chapter we explain the different sources of real-time data available for developing the latest generation of indicators for monitoring a city’s smartness. The summary recaps on the need for a final synthetic index of the Smart City set of indicators, to make it possible to easily visualize a city’s steps towards “smartness”.

2.2. Learning from the Sustainable City and the problems with the LA 21 set of indicators

Local Agendas 21 were conceived of as a sustainability agenda based in the principles of urban ecology [42]. From the origins of the sustainability movement, sustainable development was projected as an activity best generated and most appropriate at a local scale. This localization of the phenomenon was central to the design of the agendas [6]. Their local character resulted in their application to not only big and medium sized cities but also to small towns in non-developed countries [186]. LA 21s have a proven capacity to enhance sustainability and the quality of the urban environment for the benefit of citizens, but the road to sustainability through LAs has only been in existence for 10 years. In our opinion, the lack of a summarizing indicator giving information about a city's overall sustainability level, thereby allowing comparisons and rankings between cities, has been their big mistake. Since the beginning, LA 21 contained a standard set of indicators with few variations when it was applied locally.

The Barcelona Local Agenda 21 Indicators

(26 indicators in total organized in 11 strategies)

Strategy 1: Protection of green spaces and biodiversity and increasing urban green spaces

1. Green area per inhabitant

2. Birds Biodiversity

Strategy 2: Defense of a compact and diverse city, with a quality public space

3. Availability to public spaces and basic services

4. Index of urban renovation

Strategy 3: Improve mobility and make pedestrian life a welcoming setting

5. Modes of transport of the population

(5.1 bicycle and on foot; 5.2 public transport, 5.3 private vehicle)

6. Proportion of streets with priority to pedestrians

Strategy 4: Obtain optimal levels of environmental quality and create a healthy city

7. Level of noise pollution

8. Environmental quality of the beaches

9. Quality of the air (9.1 Ozone concentration; 9.2 NO2 concentration)

10. Birth life expectancy

Strategy 5: Conserve natural resources and promote the use of renewable ones

11. Total water consumption per inhabitant

12. Public consumption of groundwater

13. Energy consumption from renewable sources

Strategy 6: Reduce waste production and strengthen the culture of reusing and recycling

14. Generation of urban solid waste

15. Collection of organic material

16. Selective waste collection

Strategy 7: Increase social cohesion; enforce mechanisms for equity and participation

17. Academic failure

18. Population finishing university studies

19. Accessibility to housing

(19.1 proportion of the overall household incomes needed to buy a new house; 19.2 annual amount of renting contracts; 19.3 square meter average price of a rented house)

20. Degree of association

21. Participation in municipal affairs

Strategy 8: Foster economic activity oriented towards sustainable development

22. Number of organizations with environmental certification

Strategy 9: Progress in a culture of sustainability through environmental education and communication

23. Number of schools that participate in environmental education projects

Strategy 10: Reduce the city's impact on the planet and promote international cooperation

24. Annual equivalent CO_2 emissions

25. Number of points of sale or consumption of fair trade products

Strategy 11: Indicator related to all the objectives of aforementioned commitment to sustainability

26. Degree of citizen satisfaction

Fig. 1. *List of strategies and their indicators contained in Barcelona's LA 21*

Own elaboration based on Barcelona's LA21 indicators

Above we exemplify the LA 21 set of indicators using the city of Barcelona [2], in Spain. We use PCA to examine the relationship between indicators in a set defining Local Agenda 21 for Barcelona, in order to determine the number of principal components representing the indicators and the feasibility of using them in a synthetic sustainability index.

Principal component analysis (PCA) has been demonstrated to be a very useful technique with which to synthesize sets of monitoring indicators. PCA is a mathematical procedure that uses a linear transformation to convert a set of correlated variables into a set of linearly uncorrelated variables named principal components. The number of principal components is less than or equal to the number of original variables. This transformation is defined in such a way that the first principal component has the largest possible variance and each succeeding component in turn has the highest variance possible. A reduction of data dimension can be obtained while substantial information is retained in the new data set. Stated another way, the ratio of information comprised in the dimension of the new data set is increased. In addition to the reduction of dimension, PCA models can be utilized to construct two statistics frequently used in monitoring processes, the Q-statistic and the Hotelling's T2 statistic. The Q-statistic corresponds to the non-modelled, supposedly non-informative part of the data set. Therefore, this measure shows the lack of fitness of a (new) observation for the model. The Hotelling's T2-statistic is the squared distance from the projection of a (new) observation onto the center of the model.

We can find some significant examples in the urban context. Wong [203] uses PCA to examine the relationships amongst a set of indicators defining Local Economic Development (LED). Based on a conceptual framework of 11 factors widely perceived to be the major determinants of local economic development, 29 indicators were identified to measure these factors. The author, besides examining the structure of relationships among the LED indicators compiled, used PCA to explore the spatial patterns emerging from the analysis. A series of multiple regression models were then calibrated to investigate the relative strengths of relationships between the LED indicators and suggested performance variables. Still in the area of urban economics but turning to urban functional analysis, Chen et al. [37] used principal component analysis, cluster analysis, and location quotient methods to analyze the economies and industries of cities in the Xinjiang region of China, assessing factors such as urban scale, growth pole level, specialization sectors and industry gradients. In the field of real estate economics, Li [112] aimed to solve contradictions between the certainty of fixed reference land prices at a certain time point and the uncertainty of land price changes, which lead to difficulties in the application of reference land prices using principal component analysis to select the main factors affecting land prices.

Focusing more on environmental monitoring, Liu et al. [118] utilized PCA methods to perform a qualitative and quantitative analysis of the spatial and temporal distribution of various eco-environmental factors, in order to determine the main features that impact on the eco-environment. Tu and Lin [185] conducted a principal component analysis using collected data sets of citizens' perceptions of residential environmental quality in order to extract the major scales and factors of the residents' assessments. PCA was performed with the results of a questionnaire consisting of 45 questions which was administered to 240 residents randomly selected from 80 residential buildings in residential-commercial mixed-use zones. Combining environmental issues with social monitoring, Takano et al. [176] used PCA to study the associations between public spaces filled with greenery located near residential areas and easy to walk to, and the longevity of senior citizens in a densely populated developed megacity.

Examples of PCA can also be used to study urban patterns. Weng et al. [199] analyzed the spatial patterns of urban land surface temperatures (LST) and examined the factors contributing to LST variations using PCA, with potential factors being grouped into different categories. PCA helped to determine the relative importance of each group of variables within its category. Qi et al. [144] constructed an index on urban land gradation which considered 12 factors (commercial/services prosperity, road access, public and external transport convenience, infrastructure, public services, cultural/sport facility maturity, natural conditions, environmental quality, population density, industry clustering and urban planning) to finally develop a system consisting on 35 indicators. PCA helped to analyze the index system on urban land gradation. Ewing et al. [59] consolidated the variables which define urban sprawl using PCA. The variables considered were density, land use mix, degree of centering, and street accessibility. These were then related to other factors such as vehicle ownership, commute mode choice, commute time, vehicle miles traveled per capita, traffic delay per capita, traffic fatalities per capita and 8-hour ozone level, to analyze how the factors affected the variables and vice versa. The study of the correlations was made with multiple regression analysis. Finally, Li and Yeh [113] developed a PCA to reduce errors in multi-temporal images. Multi-temporal images are usually used to monitor urban expansion for change detection, but tend to over-estimate land use changes because classification signatures have been inadequately created. The authors demonstrated that PCA could reduce such errors and provide a more reliable method for monitoring rapid land use changes and urban expansion.

Similarly to Wong [5] we use PCA to analyze a set of indicators, but then go one step further by testing to aggregate indicators in a single index. As just seen in the state-of-the-art of PCA applications, there have been no attempts to use PCA to elaborate a value summarizing a data set. This is the target of our experiment, as presented hereafter.

We use data corresponding to the Barcelona Local Agenda 21 set of indicators for 11 years (from 1999 to 2009) to obtain a PCA model. From the original set of 30 indicators described in figure 1, only 24 have been selected, because of lack of information regarding the other 6.

Results from our experiment show how the set of indicators is extensively represented in the first component, accumulating more than 70% of variance. This means that all the original indicators are highly correlated. For this reason, in our experiment, only one principal component has been chosen as the proposed LA 21 synthetic index. In a different experiment, if more than a principal component would be required, the Hotelling's T2-statistic could be use to summarize the information in the proposed synthetic index.

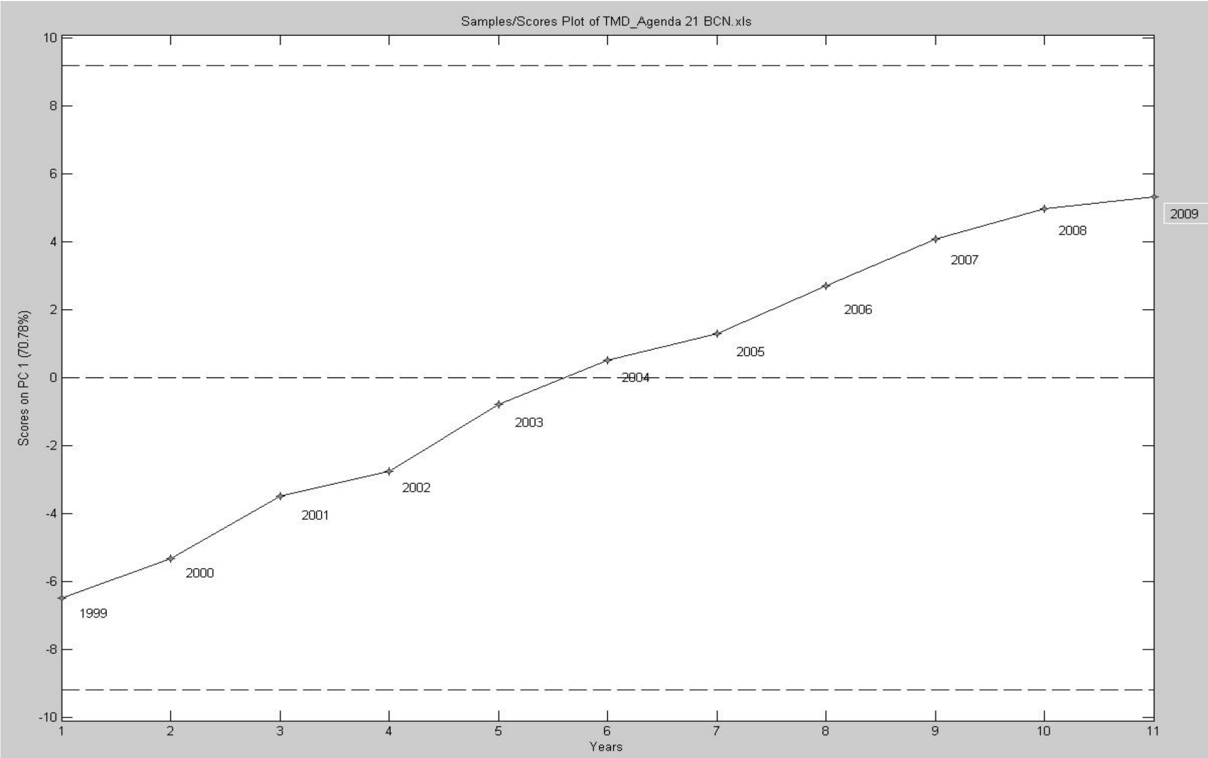


Fig. 2. *Shows the sequential development of the first PC over 10 years. Own elaboration*

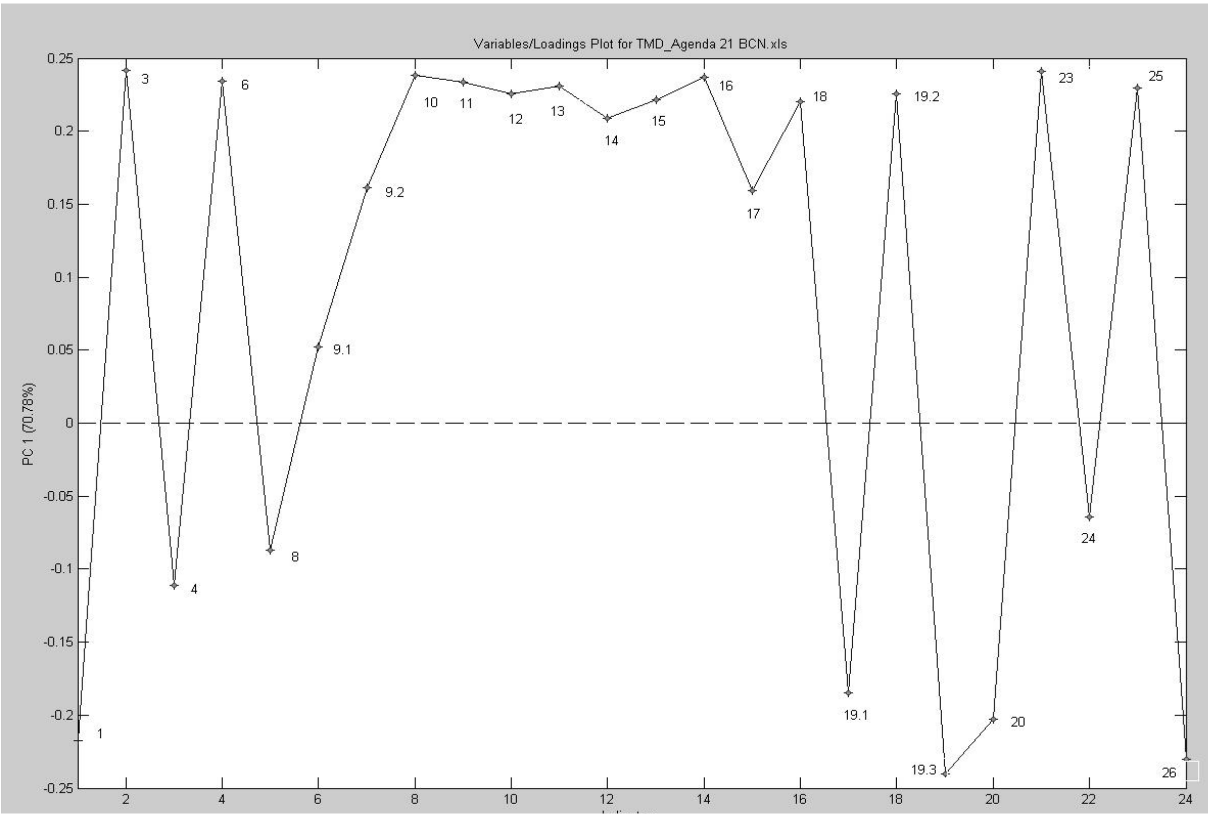


Fig. 3. *Shows each variable contribution (indicator) in the construction of the first PC. Own elaboration*

The way each original indicator is represented in the new index can be easily observed by means of the so-called loadings. In our experiment (see figure 2), it is interesting to note that a significant number of indicators (14 of 24) have approximately the same loading. This means that from a statistical point of view, they are highly correlated. They have similar behavior during the observed period of time, and consequently their role in the PCA model is also similar. Negative loadings show that the role of some indicators to the LA 21 synthetic index diverges from the rest.

Finally, figure 3 shows the temporal evolution of the proposed synthetic index (first principal component) over 11 years (from 1999 to 2009). In our experiment, the first PC successfully summarizes the set of LA 21 indicators. The LA21 summarizing index (figure 3) shows us how the city of Barcelona has better compliance with LA 21 objectives every year. For the Barcelona case study, the utility of the proposed LA21 index is demonstrated.

2.3. Learning from the Livable city and the successful QoL index

The livable city initiative monitors a city's welfare and well-being with a quality of life (QoL) index. The term quality of life should not be confused with the concept of standard of living, which is solely related to income. The standard set of QoL indicators proposed by both Mercer and The Economist Intelligence Unit includes data on wealth, employment, urban environment, social health, education, time-use, family and community services. In both cases, an aggregated index summarizes a QoL set of indicators. QoL data is collected from two different sources: life-satisfaction surveys of citizens, providing a subjective view of a population's emotional well-being in various life domains, and quality of life indicators, an objective evaluation of more socio-economic factors. Results of life-satisfaction surveys are primary data and hence surveys are designed specifically for that purpose. In contrast, objective data to capture the social and economic dimensions comes from secondary sources such as a city's or country's statistical offices[1].

Mercer publishes its quality of life survey annually. Initially, it was conceived as a tool to help employees planning to work abroad and companies that were opening new businesses and needed to know what conditions to offer their expatriate employees. The survey measures 39 criteria grouped in 10 key or categories (see picture below). The criteria have different weights according to their importance. New York serves as benchmark, with a score of 100, and other cities are ranked in relation to this baseline. The survey compares 221 of the world's major cities [131].

The second widely recognized and important index measuring QoL is the one published by The Economist Intelligence Unit, which uses data from Mercer. However, unlike Mercer's The Economist index ranks both countries and cities. If we compare the criteria used by the two organizations (see pictures below and above) we quickly notice that The Economist uses fewer indicators: 9 as against 39. In reality, from a much wider set of indicators than the 9 displayed, The Economist selects the correlated variables which would explain more than 80% of the inter-country variation using a regression model, and ends up with the 9 shown below. To create the final index, these 9 indicators are weighted in an equation using the so-called Beta coefficients [179]. The indicators weighted most are health, material wellbeing, political stability and security. These are followed by family relations and community life. Next and last in order of importance are, climate, job security, political freedom and gender equality [179].

[1] In European countries, a large set of data can be obtained from the Urban Audit of the European Office of Statistics (Eurostat). This monitors the quality of life in 321 cities with 338 indicators. The data set covers the following domains: demography, social and economic factors, civic involvement, training and training provision, environment, travel and transport, information society, culture and recreation. Beside these objective data, the Urban Audit provides perception surveys as well. The last perception survey was conducted in 2009 in 75 European cities. In random telephone interviews, 500 citizens per city were asked about their perception of the quality of life in their city (European Office of Statistics, Eurostat).

Regarding indicators that were not considered (variables accounting for the remaining 20% of inter-country variation), these were education level, rate of real GDP growth and income inequality (the Gini coefficient). The most significant correlation amongst these variables is between education and overall life-satisfaction, as education has an impact on incomes, health and possibly on political freedom [179].

Brief reference should be made to two international journals that publish less well-known annual lists of most livable cities. In their lifestyle magazine the media company Monocle (Monocle, Top Livable Cities ranking) [134] lists the world's 25 top livable cities according to criteria similar to that seen in the previous surveys. And, International Living Magazine, which recommends the best places to retire to, travel to, buy real estate in and enjoy life, ranks 194 countries yearly according to their quality of life. To produce its index, the journal uses governmental sources such as the World Health Organization, United Nations and others like The Economist. Nine factors, similar to those seen for the previously mentioned indices, are given weightings: cost of living, culture and leisure, economy, environment, freedom, health, infrastructure, safety and risk, and climate [87].

There is a growing interest in monitoring quality of life not only for the world's largest cities but for others as well, as a way to sell an image and attract new residents and businesses. Not being rated in the Mercer and Economist lists is not an issue for small and medium sized cities; it is reasonable to suppose they can demonstrate elsewhere their quality of life. Local and national governments are behind these efforts. For instance, the UK Government has drawn up local quality of life indicator guidelines to support livability monitoring in UK municipalities [188]. Accordingly, cities, Bristol [21] and even London (although ranked in the QoL surveys already mentioned) [122] publish their QoL scores in line with the UK government's proposed indicators [121]. Quality of life indicators are also drawn up at regional level; South Gloucestershire [170] and Wales [195] or Shropshire [162] county are examples.

In the US, we find QoL indicator guidelines published by universities, such as the University of Wisconsin's [189]. As an example of a city publishing the values of QoL indicators we have Jacksonville (Jacksonville Community Council) [88]. North West Indiana is an example at regional level [136]. In India, QoL indicator guidelines for cities have been produced by that country's government in collaboration with an NGO [84]. Those proposed by the government of New Zealand [135], or by the city-state of Hong-Kong [78], or the Canadian city of Edmonton [53] are further examples of governments working to disseminate the quality of life of their cities.

The research community has also shown itself to be interested in the subject of quality of life, for the most part focusing on the study of the monitoring indicators. In general terms, Senecal and Hamel [160] relate urban quality of life and a city's sustainability with a compact model pattern. Still in a general frame, Fahy and Cinneide [60] have researched QoL criteria to produce an operational framework to assess quality of life in an urban setting. The same authors [61], in a more focused study, state that subjective QoL indicators are unlikely to be acceptable or particularly useful unless they are designed in close consultation with the target populations. The authors defend the use of community derived quality of life indicators instead of standard life-satisfaction surveys. Campanera et al. [31] have researched QoL indicators that would allow better comparison between urban-classified and rural-classified municipalities. Lee [109] proposes a set of indicators to evaluate the quality of life of urban dwellers with regard to the semi-public spaces of high-rise mixed use housing (HMUH) complexes in order to help in the design of more livable complexes. Lastly, Galster et al. [66] have studied the key factors eroding neighborhood quality of life. This study was carried out in US metropolitan areas. The findings showed that the poverty rate, male unemployment, the overall adult unemployment rate, the female headship rate for families with children, and the secondary school drop out rate, were the most important factors in determining a neighborhood's quality of life.

Although the efforts of both governments and academia to research and improve QoL indicators for small and medium-sized cities are of great value, a synthetic index is essential to make these efforts both more comparable and easier to assess.

2.4. The Smart concept

Mention needs to be made of the close connection between the quality of life concept and the "transitional initiatives" to the Smart Cities concept. Richard Florida's concept of the creative city (2002) is a compelling argument about urban development and its dependency on novel combinations of knowledge and ideas. The concept is based on the assertion that certain occupations specialize in the creative task. People in these occupations are drawn to areas providing a high quality of life, and therefore it should be an essential development strategy for cities to create an environment that attracts and retains those workers [129].

More or less in parallel with the concept of the creative city appeared the concept of the digital city (2004) or e-city, focusing more on the idea of a "connected community", combining broadband communications with government open data and open industry standards as a way to enhance the quality of life of "e-citizens" [45]. Before going further into the Smart City concept we should mention the knowledge city concept (2008), with closer connections to specialized education as a key issue for ensuring a society's long-term quality of life. The Knowledge City can be considered a "bridging initiative" to the Intelligent City [149] or better known Smart City.

Despite its apparent novelty, the concept of Smart Cities was coined back in the early nineties. In 1993, Gibson, Kozmetsky and Smilor, in their book *The Technopolis Phenomenon - smart cities, fast systems, global networks* [72] anticipate a kind of urban-tech phenomenon to come that, through a twenty-first century infrastructure, would contribute to the enhancement of the quality of life as well as widening the range of global marketplaces. The authors' vision was that academia, together with governments and industry, would present information, ideas, programs and initiatives in a new manner, much more technological and informed than previously, that would accelerate the creation of *smart cities, fast systems, and global networks*. They were not that wrong. In 1999 we find the earliest application of Smart Cities experiences. Mahizhnan [124] presents the case of Singapore, whose transformation into an information economy on the back of information technologies was made necessary by the island's lack of natural resources plus the need to reinvent its traditional industrial economy. Nearly contemporaneously, in 2001, we find the experience of Edinburgh, where the government made a huge investment in the necessary technological infrastructure to turn the city into an experimental IT centre, and where the first e-Government initiatives took place.

But despite its earlier development, the Smart Cities concept only became widely known after 2009, and even today it is still a somewhat fuzzy idea. In an attempt to provide an overall definition of the concept we could say that Smart Cities have evolved out of livable, creative, digital and knowledge cities, drawing heavily on the concept of the sustainable city and having in common a large technological component.

A less conceptual definition would be that the Smart Cities initiative tries to improve urban performance by using data, information and information technologies (IT) to provide more efficient services to citizens, to monitor and optimize existing infrastructure, to increase collaboration among different economic actors and to encourage innovative business models in both the private and public sectors. Adding to both definitions, in a more technical description, we could say that cities wishing to become smart must be equipped with a "brain" (software) supplied with lots of real-time information (data collected from sensors) enabling them to take more sustainable, efficient and citizen-centered decisions, smoothly transforming decisions into actions by means of technological solutions.

On the basis of the definitions and the technical description we can anticipate an important issue with regard to monitoring: a Smart Cities initiative must be monitored in real-time in order to asses it properly. Because it seeks to measure cities' urban performance on the basis of high IT levels, it can not be monitored with statistics based on historical data.

The Smart Cities concept's point of departure is that individuals are permanently connected with others and with their machines. This hyper-connection does not only relate to the common image of users connecting with their smart phone but with their washing machine, fridge, heating, lights, etc. through sensors in connection with their smart phones. In technical terms, the connecting network between digital devices and sensors is given the name Internet of Things (IoT). Each device is equipped with sensors so that humans and other mechanisms can operate them at a distance. Here, it is worth mentioning that in today's cities, people, companies, governments etc. generate digital data on almost all the urban activities they perform, but it is estimated that only 5% of the available digital information is currently being used. This hyper-connection in society anticipates the idea of the "sensor-citizen".

In the Smart Cities context all these technological interconnections are known as ambient intelligence. Several studies have developed standardized frameworks for its application to Smart Cities [175]. A similar concept is ubiquitous computing. The example of South Korean smart cities promotes the development of standard architecture to integrate both ubiquitous computing and ambient intelligence in green technologies [110]. The technological possibilities offered by ambient intelligence, together with ubiquitous connectivity, the fast internet and a dramatic cost reduction in sensors suggests extremely well monitored cities in the near future.

If we consider these extremely well monitored cities of the future and today's fast-evolving society, which is changing more rapidly than statistics are being updated, we are forced to the conclusion that we will have to use sources other than historical statistics to monitor Smart Cities. In our opinion, indicators based on historical statistical information should be substituted by indicators constructed out of real-time data. Smart Cities need "smart indicators": information extracted from the city, which duly processed is converted into indicators and returned to the city as monitoring values.

We have found two Smart Cities monitoring initiatives already in operation, both producing indicators from historical statistical data.

The first initiative is the European Initiative on Smart Cities, promoted by the European Commission, or more specifically the Strategic Energy Technologies Information System (SETIS) [174]. This initiative focuses on achieving more efficient models for reducing carbon emissions in Europe and, according to our understanding, at least is therefore more a smart energy than a Smart Cities proposal. Its specific objectives are to involve the minimum of 5% of the European population in the use of low carbon emission technologies as well as to reduce by 40% greenhouse gas emissions by 2020 and to spread across Europe best practices in the area of sustainable energy. The initiative proposes specific actions for buildings, energy networks (heating, cooling and electricity) and transport, and seeks the participation of 25 large cities (>500,000 inhabitants) and five very large cities (>1,000,000 inhabitants) to commit to implementing programs in these three sectors. A set of key performance indicators (KPI) are proposed. For energy networks, these include: meeting 50% of heat and cooling demand from renewable energy sources (RES), establishing at least 20 pilot schemes by 2015 for "smart grids" coupled with "smart building" equipment, and measuring energy consumption with "smart meters" [174].

The second initiative in the field of Smart Cities monitoring comes from academia. A consortium made up of the Vienna University of Technology, University of Ljubljana and Delft University of Technology [190] has produced a ranking of European cities based on an index of "smartness" consisting of 74 indicators in six categories: Smart Economy, Smart Mobility, Smart Governance, Smart Living, Smart People and Smart Environment. The ranking is composed of 70 medium-sized cities with urban populations of between 100.000 and 500.000 inhabitants with at least one university and a catchment area of less than 1.500.000 inhabitants (to exclude cities dominated by a bigger city) [190]. The indicators were created using the previously mentioned Urban Audit database, produced by the European Statistical Office (Eurostat) [58]. Examples of indicators for the Smart Living category are: number of cultural facilities, health conditions, individual safety, housing quality, number of educational facilities, touristic attraction and social cohesion. To compare the different indicators values are standardized. The method utilized is the z-transformation in which all indicator values are transformed into standardized values with a 0 average and a standard deviation of 1. To obtain results at the category level, indicators must be aggregated. In the aggregation, the indicators' coverage is considered, weighting indicators according to coverage. The aggregation is additive, meaning that totals are divided by the number of values added. No further corrections or weightings are made to produce a city's final index of "smartness".

In the research arena, Cargaliu et al. [32] have also used the EU Urban Audit data set to analyze the factors determining the performance of Smart Cities. They found that the presence of a creative class, attention to the urban environment, level of education, multimodal accessibility and the use of ICTs for public administration are all positively correlated with urban smartness. More interested in summarizing indices than working with a set of indicators, Malek [125] studied the suitability of an existing index, the Informative Global Community Development Index (IGC), for monitoring the Smart Cities initiative.

We have already stated our view that the monitoring of Smart Cities needs smart indicators. Smart indicators are obtained from real-time data. A set of smart indicators would monitor a city's technological and information advances, quality of life and sustainability improvements. To monitor all these aspects of the Smart City, real-time physical and non physical data would be needed.

Today's technology providing the most updated data on cities' physical recognition is remote sensing imagery. It would take too long to mention just some relevant examples of urban pattern recognition for the physical monitoring of cities using information provided by remote sensing satellites thus there are several successful experiences in that area of application. In the urban context, remote sensing imagery has been used not only for pattern recognition but also for building features extraction and automatic reconstruction; here, we will also avoid having to draw up a long list by not referring to examples. Instead, we will mention some techniques based on remote sensing data that make possible a more detailed study of urban pattern changes.

The most traditional methodologies for analyzing settlement patterns on the basis of remote sensing imagery are principal component analysis (to determine differentiation patterns), cluster analysis (to determine homogeneity patterns), and regression analysis (to identify the explicit functional relations between settlement patterns and their underlying variables). Additionally, Rebelo [146] has studied the use of decision trees, neural networks and the link between neural networks and the nodes of decision trees for urban settlements pattern classification. In the field of simulation, Han et al. [71] aim to predict urban growth by adding cellular automata techniques to satellite imagery. Also using simulation techniques, Schwarz et al. [157] and Schetcke [154] have studied the opposite phenomena: urban shrinkage.

When we focus on the more common and accessible applications of satellite imagery we find, in 2006, the appearance of Google maps. In combination with the GIS tools that already existed, these changed the way location aware systems worked [178].

Internet mapping left traditional cartographic techniques by the wayside. These had depended on expensive specific photographic flights which only allowed updates ever five years, approximately.

Besides the physical urban surface, the non-physical data obtained from the city needs to be monitored, and this is even more interesting for the Smart Cities concept. Here the good news is that even more updated data than that obtained from physical assessment is possible: the extensively monitored Smart City will provide real-time data through its citizens (citizen-sensor) and organizations (data captured by companies providing services to the city).

To provide an example of what could be a smart indicator and show its advantages over parallel information obtained from historical statistical sources, we have studied the occupancy and utilization of built stocks in two Catalan cities over a 5-year period. Data was extracted from the Spanish National Institute of Statistics (Instituto Nacional de Estadística) [86] and kindly provided by the Spanish energy company, FECSA-ENDESA Energia 21 (as an example of data captured by companies providing services to the city). Data provided by the energy company was partially obtained from the so-called smart grids. Smart grids have more powerful monitoring applications than that of merely providing information about total amounts of energy consumption; they can even monitor the contribution of renewables to the net.

Smart grids exemplify the concept of producers and energy consumers being in constant communication in order to achieve a more efficient, profitable and reliable supply of energy. It is clear, then, that indicators for monitoring smart energy will not be the number of solar panels installed, for example, but their real-time contribution to the energy net.

The figures below compare the latest statistical data available (Spanish Census, 2001) [86] on the occupation of residential stocks (main residence, holiday residence or unoccupied residential units), the utilization of commercial buildings (with and without activity) and industrial installations (differentiating between services and facilities, commercial and industrial), with the number of electrical supply contracts in the same categories. Billed energy and billed power are also shown in the figures.

Blanes	Main Houses	Holiday&Empty Houses	Total Residential Units	Total Units
2001	11301	11691	22992	25292

Blanes	General clients	Energy (kwh)	Power (kW)	Total Clients	Energy (kwh)	Power (kW)
2006	22780	71904768	665319,48	27632	236511397	1262742,53
2007	23740	75494312	717208,94	28209	171977629	1290859,91
2008	23695	77848190	845845,04	28509	192663872	1382697,59
2009	23308	32913557	665040,48	28856	175992431	1931616,04
2010	22479	32844003	665076,19	29010	188870819	1937026,90
2011	21920	32814289	665061,69	29070	175865453	1888447,84

St. Feliu Guíxols	Main Houses	Holiday&Empty Houses	Total Residential Units	Total Units
2001	7834	5992	13826	15431

St.Feliu Guixols	General clients	Energy (kwh)	Power (kW)	Total Clients	Energy (kwh)	Power (kW)
2006	14744	43192209	440566,41	17566	74602437	626051,49
2007	15162	45109909	475939,98	17701	75227939	665785,78
2008	15056	47311664	554940,17	17878	78793735	752917,84
2009	14922	22352479	433248,21	18315	77655630	1135611,24
2010	14450	22200167	433239,92	18273	78395647	1146040,55
2011	14000	22162364	433239,92	18276	71267554	1075535,83

Fig. 4. *Statistics of built park and energy consumption measurements: aggregated and residential data. Own elaboration based on FECSA data sets*

More than a simple monitoring of energy consumption using collected data, the updated information provided by the electricity company can help in the monitoring of more hidden or latent phenomenon affecting cities such as the current economic crisis. We can observe how the number of general clients' contracts (domestic clients and small businesses up to 15KW of supplied power) and consumption started to decrease in 2008 in both cities (Fig. 4). But, interestingly, we can observe the opposite with medium sized businesses and large companies: the number of clients, billed energy and power rose considerably (Fig. 5). This suggests that the current crisis has hit families and small businesses particularly hard.

Blanes	Services & Facilities	Commercial& Industrial	Industrial&Ser vices Un.	Total Enter prise Units
2001	580	567	1147	1153

Blanes	Small and medium-sized clients	Energy (kwh)	Power (kW)	Industrials and big clients	Energy (kwh)	Power (kW)
2006	3900	138817697	490909,9	952	25788932	106513,15
2007	3911	60458772	445274,7	558	36024545	128376,25
2008	4248	58156209	410932,1	566	56659473	125920,43
2009	4866	98730269	1140829,3	682	44348605	125746,21
2010	5101	90248286	1062236,7	1430	65778530	209713,98
2011	4964	64709290	899294,7	2186	78341874	324091,39

St. Feliu Guíxols	Services & Facilities	Commercial& Industrial	Industrial&Ser vices Un.	Total Enter prise Units
2001	419	480	899	706

St.Feliu Guixols	Small and medium-sized clients	Energy (kwh)	Power (kW)	Industrials and big clients	Energy (kwh)	Power (kW)
2006	2291	24475875	147708,7	531	6934353	37776,30
2007	2291	26214638	167614,9	248	3903392	22230,87
2008	2556	27812848	180706,9	266	3669223	17270,70
2009	3041	52026196	681752,7	352	3276955	20610,24
2010	3061	45997914	645454,4	762	10197566	67346,17
2011	2918	33877770	527923,9	1358	15227420	114371,97

Fig 5. *Statistics of built park and energy consumption measurements: industrial and business sectors data. Own elaboration based on FECSA data sets*

Remaining in the area of energy consumption monitoring, a further example of smart indicators would be the data processed out of so called smart meters. Here, the citizen collaborates in obtaining data. The Google PowerMeter visualizes individual energy usage by capturing data from smart meters. Google.org, promoters of the initiative – currently solely implemented in the US - state that it was designed as a free monitoring tool to raise awareness about the importance of giving people access to their energy information. Besides visualization, the tool includes the feature of sharing information with others through smart phones and the possibility of receiving personalized recommendations on saving energy. On June 24, 2011, Google announced they were discontinuing the PowerMeter because manufacturers and their utilities partners were opening direct access to their energy information services.

2.5. Summary

This summary recaps the lessons of previous experiences of city monitoring, the proposals that came out of what was learnt and their specific application to the Smart Cities initiative.

Firstly, the need for an aggregated or synthetic index to visualize monitoring results from a set of indicators has been conclusively demonstrated. Indices, apart from making comparisons and rank order lists possible, summarize large amounts of data. In an era of information excess, where information filters and synthesis are essential, an index summarizing a city's smartness will unquestionably guarantee an initiative's success. Different techniques for obtaining summarizing indices have been shown. Particularly, we analyze the use of principal component analysis in the example of Barcelona's LA21. The experiences of private bodies and academic research have shown how mathematical models are also a promising technique.

Secondly, we would stress the need for real-time indicators (what we call smart indicators) as the appropriate monitoring tool for developing a final smart or intelligent index. It has been illustrated how historical statistics can be extremely out of date. The Smart Cities initiative attempts to asses what is happening in the present in a city in terms of urban IT, quality of life and sustainability. Therefore, there is no question about the need for real-time data to illustrate the city's smartness status. We showed the possibilities extended by real-time data with the examples of information provided by a services company and by citizens through their smart phones, taking the place of statistical information on the city's built stock status. Here, the target for the scientific community is to find different real-time data sources that correlate with historical statistics and can take their place.

The basic concept of the Smart Cities initiative can be expressed as follows: *the Smart Cities initiative seeks to improve urban performance by using data, information and Information Technologies (IT) to provide more efficient services to citizens, to monitor and optimize existing infrastructure, to increase collaboration between different economic actors and to encourage innovative business models in both the private and public sectors.* Urban smartness extends to any city aspect, including urban planning. As mentioned earlier, urban planning design values need an urgent update and revision. It is the main objective of this dissertation to use urban technologies being developed in the Smart City context to update and review urban planning standards. Moreover, taking into account that there have already been examples of successful collaboration between different actors - citizens, private and public bodies – in the creation of real-time data, in the future research of this work, we aim to study the goodness of data close to real-time for more frequent updates of the urban planning design values to better match with the rapidly changing urban needs.

3. METHODOLOGY

Traditional urban planning methodologies cannot solve the planning challenges that cities confront today. Citizens' needs have substantially changed over the last decade, while urban planning methods have remained the same since the 1970's. A more citizen-centered urban planning method is presented in this chapter. To that end, and to effectively deal with the larger amounts of citizen data needed for the urban planning methodological reinvention, interdisciplinary work is supported with ICT technologies. Particularly, our method is comprised of adaptive hypermedia techniques, visualization solutions, and agent technology tools. Some other methods are conceivable, establishing a step forward towards the intelligent toolboxes an urban planner should have available to support urban planning activity.

3.1. Introduction

To develop the Smart Urban Planning Method, inverse engineering principles are applied as follows:

> The problem of giving a real and accurate answer to citizens' needs is tackled through a pioneering algorithm which transforms the urban time use of citizens into urban land use, obtaining rules of correspondence and indicators of equivalence between urban time use distributions and urban land use allocations.

To that end, citizens are questioned on a) their current urban activities during a twenty-four hour time period, and b) their desired or ideal scenarios for urban activities. The rule of correspondence and indicators of equivalence operate with two sets of values, those obtained from citizens' real use of the city, and those obtained from citizens' desired or ideal use of the city. Thus, the optimal urban land use allocation which forms the basis for design will be the set of urban land use values corresponding to citizens' desired use of their city.

Urban time use surveys are typically oriented towards learning about gender differences with respect to the use of cities. In addition, the effects of mobility on time use distribution and how time use affects socialization have been studied. To the best of our knowledge, there have been no attempts to learn the correlation between urban time use distribution and urban land use allocation.

There is some interesting research related to urban time use which is relevant for our study. First, research on time stereotypes based on identifying a typology of latent "time-styles" which define the different ways people allocate time to multiple and sometimes competing daily activities [91]. Second, studies of how time use patterns can be used by local authorities to increase the involvement of residents in different urban activities [9]. Third, analysis of whether and in what ways the use of time and space has changed due to increased access to ICT [191]. And, finally, studies which classify time use patterns into "maintenance", "subsistence", and "leisure" urban activities [217].

However, although some research has been carried out in the area of urban time use distribution, our study and method is the first to correlate urban time use distribution and urban land use allocation.

Urban time use data is obtained by means of a survey of citizens on urban-time-use, which is the main pillar of our Method. The results on urban-time-use distribution are converted into urban-land-uses as pioneering methodology for the reinvention of urban planning. The survey aims to bring more public participation in the urban planning decision making processes, such as master plan elaboration. Regarding the social aspects of Smart Cites, public participation together with citizens' inclusion are the basis for designing Smart Cities solutions.

3.2. A novel approach which reinvents public participation in urban planning: an opinion survey on urban time use to obtain citizen-centered design values for master plans

We propose that information from citizens form the basis for the design values for master plans:

> Distinct from the traditional urban planning participatory processes, the proposed opinion survey occurs prior to design of the master plan. Citizens are surveyed on their real and desired urban activities during a twenty-four hour time period, for both working and non-working days.

Imported and exported hours of citizens who perform their activities in a municipality other than their place of residence are considered burdens or benefits to the corresponding municipalities, and duly accounted for. For example, citizens working in a city were they do not live place a burden on public services (unless they pay some additional city taxes), and their working hours are calculated as time which is exported from their city of residence. It is necessary to keep in mind that the Smart Urban Planning Method considers the desired use of the city as the simulation providing the optimal scenario to reinvent the urban planning design values.

Under the current traditional approach, public participation in urban planning processes fails to generate collective intelligence. It settles for building limited consensus after the process is underway, instead of gathering data and assessing the desires of citizens during formulative stages. Indeed, research by J. Carr [33] indicates that political elites may use public input garnered by planners as a form of “shadow referendum”, to determine whether any powerful actors might oppose proposed policies. Xing et al. [207] sustain that lack of official trust in public participation and limited avenues for expression reduce interest and cause passivity amongst the citizens.

Practical innovation in public participatory processes is limited to the area of virtual environments to improve public participation by seeking user immersion [68]. Methods for obtaining user immersion include geographic information systems, computer aided design, visual support systems, virtual environments, and digital games. Closer to our study, we find some research on how virtual supports for the exchange of more visual information between administration and the public can help in solving long-standing conflicts and ensure successful implementation of plans [81].

However, there are no previous studies which utilize opinion surveys launched prior to the urban planning process to achieve more objective planning, and ease the approval process for master plans through a citizen-centered approach that promotes satisfaction. Thus, our study is the first of its kind in this regard.

3.3. Obtaining new urban planning values and citizens' satisfaction thresholds

Next, to define the conversion rule between the respondents' current twenty-four hour urban time use distribution for a typical working and non-working day and the corresponding urban land use allocation, urban time use is mapped into the corresponding physical locations. Time use distribution is allocated according to the physical location of performance, in order to establish the targeted direct correlation between urban time use and urban land use. Therefore, survey results on urban time use are expressed according to the following physical urban locations:

- House: Number of hours spent at home
- Work: Number of hours spent at work (including all activities conducted at the work place, such as time spent in training or at the cantina, etc.)
- Main Facilities: Number of hours spent in a facility which constitutes respondent's main activity (equivalent to a university for students or a day-center for pensioners)
- Secondary Facility: Number of hours spent in a facility other than the one constituting respondent's main activity (such as a library, sports facility, learning center, etc.)
- Consumption: Number of hours invested in consumer activities (such as shopping, eating in restaurants, going to the cinema, etc.) or personal services (going to the hair dresser, visiting a private doctor, etc.)
- Public Space: Number of hours spent in public spaces (including city squares, parks and gardens), but not including mere transit
- Public Transport: Number of hours commuting with public transport
- Private Transport: Number of hours commuting with private transport.
- Self-transport: Number of hours commuting on foot or bicycle
- Outdoors: Number of hours spent in natural surroundings outside of the urban area (mountains, beaches, rivers, natural parks, walking trails, farms and orchards, etc.)
- Different city: Number of hours spent in a city other than that of residence, performing activities other than those specified above (visiting friends, weekend stays in a holiday house, etc.)

Applying the rule of correspondence, we found the indicators of equivalence between the time spent on each urban activity and its location. The rule of correspondence and indicators of equivalence were calculated for each municipality, as correlations between time and land are variable. Rule of correspondence and indicators of equivalence were calculated for each municipality in which we obtained responses, and weighted according to the number of responses.

The indicators of equivalence obtained in the current correlation between urban time use and urban land use serve as a basis for the new urban planning design values.

However, they must be adjusted to account for desired urban time use. Thus, the new urban planning design values are obtained as follows:

> Using the indicators of equivalence obtained for the correspondence between current time and land use, and knowing the desired time use distribution, we use correlative equations to obtain the land-use allocation corresponding to the desired activities time-distribution.

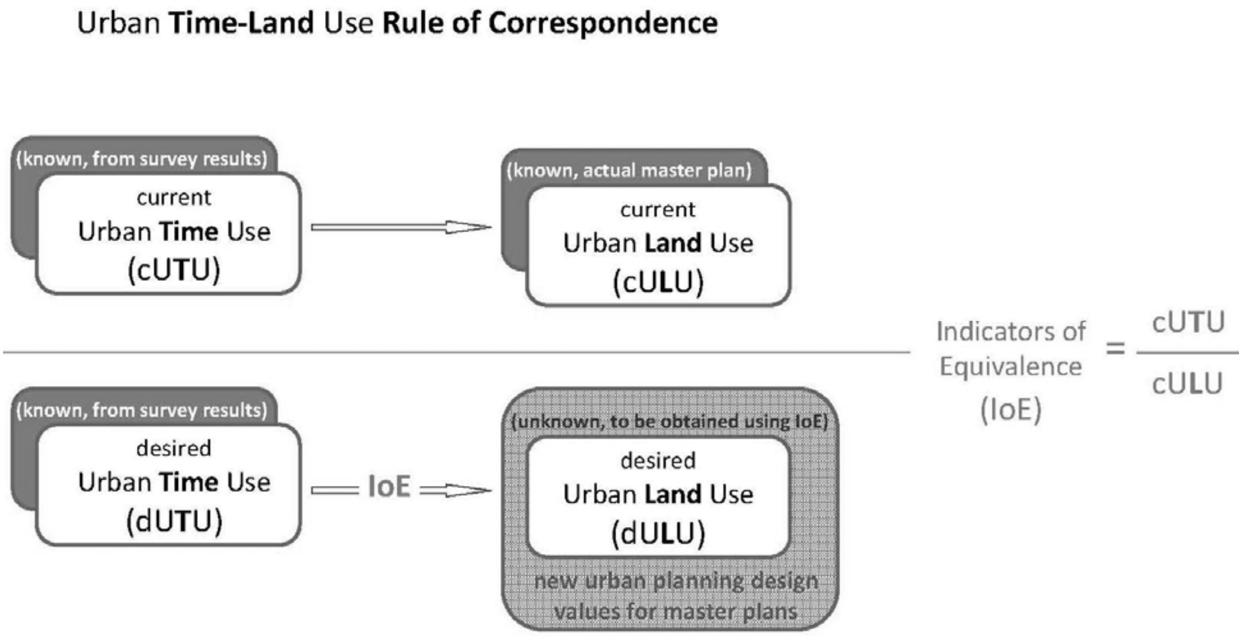


Fig. 6. *Rule of Correspondence between Urban Time Use and Urban Land Use. New planning values for optimal urban design are obtained from the desired urban time use and the indicators of equivalence, current relation between urban time and land use. Own elaboration.*

3.4. INSIGHT on citizens' adaptive hypermedia surveys

MODELING CITIZENS' URBAN TIME-USE USING AN ADAPTIVE HYPERMEDIA SURVEY TO OBTAIN AN URBAN PLANNING, CITIZEN-CENTRED, METHODOLOGICAL REINVENTION

Deepening the technological aspects of the survey proposed in our Method, and in order to obtain more accurate results, the survey would use hypermedia adaptive systems. Besides presenting it to the citizens in a friendlier manner, this would permit periodical updates that make the results more up-to-date, thereby approaching the ideal of real-time data.

This insight aims to explain why a hypermedia survey is chosen as a method for citizens' participatory process, how thesis's hypermedia adaptive survey on urban time-use is designed, and how it has begun to be conducted. Mainly, the steps have been the following:

1. Selection of adaptive hypermedia techniques
2. Consideration of standards
3. User-group construction
4. Personalization through feature-based survey

3.4.1. Selection of adaptive hypermedia techniques for survey purposes: stereotype and feature-based models combination to collect citizens' information on their urban-time-use

Adaptive hypermedia (AH) is generally accepted as a crossroads in hypermedia and user modeling (UM) research [22], [23]; [17], [18]. *Adaptive hypermedia systems* (AHS) belong to the class of *user-adaptive software systems* [156]. These technologies allow an individual user of a hypermedia application to personalize the content and presentation of the application according to their preferences, objectives and knowledge [140], [147]. Personalization is defined as how an application's content, navigation and interface are tailored to match the specific needs of an individual *(user modeling*) or a community (*group modeling*) [30].

User and group models are created through user modeling (UM) and group modeling (GM) processes in which unobservable information about users is inferred from observable information from such users [219] by modeling user interactions with the system for a specific *domain concept.* A user model, as a representation of information about an individual user, is essential in order for an adaptive system to provide an adaptation effect [25]. User interaction modeling represents and defines the interaction between the user and the application. The data stored in the interaction model are used to infer user characteristics with the objective of updating and validating the UM. For this purpose, this component includes evaluation, adaptation and inference mechanisms [10], [17]. The domain model represents a set of domain concepts in which each concept is related with other concepts and represents a semantic net. The most important function of this model is to provide a structure for the representation of user domain knowledge (i.e. to store the estimated level of the user's knowledge for each concept) [10], [17].

In order to better understand the newest AHS applications of our interest - which include information systems, volunteered geographic information and geodata collection-, a reference to the earliest and most well-known AHS applications is a must. Adaptive educational systems (AES), commonly used in e-learning are the first AHS deployments, paving the way of any later evolution. A typical AES system operates as the following: when a user is studying content supported by AES (e.g. the meaning of a word) the user can select the depth of the information displayed by the application by prioritizing and highlighting the most important information based on the user's existing knowledge (such as "expert, intermediate or novice") thanks to adaptive navigation techniques such as web-based mechanisms like "hide, sort or annotate" details of a piece of information, etc. In AES, *user knowledge* is frequently the only user feature being modeled as it is the sole AES objective.

User knowledge modeling used in AES is similar to a *scalar model,* where the level of a user's knowledge is estimated by rating values using a numerical scale or by qualitative ranking using a categorical scale. Scalar models, especially qualitative ones, are quite similar to *stereotype models* [10] which are of interest of the research presented in this section as a method to initiate the public participatory survey proposed here. Stereotype models, developed by Elaine Rich [148], [147] in the late seventies and extensively used in early adaptive systems, especially between 1989 and 1994 [77], attempt to cluster all possible users of an adaptive system into different groups or stereotypes with one adaptive solution being developed for each stereotype. What makes scalar models and stereotype models slightly different is that knowledge assessment in the former is made by the user him or herself while in the latter the assessment is made by a third party. The shortcoming of both models is their low level of precision [25] due to the techniques' generous averages of what is being modeled.

More recently, in search of more precision, many of the AHS that focus on advanced user modeling use more elaborated techniques based on user feature modeling, the so called *feature-based models.* Feature-based modeling is today's dominant approach in AHS user modeling, with new contributions constantly coming from different researchers. Although feature-based models have overtaken stereotype models, the latter are useful for user and group modeling purposes in combination with the former.

One of the most popular combinations is the use of stereotypes to initialize a feature-based model [183]. This technique avoids the difficulties presented by employing user feature modeling from scratch. As we'll see in the next section, we utilize this combined technique in our research: a two-step approach where feature-based models help us to elaborate the results of the participatory process of the previously formed stereotype groups.

An interesting application for us of stereotype and feature-based techniques in combination is found in information systems. The AVANTI project [63] provides a good example. The project aims to develop and evaluate a distributed information system providing hypermedia information about a metropolitan area (e.g., public services, transportation, buildings) for a variety of users with different needs (e.g., tourists, citizens, travel agency clerks, elderly people, the blind, wheelchair-bound people, and users with less serious forms of muscular dystrophy). A stereotype model is constructed by means of an initial interview that provides the basis for primary assumptions about the user. This is a valuable source of information for initially assigning the user to certain user groups, or stereotypes. The final feature-based user model will contain explicitly modeled assumptions which represent the important characteristics of an individual user, like preferences and interests, domain knowledge, and physical, sensorial, and cognitive abilities [63].

The AVANTI project demonstrates that stereotype and feature-based techniques in combination can be very powerful for distributing information. Similarly, our research will show how a combination of stereotype and feature-based models can be extremely useful not only in distributing information but also in gathering user information. In our model, users are citizens who are surveyed using an adaptive hypermedia survey to collect information about their time-use distribution to rethink urban planning methodologies focusing on citizens' urban needs. To discover these needs we'll use the above presented two-step adaptive survey on citizens' time-use distribution in relation to their urban processes. As mentioned earlier, the results will be transformed into the amounts of different land types (based on the land's different urban uses) needed for citizens' urban processes to be performed through a "rule of correspondence" (to elaborate qualitative pairs between different time-uses and different types of land use) and "indicators of equivalence" (to elaborate quantitative correlations between time-use and land-use amounts).

3.4.2. Adaptive Hypermedia Survey on Urban-Time-Use is based on normalized adaptive hypermedia techniques and designed according the existing standards of adaptation

Standardization is very important, not because the main goal of this thesis is to rethink urban planning standards but because it provides a framework where to build on further developments of a given topic. We'll design our citizens' participatory process through the survey on urban-time-use capitalizing on the existing standards of adaptive hypermedia techniques.

Recently, adaptive systems, also called *personalized systems*, have been developed in many fields other than the educational, such as e-commerce, information distribution and e-scheduling. What all these applications of adaptive systems have in common is that they are user-centered and every user is modeled to obtain the different user profiles. Depending on the field applied, the user profile will contain different descriptive information (e.g. personal identification, preferences, habits, etc). From that the system usually provides user services or information appropriate to the profile [50]. In contrast, user profiles in what we call the "adaptive survey method" help not to provide but to retrieve user information in an accurate and precise way. This thesis proposes an "adaptive hypermedia survey model" as a retrieval information technique in two steps, from a stereotype-based user survey to a feature-based user survey. We will model feature-based survey results relating to citizens' urban time-use distribution for the urban planning methodological reinvention.

As has been seen, adaptive educational systems (AES) are older than the rest of AHS. The educational field can be considered mature in comparison with other AHS areas (commerce, information systems, scheduling management, etc.) since certain standards have been already developed and some organizations are applying different regulations. The "Learning Technology Standards Committee" (LTSC) and the "Global Learning Consortium" (IMS Global) are examples of organizations that define specifications and standards for e-learning. More specifically, the "Computer Society Standards Activity Board" of the LTSC has defined data-centered specifications (such as P1484 and P1484.2) to simplify interoperability between different systems and to facilitate the reuse of learning tools and contents [127].

Another standardization initiative is the one promoted by several working groups (WG, http://www.jtc1sc36.org), where certain specifications (ISO/IEC JTC1/SC36) in respect of student information exchange between different systems are defined. Such specifications, called the "IMS Learner Information Package Information Model", define data models and the syntax and semantics describing user characteristics, knowledge and abilities. User acquisition of knowledge, capacities, aptitudes, personal information, relations, security parameters, preferences and learning style, performance, portfolio etc. are also described [127]. In a similar way to IMS, "Public and Private Information for Learners" (PAPI Learner) standardizes not students' curricula information (IMS) but their performance [41].

Within the adaptive educational field, various standards and normalized methods can be found in the area of tools and techniques. It is widely accepted inside the adaptive hypermedia research community that the first benchmark technique for adaptive hypermedia applications was a tool called AHA! [16]. This seminal technique provided a generic architecture that led to further research in many different directions. A complete list of normalized methods and tools for adaptive educational purposes can be found at [98]. Amongst these methods, and bearing in mind our adaptive survey design, it is particularly worth highlighting the AtoL technique [23], [141]. AtoL models groups of students according to a sequence of answered questions and their level of correctness, so that educational content can be adjusted to the students' learning patterns. As will be seen in the following pages, we'll capitalize on this technique when designing survey's stereotype step by using a sequence of answered questions, while not taking into account the degree of correctness but the user's cognitive skills, in order to better adjust survey's feature-based step.

In contrast with the educational field, in generic adaptive hypermedia systems there are no regulations or specifications for data exchange and system interoperability, but standard methods and widely accepted tooling do exist. A complete list of most recognized methods and tools for AHS design can be found at Martins Antonio et al. [127]. The previously referenced AVANTI system is also listed here. On the list, we found two methods of particular interest in respect of our urban-time-use survey design. Both methods are based on stereotype models, either in terms of initiating a feature-based model (as in our case) or taking stereotypes as a single technique: HYPERTUTOR [95] is a system to describe the user strictly based on stereotypes. It uses exercises to obtain information about users and employs stereotypes for user modeling. The user can belong to one of three groups: novice, medium or expert. INTERBOOK [95] is a tool for authoring and delivering adaptive electronic textbooks on the web. This AHS initiates a user model using stereotypes. For the interests of this thesis, we'll consider HYPERTUTOR method when forming stereotype groups. INTERBOOK will be considered as a reference technique to initiate a feature-based model with stereotype groups.

Finally, to conclude this review on methods and techniques in whose we build on, we need to mention what has been standardized and normalized in generic adaptive hypermedia systems to date. It is widely agreed within the AHS research community that the adaptive process is divided into three levels or layers: *direct adaptation techniques, adaptation language* and *adaptation strategies*. This classification is aimed at standardizing adaptation techniques at the different levels. It therefore works towards exchanging adaptive techniques between different systems, as well as helping the authors of adaptive hypermedia by giving them higher-level handlers of low-level adaptation techniques [46]. Direct Adaptation Techniques are the lowest level of adaptation, including all existing adaptive hypermedia applications: from adaptive presentation (inserting/ removing fragments, altering fragments, stretching text, sorting fragments, dimming fragments) to linkage adaptation techniques (adaptive guidance and adaptive navigation support: direct guidance, link sorting, link hiding/ removal/ disabling, link annotation, link generation, map adaptation). For an extended summary, visit Brusilovsky [23] and Wu [204]. Adaptation Language is the medium level of adaptation. Here, higher level techniques are grouped into standard adaptation mechanisms and structures, commonly known as programming language [46]. Lastly, Adaptation Strategies are the highest level of adaptation. In this last level, adaptation techniques are based on cognition, modeling the user's profile and processing user information. This model is closer to the Adaptation Strategies as survey's feature-based step is based on user's cognition level. Therefore, we will consider Adaptation Strategies standard framework when building up our survey's feature-based part.

By using the described existing standards for adaptive hypermedia systems in the design of both stereotype and feature-based surveys, we ensure this model can help other survey projects to build on existing standards as well as to enlarge the current framework of hypermedia system standards implementation.

3.4.3. Stereotyped survey: user groups construction

As a first step, a stereotype survey is constructed by means of an initial interview to citizens which provides the basis for primary assumptions about the user, and is a valuable source of information for initially assigning the user to a certain user group or stereotype [63]. The object of this survey is not to uncover information about urban time-use but specific details of citizens' technological motivation and knowledge, in order to assign them to more precise stereotype subgroups prior to conducting an adaptive hypermedia feature-based survey on time use.

Based on primary assumptions about the user (stereotype groups) and additional information collected about his/her knowledge of the application domain (stereotype subgroups), and once the right technique is selected, the system will be able to draw further inferences in order to create more precise assumptions about the user (a feature-based model). For instance, if the user is a retired person (primary assumption-stereotype group definition) and they are familiar with the web because they are used to talking with relatives using internet telephone systems (user knowledge of application - domain-stereotype subgroup definition), this information can be exploded and a precise feature-based model designed using clustering techniques, as we will see in the following section.

Questions for stereotype groups formation:

1. To which of the following **age groups** do you belong?
2. To which of the following **occupations categories** do you belong?

Question for stereotype subgroups formation:

3. Which of the following options best describes your **preferences for a survey on-line based**?

Questions for feature-based survey's level of adaption:

Preliminary questions on urban-time-use distribution to know about cognitive and communicative skills

1. What is your city/town's **approximate number of inhabitants?**
2. Do you carry out all your daily activities (during work and non-work days) in the city/town where you live? If not,
    2.1 What are your out-of-town urban activities?
    2.2 In which town (s) /city (ies) do you perform these activities?
3. Please, give us the time-use distribution of the urban activities you have mentioned using a 24-hour period as a time reference.
4. Which activities and/or time distribution would you like to change in the future? Are you willing to add or subtract any activity? To what extent?
5. Which of the urban activities you have mentioned form part of the same urban process? (e.g. using public transport to go work, driving to go shop, etc)
6. Would you like to change any of your urban processes by adding, subtracting or modifying activities?
7. In the city(ies) where you perform your activities, is there any configuration that doesn't allow you to conduct your urban processes in the way you would like?
8. Which activities do you practise remotely (e.g. shopping on-line, gaming, socializing, working, studying, etc.)?
9. Do these e-activities form part of a process (e.g. searching for a product in different physical shops, trying out the product in a physical shop and shopping on-line as constituents of the shopping process)?
10. Which of the activities that you perform physically would you like to perform remotely?

Fig 7. *F2F Stereotype Survey Questionnaire: Questions for initial stereotypes groups and subgroups formation and feature-based survey's user model profiles construction. Own elaboration.*

Although the stereotype survey will focus on retrieving information about a user's technological knowledge and motivation in order to better design the feature-based survey's applications and presentation, there will be some preliminary questions about time-use in order to collect information for the feature-based survey's content adaptation. The user's cognition, concision, explanatory skills, etc. revealed in these basic time-use questions will be the

basis for constructing the feature-based survey's user model. However, it could happen that a number of user models would be created because a feature-based survey needs to adapt survey content to several user profiles.
Let us continue with the example of a retired person (stereotype group) interested in and knowledgeable about technology (stereotype subgroup). This person may have good explanatory skills so the use of free-text, for example, in the feature-based survey could be a good option for him/her and other users with this profile or, what amounts to the same thing, for all users attached to the same user model. On the other hand, another elderly person with the same amount of knowledge about and interest in technology could have no explanatory skills, and here a feature-based survey would be conducted with predefined options only, for example. Therefore, as will be seen shortly, the user model will accumulate all explicitly modeled assumptions gathered in the early stages of the stereotype phase representing the significant characteristics of the individual user. In this model these are age and occupation (initial stereotype group formation), technological preferences and interests -domain knowledge- and cognitive and communicative abilities -explanatory skills- (for stereotype subgroups formation and feature-based survey initiation).

To achieve the above, the stereotype survey is constructed in the following steps:

1) Stereotype group formation: stereotype groups are formed using age groups and occupation as first assumptions in a citizen's profile

2) Stereotype survey design: technological interests and preferences are surveyed in order to define stereotype subgroups. Basic questions about time-use are asked in order to gather information about a user's cognitive and communicative abilities, so that accurate user models can be constructed

and used to conduct a feature based survey on time-use that is as personalized as possible.

3) Conducting the stereotype survey and data collection: this first survey is face to face. It is done in the universities participating in the pilot. Undergraduate students are requested to both take part in and administer the survey in their immediate context (family, friends, etc). In addition, they are asked to conduct the survey amongst a representative sample in a different context (e.g. a family in a different neighborhood). Students gather all data collected in databases specifically designed to fit with standards of adaptive hypermedia systems.

4) Data pre-processing and information extraction: information obtained in the previous stage cannot be directly processed. Noise and inconsistencies have to be cleaned. In this phase it is very important to prepare data for pattern discovery algorithms for feature-based modeling in the steps that will follow. Pre-processed data is pre-classified. All *training items* (data) receive a unique label signifying the *class* (stereotype group) to which the data belongs. Given this data, a supervised learning algorithm builds a characteristic description for each class, covering all its training items. The process of assigning each training item to a unique class is called *pre-classification*, and supervised learning techniques apply here.

5) Data processing: in contrast to data pre-classification into pre-set stereotypes, the construction of groups of individuals who share the same technological interests and knowledge (the same characteristics featured in the former stereotype group) is performed using clustering techniques. Clustering techniques belong to the group of unsupervised learning methods which do not require pre-classification of the training items. The main difference between these and supervised learning methods is that the categories (classes) are not known in advance but constructed after the

clustering. When the cohesion of a cluster is high, it means that the training items in it are very similar and thus define a new class (in our case, stereotype subgroup definition).

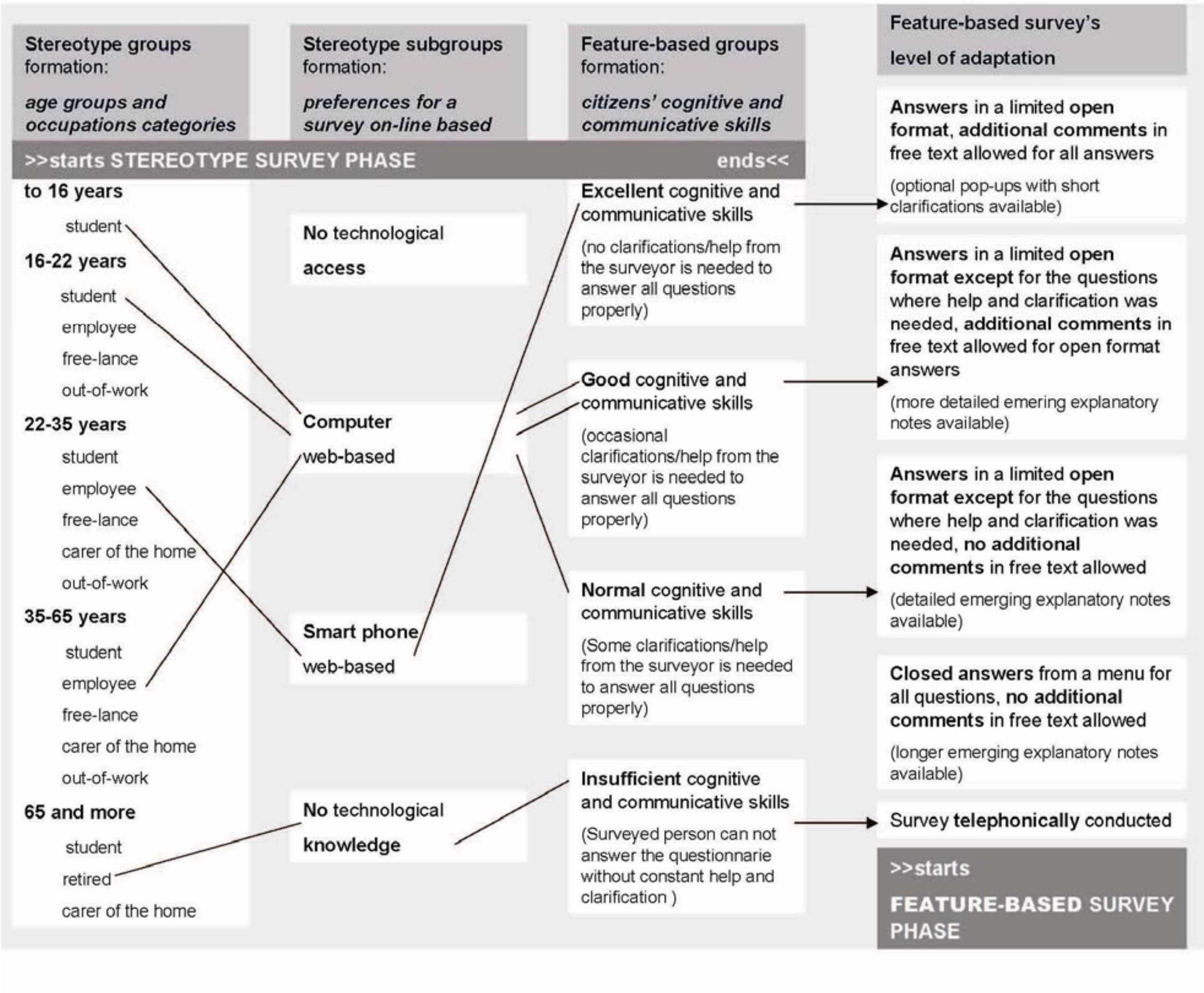


Fig. 8. *Stereotype Survey Pilot test: Most common correlations between initial stereotypes groups, stereotype subgroups and feature-based survey's user model profiles obtained in a pilot test. Own elaboration*

A clustering algorithm finds the set of concepts ensuring that: 1) the similarity between training data of the same concepts is maximized, and 2) the similarity between training data of different concepts is minimized. In a

clustering algorithm, the key question is how to establish the similarity between two items in the training data set [64]. Clustering techniques can be classified into hard clustering and fuzzy clustering. In hard clustering, data are divided into crisp clusters, where each data point belongs to exactly one cluster. In fuzzy clustering, the data points can belong to more than one cluster, and associated with each of the instances is a membership grade that indicates the degree to which it belongs to each of the different clusters [64].
In this model, stereotype survey results will be clustered using hard clustering techniques because it is wanted that data belongs to one single cluster for subgroup formation for the creation of further feature-based groups. Hard clustering techniques may be grouped into two categories: hierarchical and non-hierarchical [89]. A hierarchical clustering procedure involves the construction of a hierarchy or tree-like structure, which is basically a nested sequence of partitions, while non-hierarchical or partition procedures result in a particular number of clusters at a single step [64]. Non-hierarchal techniques will be applied in this model to clusters coming out of stereotype survey results, with the aim being to obtain a specific number of these clusters.

The main non-hierarchical clustering techniques are: 1) k-means clustering and 2) self-organizing maps (SOM) [64]. In the k-means clustering technique [89] the number of K clusters is given as an input. The algorithm then picks k items, called seeds, from the training set in an arbitrary way. Then, in every iteration, each input item is assigned to the most similar seed, and the seed of each cluster is recalculated to be the centroid of all items assigned to that seed. This process is repeated until the seed coordinates stabilize [64]. The SOM algorithm [100], apart from being used in a wide variety of fields, is an interesting tool for exploratory data analysis, particularly for partitioned clustering and visualization. It is capable of representing high-dimensional data in a low-dimensional space that preserves the structure of the original data. SOM's main advantage, in comparison to k-means clustering, is that similar input vectors are mapped to geometrically close winner nodes on the output map. These are called neighborhood preservations, which have turned out to be very useful for clustering similar data patterns [64]. The SOM algorithm has been selected to run stereotype survey results in this model as it works in one step and gives faster results, as well as being able to map an illustrative gradient of data distribution within the cluster.

We can find successful examples of SOM algorithm application in adaptive educational projects for student modeling. In the work named "Student modeling using principal component analysis of SOM clusters" [107] the SOM algorithm is applied as a pre-processor of PCA (principal component analysis). The authors, Lee and Singh [107], chose the SOM technique as it enables natural clustering without priori knowledge. SOM quantizes the data set into clusters, grouping vectors with greater degrees of similarity together, which facilitates cluster analysis. Furthermore, principal component analysis has been chosen because it does not require the number of clusters to be predetermined, as is the case with k-means clustering. Principal component analysis relies on the degree of variance to determine the number of clusters. PCA eigenvalues indicate the strength of the eigenvectors, thus verifying the number of clusters in the data set [107]. We can also find some examples that use fuzzy clustering, as in Romero and Ventura [150] Educational Data Mining review, where the fuzzy technique is chosen to support mobile formative assessment to help teachers to understand the main factors influencing learner performance [38]. Fuzzy clustering application examples show that the technique is mainly chosen for mobile or changing data environments.

In general terms, clustering techniques are used to discover *usage clusters* and *page clusters [64]*. The *usage model* is a subcomponent of the user model that contains relevant characteristics of the environment (e.g. terminal location, user interface characteristics) in order to support a user's technical motivation and to provide a convenient usage-oriented adaptation [63]. Usage clusters aim to establish groups of users exhibiting similar technological interests and knowledge. Amongst the well-known and normalized models for usage clustering, we have paid particular attention to the Fu model [130]. This model groups different users by taking into account their behavior and access patterns when using a web server. A complete list of normalized models for usage clustering can be found at (de Virgilio et al., 2007). In this model we will use the SOM clustering technique to elaborate usage clusters within the predefined stereotype groups while considering the Fu model for usage pattern identification. These usage clusters group profiles into groups of users that require similar technical adaptations to match their technological interests and knowledge, which greatly alleviates the adaptation process [192]. On the other hand, page clusters are not of interest in this model thus the clustering of pages only reveals groups of pages with related content, to provide personalized Web content to users in an e-commerce environment, for example [64].

In this model, the introduction of a threshold of similarity in the design of stereotype clusters would be particularly interesting if extreme cluster situations would exist. As some authors [192] state, a threshold of similarity avoids situations in which many clusters with few profiles exist or, conversely, a situation in which a limited number of clusters includes many profiles. In the former case, the selection of a profile would require an exhaustive search. In the latter, update operations would become rather inefficient. The threshold of similarity estimates that a profile can be included in a cluster if the distance from its root is lower than the threshold of the cluster [192].

3.4.4 Feature-based survey: personalization

As stated in the previous section, certain user actions developed in the stereotype model will be exploited for the acquisition of primary assumptions to elaborate the feature-based model. Specifically, we refer to the cognitive and communicative skills that users have shown in the short questionnaire about time-use contained in the stereotype survey.

The feature-based model's target is to refine stereotype subgroups already obtained from usage clusters with the introduction of users' cognitive and communicative styles. The model will contain relevant characteristics from former stereotype groups (e.g. "retired/elderly") and from stereotype subgroups (e.g. "internet expert/quite familiar with internet/never used internet"), and the final introduction of a user's cognitive and communicative skills, so that a feature-based survey on urban time-use that is personalized as much as possible can be designed. With that purpose, precise user models will be set. When feature-based conditions' are met, a specific profile will be activated (or created) in order to classify a certain user. This will mean that features contained in the feature-based subgroup become assigned to the user.

Every user model will need a different adaptation for a personalized feature-based survey on time-use in accordance with the user model to be conducted. For example, although several users could be classified as "retired (stereotype group) + internet expert (stereotype subgroup)", some of them might have good communication skills that will allow them to give excellent explanations of how they use their urban time. For these users it makes sense to activate some kind of free text application in the web-based survey. Such adaptation to cognitive style hides a three-fold implicit adaptation: adaptive content selection, adaptive navigation support, and adaptive presentation

[24]. When the user is asked for information in the survey the system will adaptively select and prioritize the most relevant requests according to the user's profile. When the user navigates from one item to another, the system will manipulate the links (for example, "hide, sort, annotate") in order to provide adaptive navigation support according to the user's profile. When the user gets to a particular page, the system will present its content adaptively as well as presenting adaptive solutions to interact with the user according to his/her profile.

It will happen that some user models will provide low-hypermedia profiles (e.g. "retired + quite familiar with internet") or even non-hypermedia profiles (e.g. "retired + never used internet"). In the first case, for low-hypermedia profiles, blended solutions can be used, similar to the already proven blended learning (BL) techniques. *Blended learning* (BL) is becoming an increasingly popular form of e-learning, particularly suitable for use in the process of transition from traditional forms of learning and teaching towards e-learning [180], [115], [26]. In this model of teaching and learning, significant numbers of f2f elements are combined with technology-mediated teaching [77]. For non-hypermedia profiles, f2f solutions or telephone conversations are the only possible ways of conducting the feature-based survey in this model.

As in the case of stereotype group construction using clustering techniques, the key question will be what knowledge needs to be captured in order to choose the most suitable machine learning technique. Additionally, the choice of the learning method will depend greatly on the type of training data to be processed. We already know that the distinction between supervised and unsupervised methods is the need for training data pre-classification in the former case. Unlike in the previous case of usage cluster definition, in the modeling of a user's cognitive style categories, or classes, may be known in advance as they will generically represent standard levels of cognitive skills (e.g.: “excellent, good, regular, insufficient”). As a result, supervised learning techniques will apply.

The main supervised learning techniques are decision trees, classification rules, neural networks, k-NN and SVM algorithms, all of which are used to model user behavior [64]. We have selected decision trees as they are typically used to execute classification tasks. The classification tree will be used to construct a personalized user model that takes into account levels of expertise in various areas, cognitive styles, etc. [184], [8]. Due to its ability to group users with similar characteristics, classification trees can be also used to implement recommendation tasks [137], [198], [218]. Decision trees go together with classification rules as the latter are an alternative written representation of the knowledge obtained from classification trees, which is in graphical form.

3.4.5. Summary of the advantages of using adaptive hypermedia techniques for survey purpose

We have presented a two-step innovative technique to conduct personalized surveys based on user modeling. The proposed technique can be summarized as a blending of stereotype and feature-based models so that the user model does not have to be initiated from scratch. What makes the mixed technique and its application to surveys even more interesting is its capacity for accurate prediction, a feature that is extremely important for urban planning aims.

Starting with the survey based on data concerning the ages and occupations (the initial stereotype groups) of a certain population set, and thereafter obtaining accurate results regarding that population’s urban time-use thanks to the feature-based model, the method allows urban-time-use results to be extrapolated to the non-surveyed remaining population of a specific city merely on the basis of knowledge of its citizens' age and occupation. Age and occupation are information readily available and collected in periodic population censuses. In other words, extrapolation functionalities of the method -based on initial user profiles and refined with personalization-, will permit to extend survey's results of a very significant sample to the remaining of citizens, allowing to represent the whole population of a certain city. This functionality is extremely important for urban planning purposes as the later can not be biased, which means completeness when using data to represent urban features. Since the whole population of the city that needs to be planned is represented, the method is valid. With this, it is demonstrated that the blended technique of stereotype and feature-based models applied to surveys is an extremely powerful tool. This constitutes an important functionality in terms of our model's aim of rethinking urban planning methodologies based on citizens' urban needs, using urban time-use as the unit of measurement for these needs.

As the prediction possibilities remain to be studied, we have not yet decided on a specific technique to extrapolate data to a larger set of users rather than the sample, or which prediction technique to use. If an unsupervised technique is selected then we will choose association rules. Association rules capture sets of actions that are causally related. A typical application of association rules for user modeling UM is the capture of pages that are accessed together and typically used to implement recommendation tasks [64]. On the other hand, The k-NN algorithm and neural networks would be the most suitable supervised techniques. Neural networks are commonly used to predict user behavior [163], but as behavior is not to be predicted, the best technique would be a k-NN algorithm. K-NN is a predictive technique suitable for classification [65]. Unlike other learning techniques in which the training data are processed to create the model, in k-NN the training data represents the model itself [64]. This special feature would make the k-NN technique very suitable for this model.

As already mentioned, stereotype and feature-based blended techniques applied to surveys introduce a predictive element into the model, allowing the urban-time-use distribution of not only a sample but also the overall population of a specific city to be surveyed. Stereotype and feature-based surveys' predictive functionalities will allow to plan the dimensions and uses of city's spaces as if we would have survey results for each and every citizen.

Besides introducing the predictive element, stereotype and feature-based techniques applied to surveys would permit easier updates, since only samples of different population profiles need to be surveyed. Next, using extrapolation techniques results can be extended to the overall population. This functionality moves the survey of the Smart Urban Planning Method towards real-time data in urban planning.

3.5. INSIGHT on visualization and representation tools to support decision making in the urban context

THE NEED FOR INTEGRATED VISUALIZATION AND REPRESENTATION OF URBAN PLANNING DATA

Obtaining new, more objective and citizen-centered urban planning standards contributes to city smartness. But we still need much more progress towards elaborating a set of indicators and a summarizing index to measure urban intelligence and monitor the Smart Cities initiative. One of the difficulties already being faced by Smart City experts is that available indicators, indices and statistics in general are largely historical information. Another difficulty, presented in this insight, is that urban information (statistics, indicators and indices) presents serious problems in its representation and visualization.

This insight aims to deepen understanding of the problems involved in representation and visualization of urban data. To that end, the following steps are taken:

- First, we review the different problems involved in the visualization and representation of urban data
- A complete description of current urban information representation (data, statistics, indicators, and indices) is given, including a detailed discussion of the problems and limitations of present-day urban information representation.
- We propose the Urban Information Visualization Pyramid to classify existing urban visualization techniques by making a parallel comparison with the Urban Data Representation Pyramid. These techniques are analyzed, and the existing ecosystem of visualization techniques is discussed.

- We propose a Model to deal with efficient and accurate data representation of all available urban information, and the incorporation of multiple visualization functionalities in a single tool.

3.5.1. Problems with the presentation of urban information

The United Nations Habitat Rolac Report proposes that urban information be organized in the form of a pyramid, the so called Urban Information (Representation) Pyramid. This Pyramid is composed of four levels, depending on the complexity of the information presented (see Figure 9).

At the base of the Pyramid is Data. Data is information that must be digitally transmitted or processed in order to make it meaningful. It includes both useful and irrelevant or redundant information. Statistics are the next level in the Pyramid hierarchy. Statistics are a collection of meaningful quantitative data which has been analyzed and interpreted. Statistics provide new sets of numerical data (outputs) which are developed input data. Examples are the statics of population, households, and unemployment. Further up the Pyramid we find Indicators, obtained by grouping related statistical values. For instance, from a combination of economic growth and unemployment statistics an indicator of the health of the economy can be obtained. Finally, at the summit of the Pyramid, we find Indices. An Index is a ratio, or a number which relates two items of information in a proportional manner, one of them usually a statistic. Indices, as relational proportions, are expressed in values per capita, per square meter, per household, etc. Since the top three levels of the Pyramid build upon the information contained in the immediately inferior level, all information is related.

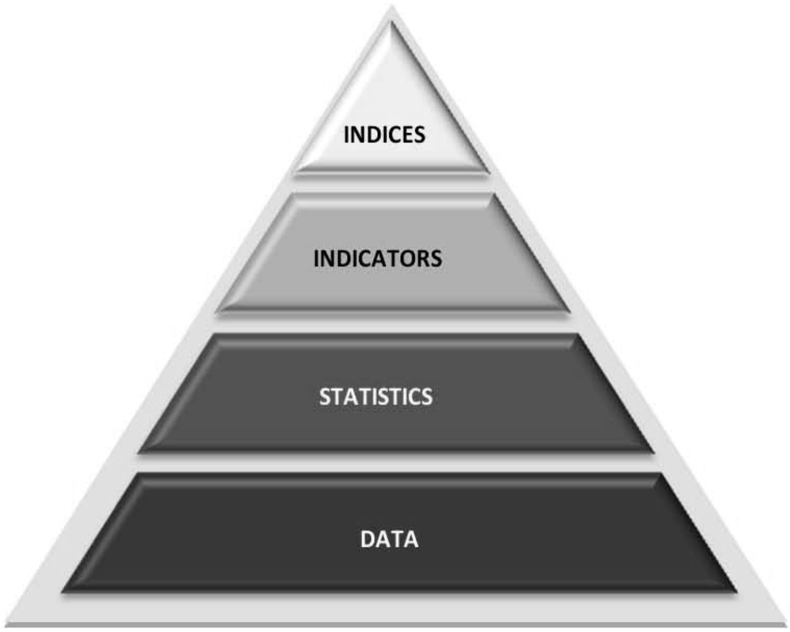


Fig. 9. *Urban Information (Representation). Own elaboration based on ROLAC report, Pyramid UN-Habitat*

The most common ways to visualize the information in the Pyramid are graphics and maps, which usually incorporate GIS functionalities. More complex visualizations such as 3D and simulations are also utilized for additional purposes such as elaboration. With regard to visualization, the main constraint of the Urban Information Representation Pyramid is that different levels of information are treated separately and in independent tools. This is graphically inefficient and hinders understanding of information. For representation, information pertaining to the different levels- although related- is not cross-processed or cross-checked. This causes complex data management and significant redundancies. Visualizing information from the different levels of the Pyramid in a single tool, and providing an integrated visualization of all levels, would promote understanding, solve graphical inefficiencies, and manage data redundancies.

3.5.2. Urban data representation

In this section we describe the three main levels of the Urban Information Pyramid. These are Urban Statistics, Urban Indicators, and Urban Indices. All are used as basic information for urban planning activity. The first or lowest level of the Pyramid (Urban Data) is not described in this section, since it refers to plain data which has not been processed to eliminate noise and inconsistencies.

Urban statistics

The first level of meaningful information is Urban Statistics, which are obtained by processing and debugging raw urban data. Generally, Urban Statistics are the responsibility of national governments (hence use of the term “official statistics”), and are only updated yearly or at even longer intervals. In Europe, national statistics are based on Eurostat standards and its classification portfolio. Eurostat is the statistical office of the European Commission. The Eurostat Urban Audit [55] is a data collection set providing statistical information and comparable measurements of different aspects of the quality of urban life in European cities.

Municipal population registers, which are the responsibility of local authorities, contain the only Urban Statistics which are outside the remit of national governments. They are always up-to date, since input and output population movements are constantly being filed. In addition, national governments conduct a census every ten years. The census is a broad survey which serves as a source of information about population, demography, households, and many other urban, economic, and social factors. Population figures from the census and municipal registers can diverge considerably. Generally, registers are considered to be the source because of their more updated information.

Urban Statistics play a role in various different aspects of urban planning, such as drawing up master plans and municipal planning reports, and monitoring urban development. The classical format for presenting urban statistical information is through graphics. But it can also be visualized in maps, since such information can be territorialized. Different Computer Assisted Design (CAD) tools are used for this purpose. A good example of urban statistics representation is the Spanish Digital Atlas of Urban Areas (Spanish Ministry of Public Works)[169]. Governments use initiatives like this to make statistical information more understandable and citizen-friendly, within both open data and e-administration frameworks.

<u>Urban indicators</u>

Like statistics, Urban Indicators, in the form of numerical outcomes after the grouping of related urban statistical values, are used in urban planning. They are taken into account when master plans are drawn up, and also in the context of municipal planning reports, monitoring urban development, etc. Indicators, as statistical compilations, are also collected by national governments. In Europe, like statistics, they are based on EU standards such as the EU Sustainable Development Strategy (EU-SDS), an initiative to develop a system of common indicators to evaluate sustainability. A major EU initiative to establish a framework for spatial information to support environmental policies is the INSPIRE directive [56]. This directive addresses 34 spatial data themes containing a number of indicators to measure the environmental impact of human activity. INSPIRE includes recommendations to Member States and technical implementing rules for environmental assessments (EU Commission).

Like statistics, indicators are frequently mapped, especially since the use of geographical information systems (GIS) became widespread. Although GIS utilization in urban planning is described in the next section, it is useful to provide a few brief definitions here. While CAD tools offer the user no functionality beyond their display mode, GIS – which are underpinned in CAD support - enable users to perform spatial queries about what is contained in the graphical model. Basically, GIS link maps to databases (in our case, an indicators database). Queries are designed by the GIS programmer, so the user can only see a display of those which are pre-arranged. Because indicators are more complex statistical information than statistics themselves, their visualization tends to be expressed in GIS systems. As with statistics, there are exceptions. Indicators are sometimes displayed in CAD maps, and statistics are sometimes offered in GIS support. The Spanish Urban Information System (UIS) [85] provides a good example of indicators displayed in GIS support. The user can pre-select queries about a specific municipality, region, or even the entire nation. Results are reported numerically (in a PDF file) and graphically (on the map).

Many countries besides Spain have developed a national UIS (NUIS) which gathers urban indicators. We find a significant example in India [83], whose NUIS is the responsibility of the Space Department, since the application is based on remote sensing. As we will see in Section 3, GIS are nourished by cartography, raster images and satellite data. This explains why, in some cases, space departments are in charge of NUIS hosting and maintenance. A good example of a municipal UIS is found in Berlin (Berlin Municipality) [11]. In this case, the UIS is larger and incorporates environmental information.

Information Systems (IS) started to take off in the early 1970s. In the beginning many IS projects failed, because the systems being analyzed (especially urban ones) were too complex. In the 1980s GIS appeared on the market, but it was not until the 1990s that public administrations started using them. GIS and UIS shared a learning phase during the 1990s and supported each other. GIS provided UIS with the spatial interface needed to deal with the complexity of systems, since UIS were the most challenging support with which to test GIS functionalities. Now, both techniques are quite mature, working together or separately.

Urban indices

Like the main Urban Indicators, which are universally standardized under the UIS umbrella, most important Urban Indices are collected by an international standard framework, the so called Local Agenda 21 (LA21). The term 'local' refers to its application domain, which is municipal. LA21 contains indices which are mostly expressed in values per capita or square meter. Nevertheless, LA21 can also contain some indicators. It is worth noting here that indices are sometimes misnamed as indicators and vice versa, not only in the context of the Urban Information Pyramid, but in many other fields.

Local Agenda 21 represents the commitment of a city to sustainability, from both the urban and environmental perspectives. In 1995, more than 1200 cities ratified the Aalborg Charter, which gave great impetus to LA21 in the European sphere. It had first been made public at the 1992 Earth Summit, a pioneer event in promoting the role of cities along the road to sustainability. As part of their support for the Charter, affiliated cities started creating specific working groups to design and implement its agenda in their respective cities. Agendas started with a diagnosis in line with the critical aspects of cities agreed in the Charter. This diagnosis was mainly based on and monitored with indices and indicators.

LA urban indices are typically grouped according to different urban strategies: in defense of quality of life in the compact city, conservation of natural resources and the use of renewable energy, social cohesion and public participation. Agendas also usually include a final index on overall satisfaction with the city.

Other significant indices referred to environmental issues. To support the policy objective of a healthy city, indices like noise pollution, air quality, beaches or river water quality, and annual equivalent of CO_2 emissions were included. In support of policies oriented towards sustainable development, we find indices such as the number of organizations with environmental certification, schools participating in environmental education projects, and the number of sales points for fair trade products. Unlike statistics and indicators, urban indices – mainly coming from LA21- were presented in the form of graphics, charts and diagrams. A representative example of an LA21 presentation is Tameside Metropolitan Borough's preparatory survey, which included guidelines for calculating sustainability indicators.

We have used the past tense when referring to LA21s because they are no longer in widespread use. Their heyday was between 1995 and 2005, when many cities around the world designed and implemented their agendas. After that time, only in limited cases were indices and indicators updated, since in most cases their information had become redundant. If we analyze the more environmental aspects of LA21s, we see that they are close to being an environmental audit. Municipalities regularly carry out environmental audits, since these are mandatory for urban planning actions. With respect to the urban side, LA21s express existing urban statistical information in values per capita or other proportional measures, and only tell us what we already know. This explains why they have fallen out of favor. In other words, what an LA21 does is express known urban statistical information in the shape of rate. It is interesting to note that the LA21 crisis (from 2005 on) coincided with the widespread adoption of UIS by local administrations. The coexistence of LA21 and UIS in a given municipality would lead to information redundancy. It is not surprising, therefore, that municipalities abandoned LA21s in order to save scarce public resources. The story of the lack of success of local agendas opens the discussion on which our proposal is based. We often find redundant urban information from agendas, statistics, and indicators that tells us the same thing but in a different format.

3.5.3. Urban information visualization

Urban information visualization has become an emerging focus of research in the visualization community. Research has focused on the geometric aspects of the problem, with emphasis on the development of schemes to exchange data between information databases and optimize engines for visualization, navigation, and manipulation. In this section, we review the state-of-the art of urban information visualization, the tooling that helps visualize the levels of an Urban Information Representation Pyramid described in the previous section. The state-of-the-art will be presented and organized by means of a classification pyramid, the Urban Information Visualization Pyramid. The proposed visualization Pyramid makes it possible to establish correlations between visualization techniques and representation levels. These correlations are the basis of our proposed Model and will be explained below.

Over the years, different visualization techniques have been proposed to display the information contained in the levels of the Urban Information Representation Pyramid. But the existing techniques limit visualization to information levels on a separate basis. Therefore, as in urban data representation, methods and techniques for urban visualization can be classified in the shape of a pyramid according to their functionalities (Figure 10). As far as we know, the proposed Urban Information Visualization Pyramid is a novel proposal for classification of software for urban visualization. The proposed classification will help us to establish correlations between both Urban Information Representation and Visualization pyramids.

At the base of the visualization Pyramid we can place maps, normally under CAD specifications, followed by GIS tools to which 3D functionalities can be added. 3D software is on the third level, and simulation tools are at the top.

The earliest and most basic visualization techniques, CAD and GIS, were briefly described in the previous section. We will now focus on providing a short explanation of the more complex 3D and simulation techniques and their utilization for urban purposes. The use of 3D technology is normally

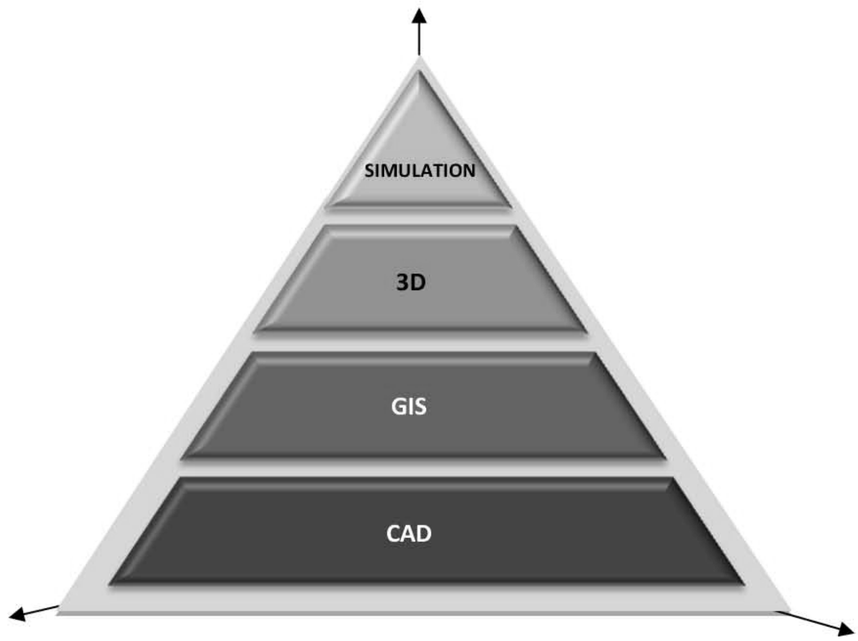


Fig. 10. *Proposed Urban Information Visualization Pyramid.*

Own elaboration

implemented with CAD and GIS support. Both 3D CAD or GIS are used to generate 3D city models. These models can depict complete cities as well as more reduced urban scenes taken from the built environment. The resulting image is called a render. The level of detail of a render will vary according to the urban scale of what is being represented, but it has no other functionality beyond display. For more complex functionalities, we have to move to a combination of 3D and GIS. With such a combination the 3D model can display answers to queries, using its linkage to the GIS spatially referenced database. More interactive 3D CAD and GIS models include navigation capabilities.

Although simulations can be represented in 2D, 3D techniques have normally been used since their widespread introduction. An urban 3D simulation model is similar to any other urban 3D model in terms of display results, since in both cases virtual representations are made. The main difference is that a 3D simulation model represents an urban situation that doesn't exist, either because it is a future scenario or because it is an alternative to reality. Therefore, simulation models are mainly used for testing.

Many urban visualization models today are three-dimensional, but there is a trend towards real-time presentation of large models. Models to visualize urban environments have many uses, from urban planning to new building work pre-visualization to utilities service planning.

As indicated, in this section we review the state-of-the-art of the most common and widespread techniques for urban data visualization. In contrast to the Urban Information Representation Pyramid, techniques composing the visualization Pyramid cannot be segmented into levels. This is because the visualization of urban information usually requires more than one of the techniques described, very often in combination with GIS. Therefore, and unlike in the previous section on urban data representation, the following review of information visualization in the urban field is organized according to purpose or functionality of the technique. We can distinguish six functional groups:

I. Tools and techniques for visualization of data retrieval, data classification and data integration;

II. Thematic map visualization;

III. Modeling;

IV. Virtual models, simulations, and augmented reality;

V. Visualization for monitoring: and

VI. Simplified and collaborative visualization for participative ends.

In the first group (I) we find various examples of the technique for visualization of data classification. One relevant model combines building footprints and LiDAR (Light Detection and Ranging) to visualize an urban area. It emphasizes buildings in a GIS environment, with the main objective being to develop and fix a vector model suitable for classifying urban constructions [3]. In the area of data retrieval visualization, Yiakoumettis at al. [212] have developed an application for automatic navigation into geo-referenced scenes, adopting the Google Earth API (Application Programming Interface) to retrieve and visualize data in GIS. Still with data retrieval, Hetherington, R et al. [74] have constructed a model for the embodiment, extraction, processing, and display of data from X3D (eXtensible 3 Dimensions) architectural models, to obtain descriptive information about urban development. In the field of data integration, the Building Data Integration System (BDIS) developed by Wang, H et al. [196] attempts to create a multidimensional system to be used in the UIS of the future. It allows multidimensional information integration, especially of 3D models. It is also worth considering collaborative spatial decision-making based on real-time data sharing with coordinated data access and synchronization between multiple geographical and dispersed participants [201]. This implemented hypermedia concepts and visualization tools such as the Dynamic Visualization System (DVS), which dynamically hyperlinks to web map servers, and the GeoConference, a commercial real-time Internet-based geospatial collaborative conference system.

In the visualization of thematic maps (II), Petrovic [142] demonstrates the possibilities of 3D thematic maps for spatial planning. They include segmented representations of the current landscape, representations for layered spatial analysis, and visualizations of a specific layer of the planning area. In the more specific field of vegetation thematic maps, El-Mezouar at al. [54] have looked at a new index to generate high-resolution maps for IKONOS imagery. The Normalized Difference Vegetation Index (NDVI) is the most popular approach for generating vegetation maps by remote sensing imagery. The proposed new index attempts to turn NDVI low resolution vegetation into High Resolution maps (HRNDVI). Moller [132] is developing a method for the automated analysis of vegetated areas, and especially vegetated roof-tops in the inner city, using multispectral and extremely high resolution imagery. Methods for visualizing geological urban risks through maps also exist [29]. Mardaljevic and Rylatt [126] have introduced an approach to evaluate total annual or monthly irradiation incidence on building facades, with results presented in render images. Wolff et Asche [202] have developed a method for 3D GIS geospatial crime scene analysis, which allows the correlations between urban features and robbery offences to be examined. Some of these correlations link pedestrian frequency with facilities such as schools, banks, etc. Crime control is becoming an important issue in urban planning, and this kind of research is therefore attracting great interest. Finally, Brennan-Horley [20] use the visualization of mental maps for planning purposes. Interviews with people in the creative industries were conducted, and the results accumulated in a GIS for visualization and analysis. Collation of the different mental maps of the subjects surveyed revealed the opinions of “creative citizens’” concerning their city. Mental maps are attracting increasing interest, since they can be drafted in several thematic fields.

Turning now to the modeling techniques group (III), Pinnel et al. [143] have developed UrbanView, a visualization system for urban modeling. Zhou et al. [216] have developed a way to integrate GIS with multitier web applications for creating 3D city models. Web applications support a digital building model, a digital terrain model, large-scale true urban orthoimages, and actual building sidewall pictures. Kim et al. [96] propose 3D GIS software for automatic modeling of 3D geo-features, which they call Rule-Based Modeling (RBD) models with 3D geo-features using 2D profiles and 3D feature attributes. Lai et al. [104] have studied the scope of 3D visualization for Environmental Impact Assessment (EIA) in urban planning. They conclude that 3D representations have a good future in EIA, due to their accurate depiction of the natural world.

In the visualization of urban virtual models (IV) Dong et al. [48] have developed a new method for modeling overground and underground entities and spatial analysis, also using Virtual Reality technology (VR). The new method can construct a virtual urban geological environment, provide integrated modeling of overground and underground entities, and facilitate interactive research functions. Serrao et al. [161] have developed a software architecture based on a geographical database which supports storage, recovery, and real-time visualization of urban virtual models. The contribution of Yao et al. [210] is a virtual reality urban planning tool based on GIS and virtual environments which generates scenarios and collaborative urban designs. The system provides an open structure for various visualization and simulation modules for prototyping urban designs. Lange [105] has studied the degree of realism of virtual 3D-visualizations. He claims that validation of simulations of virtual urban landscapes - in terms of their degree of realism (R'Degree) - has until now been neglected in the visualization research arena. Lange focuses on how and to what degree photographed real landscapes can be validly represented by means of virtual landscapes.

Remaining with this group (IV) but focusing on the simulation field, Birkin et al. [12] illustrate how open source spatial simulation models can be calibrated with crowd-sourced data. They provide some examples to illustrate this novel procedure, which is extremely credible due to its use of social networking mechanisms. The work of Schmidt et al. [155] is in traffic simulation. The SIMTRAP project is an integrated system of traffic flow information, air pollution modeling, and decision support, with interpretation and visualization results displayed in 3D GIS. Finally, in the augmented reality field, we need to highlight the work of White and Feiner [200] on how augmented reality techniques can be applied to arrangements for site visits (for data collection, discovery, comparison, manipulation, and provenance). The site visit, as a preparatory step, is very important for urban planning.

In the area of visualization for monitoring purposes (V), Bogorny et al. [15] have developed a software architecture for semantic trajectory data mining which offers a sequence of spatio-temporal points with data analysis. Chittaro et al. [40] have developed a tool for the visual analysis of navigation patterns of moving entities, such as users, virtual characters, or vehicles in 3D Virtual Environments (VEs). Zheng and Shi [215] have worked in virtual reality to create a cyberspace of a real urban area which can be entered via the internet, enabling visitors to travel around and find their location in cyberspace. Ibrahim and Noor [82] have researched how to enhance information legibility in an information visualization context to assist users in determining optimal travel routes and trajectories.

Lastly, and in the arena of simplified and collaborative visualization techniques for participative ends (VI), Yao et al. [211] have developed a virtual reality prototype to support collaborative urban planning. The prototype is a workspace that comprises a variety of technologies, from a semi-immersive stereo display to optical tracking systems. Using semantic web technology, Hoekstra et al. [76] have come up with what they call the "Legal Atlas". The goal is to help citizens understand spatial legal constraints in an urban context. The tool presents legal norms on a map with a very intuitive visualization of their scope. Wu et al. [205] have developed a highly distributed system accessible from the internet to promote participation in urban planning. End users (citizens) can select any of the available urban planning solutions for visual investigation, and compare and contrast them with a specific planning proposal. Coors et al. [43] present a new approach to tangible interaction with rear-projection tables that use physical, "active" pieces which are easy to build and track. Active pieces are used to interact with 3D-GIS and support three-dimensional queries, in addition to photorealistic visualization. Coutinho et al. [44] have prepared a 3D environment to assemble customized repositories of geographic information about a region. The system links the repository with collections of documents gathered from the World Wide Web or other specialized information sources, and monitor events that might affect decisions made on the basis of this rich information set.

Some important findings emerge from this review of how visualization software is used in the urban field: there are no applications which help with the visualization of urban planning itself. Amongst all the applications classified in the six functional groups, none helps construct and understand a master plan in a more visual way. During research outside the scope of this work, we took a deeper look at the groups which offered greater potential for finding such an application, but found nothing for visualization of data retrieval, data classification, and data integration (I), or simplified and collaborative visualization for participative ends (VI). (We have seen how applications classified in groups (II) to (V) mainly focus on visualizing certain aspects of existing or virtual cities, not related to urban planning). The fact that no tool exists to help urban planning visualization is the second justification for proposing the software Model.

This state-of-the-art in visualization techniques for urban purposes clearly shows the need for all information levels of the Pyramid to be visualized in a single tool. The Model proposed below, although this single tool, allows visualizing large data sets pertaining to different urban information levels and from different sources, using a combination of different visualization techniques.

3.5.4. Model for integrated urban information representation and visualization

We previously mentioned the issue of data redundancy in urban information. We also noted that Local Agenda 21 is nowadays dispensable due to the duplication of the information it provides in urban statistics and indicators such as the Urban Information Systems (UIS). Recapping the section on information visualization, we found that there are no effective applications which help urban planning visualization itself, or which offer a choice of visualization functionalities in accordance with the information that needs to be presented. Therefore, there is a clear need for tooling which accurately processes multiple urban information from different sources needed for urban planning activity, while helping and enhancing its visual interpretation.

To that end, we propose a Model for integrated urban information representation and visualization in urban planning. The Model presents all the types of urban information (statistics, indices and indicators) needed for the urban planning tasks using the master plan of the city as a geospatial support. This pioneering representation of urban information avoids redundancies since it is geo-referenced. And urban information is visualized with the whole spectrum of graphical techniques (CAD, GIS, 3D and simulation), to optimize both data performance and accuracy.

information to be represented	type of information	administration responsible for the information	visualization technique
data	master plan	Municipality's virtual planning office. Barcelona Municipality*	simulation
statisitics	physical variables, environment, population figures and demographic censuses, migration, vital statistics, education, standard of living, labo market, etc.	Spanish National Institute of Statistics	GIS
		Statistical Atlas of Urban Areas (Ministry of Public Works. General Secretariat of Land and Urban Policies)	
indicators	environmental, sustainability, social, demography, etc.	Urban Information System (Ministry of Public Works. General Secretariat of Land and Urban Policies)	3D
indices	quality of life in the compact city, degree of conservation of natural resources and the use of renewable energy, waste production, socia cohesion and public participation, public's overall satisfaction with the city, environmental issues, healthy city, sustainable development, etc	Local Agenda 21. Barcelona Municipality*	CAD

Fig. 11. *Model information representation: sources and visualization techniques. Own elaboration*

What really distinguishes urban planning from other urban-related tasks, such as urban assessment or urban management, is its predictive capacity. The main objective of urban planning is to ensure that the proposed city model will fulfill the needs of citizens in a time-horizon of 20 years. To that end, demographic and economic projections are employed, forming the back-bone of the proposals made by master plans. Therefore, data from projections is collected on the Model, at the levels of statistics and indicators and how projections are represented. In addition to this basic information for urban planning, the Model also collects the whole spectrum of available urban information, from statistics to indices.

To construct the Model database, the user introduces all the desired information, statistics, indicators, and indices from their original source. The Model disaggregates complex statistical information – indicators and indices – into plain statistics. After a debugging process to eliminate redundancies, processed information is systematized to unify units of measurement and indicators, and statistics are rebuilt. As an example, Figure 12 shows the most common sources of information that can be used to obtain urban information for the city of Barcelona.

Once all of the systematized information is in the model, it is classified in different thematic layers, such as demography (age, sex, etc.); population profile (level of studies, level of employment, etc.); social profile of citizens (marital status, time use, household members, etc.); and housing factors (construction date, last renovation, supply services, etc.). There are also layers more concerned with economic issues, such as industrial and services sector activities (location, number of employees, type of activity, registration date, etc.) and services and facilities (type, ownership, years of concession, number of daily visits, etc.). Statistics and indices of demographic and economic projections are introduced in their corresponding layers of demography and the economy.

In the Model, statistical information is geo-represented using GIS techniques and territorialized in the smallest possible unit. Statistical information aggregated at the municipal level is usually available. Representation using the GIS geo-referenced functionality allows its distribution by blocks, districts, etc. to be visualized. This provides a more detailed view than the municipal aggregated form. To territorialize statistical information (including statistics on demographic and economic projections) is to geo-referentially map it in the master plan of the city. Territorializing statistical information in urban units smaller than the aggregate municipal level permits lower-scale predictions, which will result in more accurate and detailed master plan proposals.

Equally interesting is the territorialization of indices and indicators. The previous process of disaggregating indicators and indices into plain statistics to eliminate redundancies is also used to break down the information they contain (normally at municipal level) into smaller physical units (blocks, districts, etc.). When rebuilding indicators and indices, the information will be presented in those smaller units. Unlike statistics, indicators are geo-referentially mapped using 3D techniques, to add a third dimension to visualize their multiple statistical content. For example, municipal demographic indicators such as age and sex distribution will be represented in the smaller units of city blocks and visualized in 3D cubic shapes of different heights depending on their values. Finally, indices will be geo-referentially mapped and visualized using simpler 2D techniques. Unlike indicators, they usually are plain statistics expressed in values per capita or per square meter, so that the information they contain can be represented in a simple 2D-vertical CAD model. Statistical information is shown on the X axis, while the Y axis shows the rate unit of measure.

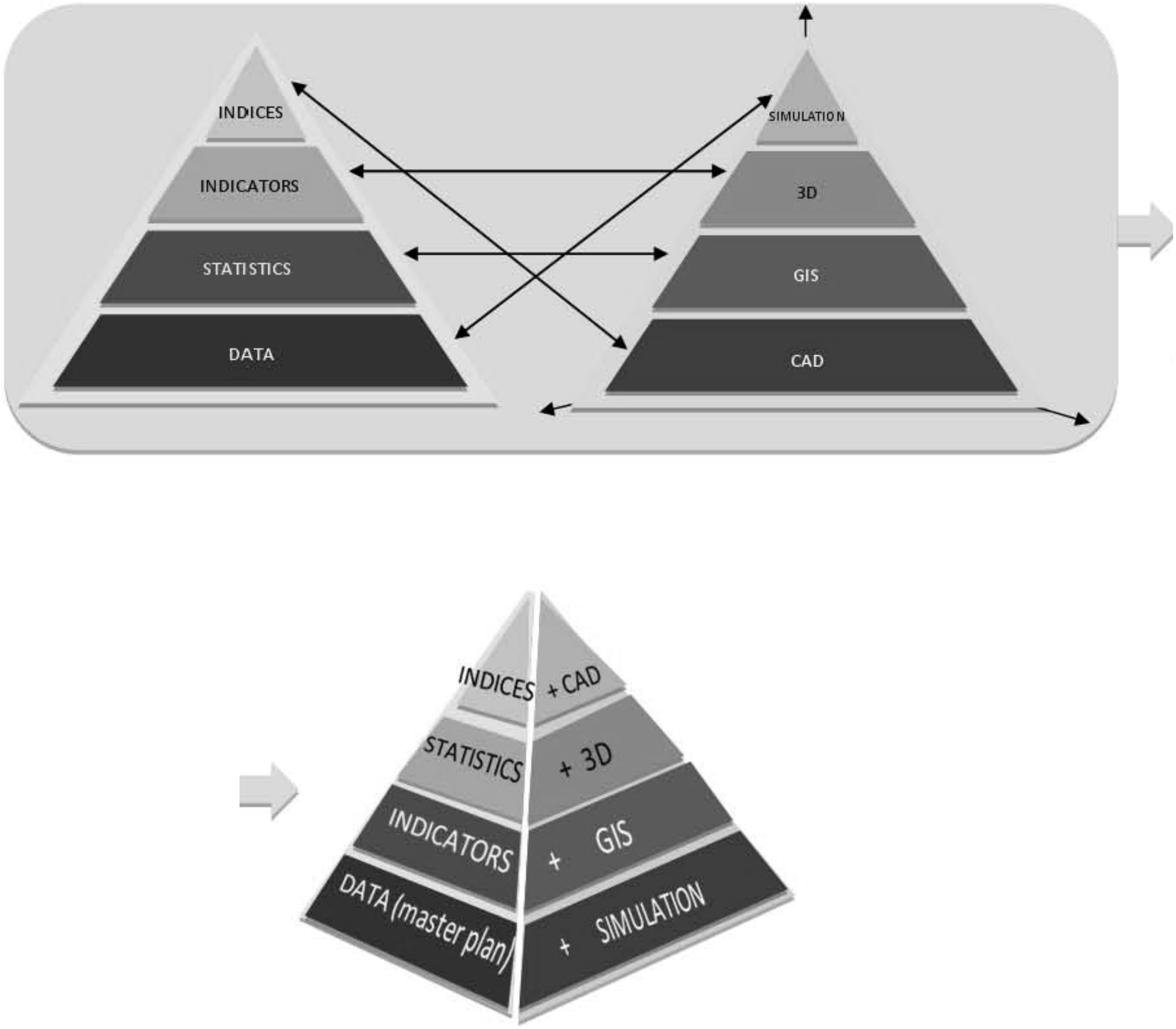


Fig. 12. *Proposed Model conceptual schema. Own elaboration*

Finally, simulation techniques are utilized in the Model to represent the planning proposals being made by master plans. Planning proposal simulation can be of the current master plan, to visualize development, or of a master plan under preparation, to assess potential impact. Simulation makes it possible to create different urban scenarios (i.e. variations in the proposals of the master plan) for testing, and to select the version that best meets the planning target. Planning proposals simulation include zoning, land uses, constructability, etc. and are visualized in the same way a master plan is depicted. Figure 12 shows how the whole set of visualization techniques and the different representations of urban information are combined in the Model.

Model users can decide at which scale they want to execute the representation and visualization analysis. Block level would be the minimum unit of analysis, in order to protect privacy.

3.5.5. Summary of the advantages of integrated presentation of urban information

There are several problems involved in the representation and visualization of urban planning indices. Our proposal, the 3D-Visual Urban Planning Integrated Data Model, makes it possible to visualize urban information in a single tool and remove both visual inefficiencies and data redundancies in the representation of information. Therefore, in the urban data visualization field, our Model is an innovative and comprehensive Model that provides all of the visual functionalities being offered separately by existing visualization tools. This is a major step forward, considering the current tendency towards excessive spread tooling. Perhaps the main achievement of our Model in the urban data representation terrain is data accuracy, which results from elimination of the serious problem of data redundancy.

The Model manages the problem of data redundancy by revealing data contradictions. This results from its functionality in disaggregating indicators and indices into plain statistics, which are followed by a combined process of data debugging and systematization to identify and remove redundancies. Next, indicators and indices are reconstructed, but without redundancies.

In our opinion, models like the one proposed here will become increasingly necessary in the immediate future. New and more up-to-date information resources are becoming available on a daily basis, making integration and systematization tools increasingly essential. Open data initiatives will also increase the need for tools such as our Model. At the end of 2011 the European Commission proposed a review of the current directive on open data in order to speed up the release of all public sector information [57]. The private sector is also actively increasing available data. The Current City Research Foundation, based on the use of different analysis techniques with anonymous data from mobile users, maps real-time urban flows and time patterns. Such real-time data is already used in several applications, from planning different responses to emergencies to studying the impact of urban development projects. The updating and introduction of real-time data from open data or mobile user initiatives can be easily carried out by the software Model proposed here. This includes debugging, and classifying and storing any new data in accordance with what is already contained in the Model.

To deal with urban planning updating needs and the increasing availability of information, we need powerful tools that help planners represent and help citizens visualize information. The better our cities are documented, the better urban planning will be. Our Model can make a significant and lasting contribution to better urban planning.

3.6. INSIGHT on agent-based public participation

AN AGENT-BASED COLLABORATIVE MODEL FOR MORE MEANINGFUL CITIZEN PARTICIPATION IN URBAN PLANNING

One mechanism to accumulate intelligence is through the use of crowd-sourcing techniques. Agent technology is very useful to manage information for specific purposes gained through crowd sourcing. In order to increase intelligence in our Model, we propose the use of agent technology in parallel with the beginning of implementation of the urban planning values obtained with our Model. After this initial step, agent technology will also be utilized during the preparation of the new urban planning proposals. In this second step, agent technology is used to monitor the response to urban planning proposals from the citizens.

This agent-based model helps the Smart Urban Planning Method to greatly increase public participation in urban planning and make it more citizen-friendly, to automate data collection processes, and to facilitate the verification of results.

The insight is structured through the following steps:

- We review the existing implementation of agent technology used in urban planning
- We explain our Model based on agent technology to mine the opinions and ideas of citizens
- We use an unsuccessful experience in urban planning public consultation, the renewal of the Diagonal Avenue in Barcelona, as a concluding example of how our Model reinvents participatory processes in urban planning

3.6.1. The problem of public participation in urban planning

Public participation in the processes involved in the design and updating of urban master plans need to be improved. As things stand, it is not easy for citizens to become involved in these processes. This is due in large measure to the fact that participatory channels open too late in the timeline of master plan development. This results in a very low level of participation, which can raise doubts about the validity and legitimacy of the plan, and even lead to its rejection.

The processes for ensuring participation during the design and approval of master plans have a similar structure in all countries: citizens are requested to give their opinions once the design process is over and the stage is set for the approval process to begin. The approval process of master plans typically has three chronological steps, each with an increasingly binding status. In the first step, immediately after the design phase is over, the authors of the plan present it to the municipal council for its initial approval. Council members can ask for changes in the proposals of the plan before they officially approve it. Once this first approval is given – the so-called initial approval - public participation starts. The council organizes a public presentation conducted by the authors of the plan. Presentation is followed by a one to two month period for public participation and input. During this period, citizens can only make suggestions about the proposals of the plan, but not give new ideas for the city. In a very real sense, the role of citizens is reduced to mere validators of the proposals already included in the plan. This limited role of citizens is a constant in all participatory steps of the master plan. Once this period for suggestions ends, suggestions are assessed by the authors of the plan. Some suggestions will be favorably considered and included in a new version of the plan prepared by the same team of urban planners.

In countries where urban planning is within the remit of the municipality, it is the responsibility of the municipal council to approve this second version of the plan. In countries where urban planning is within the remit of the regional authority or the national government, this second version will be considered by the responsible body in each case, which will either approve it or ask the planners to make further amendments. The approval of this second version of the plan is known as provisional approval. At this point, another two-month and more binding process of public participation starts. During this participatory period, the plan is available to citizens on the municipal web site and at the town hall urban planning offices. However, once again, citizens can only express their objections to it. They simply serve as validators of the proposals and, in this phase, their role is even reduced. Unlike suggestions, objections are not opinions on the proposals of the plan. Instead, they simply reject the proposals of the plan and/or point out illegalities, irregularities, or other anomalies. Once the two-month period of public consultation is over, the authors of the plan collect all the objections, assess them, and consider their inclusion in what will be the third and final version of the plan.

The third version of the plan is then presented to the competent authority. As in the second phase, the municipal, regional, or national controlling authority, depending on the legal system of the country concerned, either approves or requests amendments to the authors of the plan. This final step is usually described as the definitive approval. Once the third version of the plan is official, citizens that still object to any part of it can only lodge an appeal, thus initiating a legal process that will finish in court.

The described public participation in urban planning does not fairly respect or incorporate the opinion of citizens. It is not fair because it happens once the design phase of the master plan is over, limiting the role of the citizens to mere validators of the proposals of the plan. Moreover, some citizens that could participate do not do so because the institutional structure and procedures utilized are discouraging, demotivating, and very unpleasant if they finally result in citizens having to confront their local authorities before the court system. Participatory processes in urban planning should be more citizen-friendly, and must provide equal opportunity of expression of proposals for the city, instead of adhering to a bureaucratic process geared only towards validation. Public consultation should serve citizens so that they can identify with and take ownership of the design of the master plan which, after all, creates the city they will use and live in.

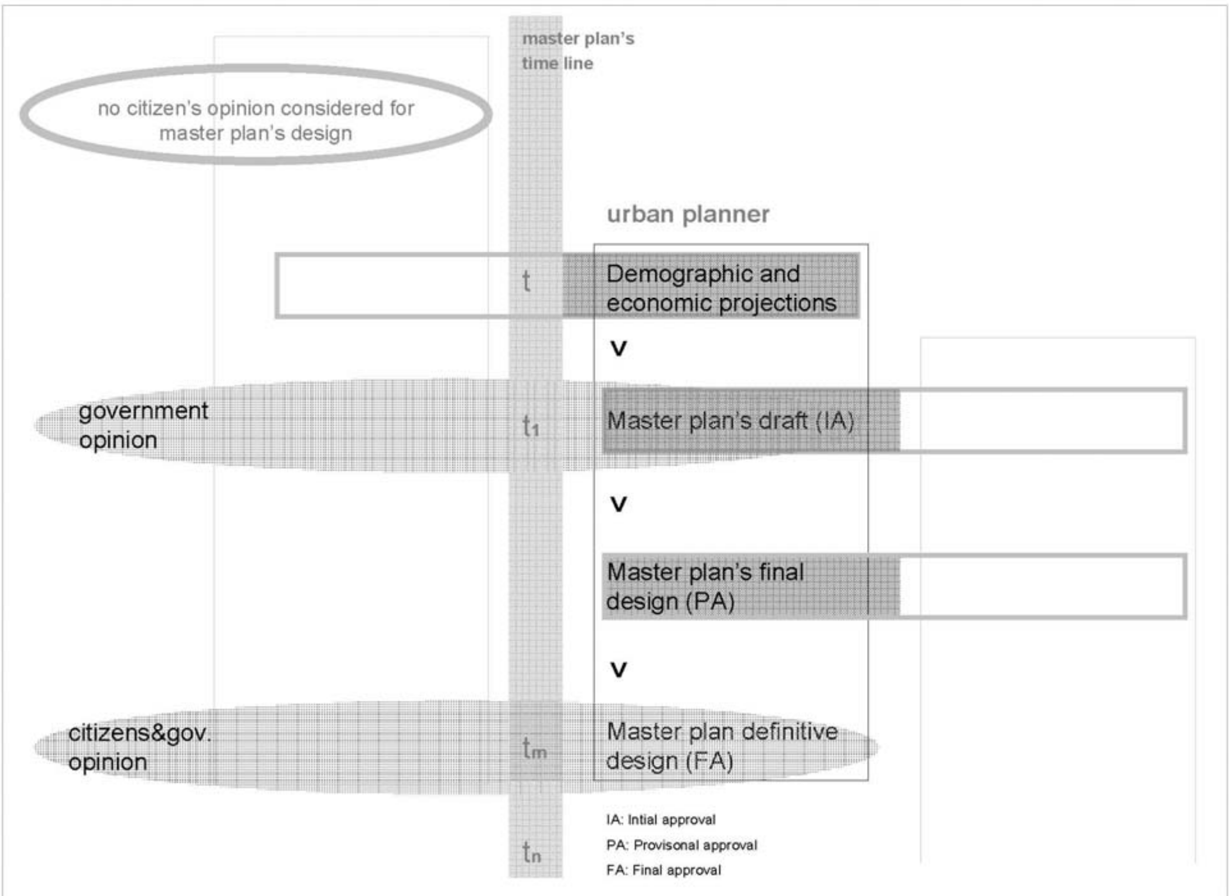


Fig. 13. *Current elaboration process of a master plan.*

Own elaboration

A master plan is a tool with which to effect change in a city: new residential developments provide new housing resources, new industrial and tertiary sites generate new job opportunities, new public spaces offer more leisure opportunities, new facilities provide more services, etc. It does not make sense that citizens should suffer rather than enjoy playing a part in the creation and design of all these resources for their city. They should be involved in the design phase, not only in the approval process. Moreover, to draft three versions of the master plan (with their corresponding approval processes) is inefficient. Reaching final approval can easily take a year or more, even if it is not interrupted or frozen before completion due to unforeseen circumstances such as political changes in one of the authorities involved, lack of resources, etc. For all described reasons, urban planning participatory processes need to be reformulated in order to allow the public to be involved in the early design phase of master plans. In addition, this should be done by employing technological citizen-friendly participatory methods.

Computer technology has helped to develop new mechanisms which incentive public participation in urban planning. More recently, the so called 'immersive planning' [68] focuses on the depth and breadth of user experience. Commonly web-based, the immersive planning techniques can be framed in three categories of immersion: challenge-based, sensory and imaginative. Geographic information systems (GIS), planning support systems, virtual environments, and 3D digital games are all methods of obtaining user immersion in one or a combination of these categories. The latest developments on these techniques comprise the following: Bugs [27] et al. analyze the impact of collaborative Web 2.0 tools applied to public participation GIS applications in urban planning actions. Brabham [19] uses a web-based crowd sourcing model typically used in distributed problem solving and production model for business as a public participation support system for urban planning. Dai et al. [47] use advanced virtual reality not only to incentive public participation in urban planning purposes but in the design of public buildings. Bogdahn et al. [14] enable users to explore in a playful way urban planning proposals in 3D models. Howard [79] ads interaction mechanisms between users inside the modeled environment.

3.6.2. The technique: Agent technology in the urban context

In terms of functionalities, what characterizes urban planning is its predictive capacity. By definition, prediction means obtaining a model for the future by modeling the present. To obtain the future urban model, the urban planning practice uses demographic and economic projections, normally with a twenty-year time horizon. Thus, the main urban planning function is to predict what a city will need in twenty years, based on demographic and economic projections. And a master plan is the graphical representation of such predictions, (through the zoning) depicting how the city will look like in two decades.

Agent technology it is useful for urban assessment and decision support as it relies on simulation. Agent technology for urban planning purposes must incorporate predictive functionalities.

The following definition will help to explain how simulation works for urban assessment and decision support purposes using agent technology. "An agent is a computer system that is capable of independent action on behalf of its user or owner in order to satisfy design objectives. An intelligent software agent has to be autonomous, reactive, proactive, and social (capable of interacting with other agents to communicate and negotiate). Intelligent agents can learn and adapt to new situations. (…). A multi-agent system consists of a number of agents that interact with one another, cooperate in order to accomplish different tasks and are able to negotiate and solve conflicts" [52].

In an agent-based urban simulation, different scenarios are created to find a solution to a specific problem. In such scenarios, agents act on behalf of people, so simulation is a fairly realistic virtual approach to better assessing a real problem. Simulation allows different scenarios to be generated by changing the macro-characteristics of the model which is being assessed. The functionality that enables the creation of different testing scenarios makes it an appropriate technique for decision support systems (DSS) assessing physical realities. As examples in the context of physical urban assessment, Ligtenberg, A. et al. [116] have developed a model to decide on the location and spatial distribution of new development areas. The model combines a multi-agent simulation (MAS) approach with cellular automata (CA). CA is used as a support to provide the knowledge an agent needs. It includes individual actor behavior with different levels of participation. Spatial intentions and related decision-making actions are defined by agents. The modeling concept is intentional and based on the Schulz DSS model where agents interact with the environment rather than between themselves. The same author [117] has developed a similar model where interactions between actors are stronger. Here the MAS also simulates a multi-actor interactive spatial DSS process for allocation purposes. It pursues knowledge sharing between participating actors in a learning approach designed to create a common view that minimizes decision conflicts when selecting areas eligible for development.

Besides assessing physical realities, agent-based DSS models are also used to assess the strategy for growth in a city, testing different approaches such as balanced growth as a whole, or uneven growth favoring some parts of the city. Kou et al. [101] adopt an MAS based on Swarm simulation to assess the process of urban growth in an artificial city. The effects of organizing the city into one or more city-centers are tested. Still in the research area of city-center simulation, Wagner [194] has developed a topological and metrical categorization of different city core areas to assess their level of attraction. The research combines an MAS of random walking agents and axial graphs. In other cases, cellular automata and agent concepts have been used to model and simulate different scenarios of growth and dissemination of slum areas as a basis for assessing control measures. Chen et al. [36] have developed a tool for urban growth control. Li and Liu [114] have combined agent technology with CA and GIS (geographical information system) techniques in a single exploratory tool to simulate different urban development patterns in order to assess their level of sustainability.

Agent –based DSS models for urban assessment have also been used at the urban building level to simulate how citizens use a city by changing the built environment, either in terms of building functions and other urban elements [116] or performance indicators [117]. Other authors have been more concerned about assessing social sustainability in a changing built environment [101]. A final point to mention is that agent-based DSS models have been developed not only for urban assessment but also for larger-scale spatial decisions. Arentze et al. [194] have developed a spatial DSS using agent-based model (ABM) techniques for land-suitability and facility-needs analysis. The authors highlight the innovation of their analysis as it combines the two related approaches of land-use-allocation and land-use-needs modeling. The resulting integrated model is able to generate different scenarios of allocated land-use alternatives by changing the features of facilities. Agent-based models (ABMs) are useful for simulating urban, spatial, and all other kinds of complex systems [36]. Applications can vary from the simulation of socio-economic systems through the elaboration of scenarios for logistics optimization and biological systems to the urban and spatial ones already seen. Interestingly, ABMs provide the means to include real decision making without losing the strength of the concept of self-organization [114] inherent in complex systems.

Despite the powerful simulation functionalities of ABMs that allow them to explore all kinds of complex systems, the addition of predictive capabilities makes them useful for the urban planning activity. In this terrain, to highlight the works of Batty [7]. He conceptualizes a bottom-up urban planning process in which the outcomes are always uncertain. This is combined with new forms of geometry associated with fractal patterns. Batty's model begins with the use of cellular automata (CA) to simulate urban dynamics through the local actions of automata. Next, he introduces agent-based models (ABM) in which agents move between locations. These models relate to many scales, from the scale of the street to the urban region. Finally, Batty attempts to understand and predict different urban phenomena with a focus in spatial modeling changing to dynamic simulations of the individual and collective behaviors of involved actors at such scales.

Finally, a conceptual clarification is necessary. Prediction and probability are completely different techniques [5], and demographic projections are much more than just an extrapolation of population to a certain time-horizon [49]. We will revisit these concepts when we present our Model in the next section.

3.6.3. A pair of opinion-miner agents that recommend the ideas of citizens to planners

Our novel contribution to the existing field of technologies for incentivizing public participation in urban planning activity is an innovative two-step agent-based decision-support system (DSS) which involves the public both before and during master plan development. Under our Model the public participation consists of citizens expressing as many ideas and opinions about their city as they choose, and it takes place before design of the master plan starts. The proposed DSS uses agent technology to mine the opinions and ideas of citizens. We propose a pair of opinion-miner agents. These agents belong to a class of recommender agents whose aim is to formulate recommendations out of a mining process, and submit these recommendations to the urban planners in charge of the master plan.

Recommender agents have been used extensively in very different fields, wherever an intelligent mechanism is needed to filter out large quantities of available information [171], and to provide customers or users with the means to effortlessly find the items they are probably looking for based on their history of prior actions [4].

Other related agents are monitoring agents which are used for location and allocation purposes. Their recommendations help tourists to find sites to visit [35] or simply provide information using location awareness technology [208]. The agents in ABM models for urban assessment described in the previous section can be considered monitoring agents.

Regarding miner agents, they are now mainly used for e-learning, a new and important area of application. Miner agents recommend educational materials [208], [73], [151] or personalized resources [214], [133], [93], to groups of students based on their profiles. This technology is also being used in the growing area of social and other networks on the Internet to provide users with useful internet and website suggestions [67], [177] (see [135] for a complete taxonomy of internet agents) and to help find potential network members [97].

Hybrid and customized agents have more specific applications, varying from agents for personal diet recommendations [108] to recommender agents that help software developers to select task-relevant software libraries [128].

The most appropriate profile of agent for our Model, whose purpose is to enhance and enrich public participation in urban planning by making the opinions of citizens more prominent, is the miner-recommender agent:

A pair of opinion-miner agents extract and classify data contained in the opinions of citizens to make recommendations to planners during the design of the master plan. The first agent mines web-requested opinions from citizens before the design of the master plan begins. The first agent assists the planner, helping prepare a more citizen-centered first draft of the master plan. Next, during the elaboration of the master plan, the second agent mines the Internet seeking opinions of citizens from other cities where similar plan proposals have been made. The second agent informs the planners regarding the success or failure of similar proposals found, helping to address the actual proposals being elaborated in the master plan.

In both cases the agents mine the web, since both opinion-mining processes will be web-based. Opinion-mining is a process similar to data-mining, which mines text seeking keywords instead of mining data. The techniques, algorithms, and methodologies used in web-based opinion-mining encompass those specific to data-mining, mainly because there is a great deal of unstructured data on the web, and data changes are frequent and rapid [92], [120].

Our first agent mines the opinion of citizens from a website specifically designed for that purpose. The second agent uses hyperlinks to discover websites containing opinions of citizens about planning proposals similar to the ones contained in the master plan under elaboration. In the second agent tasks, a complete web-mining process applies, from web-structure-mining to web-content-mining and web-usage-mining [52]. Our pair of opinion-mining recommender-agents is involved in a three-phase operational process under which the recommendation tasks are executed, the retrieval (1), the sorting (2), and the reporting (3) steps.

In the first phase, the retrieval step, a mining algorithm is used. Because it is about text-mining, the unsupervised Apriori algorithm is selected. The Apriori algorithm successively finds large item sets which satisfy the desired minimal support. Association rules are then constructed, based on the elements which satisfy the desired minimal confidence [106]. Text-mining techniques can deal with noise and data uniformity by implementing correlation rules between the selected keywords and their descriptions [102]. Nowadays, text-mining techniques are extremely advanced, and can even be used to mine scientific texts [13]. Still in this first phase, the next step is to create a structured representation of the information that has been mined using an ontology. An ontology must be defined, so that every piece of information can be represented in structured formats. Each information piece is mapped into the ontology as an instance.

The second phase, the sorting step, is to implement an algorithm to classify and map the information into the ontology. Unstructured data can be automatically classified and mapped [39], again using text-mining techniques, but based on decision rules [38]. There are several algorithms that can be used for text classification purposes. Bayesian classifiers, neural networks, and decision trees are among the most common [39]. The ratings of what is being assessed are computed using the information already mapped into the ontology.

The third and final phase of the process, the reporting step, is to make recommendations in response to the assessment request. Recommendations are made using efficient prediction algorithms. In the context of agent technology, a prediction can be defined as a value that expresses the predicted likelihood that a user will have an interest in an item [138]. Accordingly, a recommendation is defined as the list of n items in the top n predictions from the information set available [138]. To ensure quality recommendations, once the recommender agent has been implemented, it must be trained using a test data set (unseen data or training data) which is different from the data that is being assessed [164].

Still in the reporting phase and in order to select the appropriate predictive method for recommendation, we have to briefly describe two different techniques: the content-based recommendation (CBF) method [128] and the collaborative-filtering (CF) recommendation method [75]. Hybrid techniques have also been proposed by some authors [128]. CBF methods are mostly used when documents, web pages, publications, news, or similar pieces of information are to be recommended [138]. The agent provides the recommendation according to the preferences of the user and/or interests which have been either explored by the agent or preset by the user.

CF methods aim to identify users that have compatible interests and preferences by calculating similarities and dissimilarities between user profiles [75]. This technique is useful when users need refined information, and it is to their benefit to consult the opinions of other users who share similar interests and whose opinions can therefore be trusted [138]. Within CF methods there are two major categories: memory-based and model-based [153]. Memory-based CF uses nearest-neighbor algorithms that determine a set of neighboring users who have rated items similarly, and combine the preferences of neighbors to obtain a prediction for the active user [139]. Model-based collaborative recommenders do not use the user-item matrix to make recommendations directly, but generalize a model of user ratings using a machine learning approach, and then use this model to make predictions [99]. In this category the subgroup of demographic recommenders is of interest to our Model.

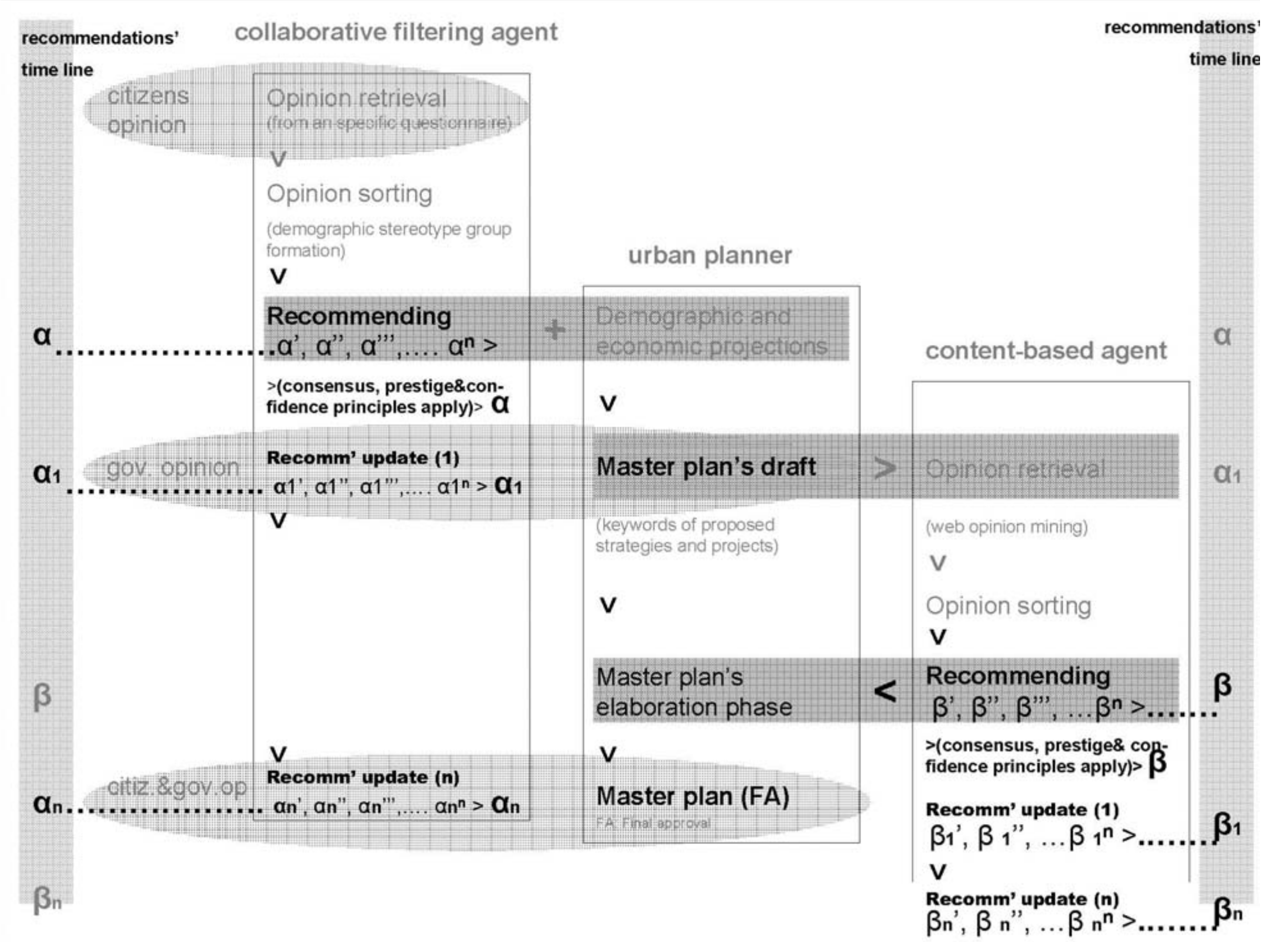


Fig. 14. *Recommendations time line of the collaborative filtering and content-based agents. The picture above represents how recommendations operate over time in parallel with the elaboration of the master plan. Own elaboration*

Demographic recommenders aim to categorize users based on their personal attributes in terms of belonging to stereotypical classes. Instead of applying learning techniques to acquire user models, these agents are based on stereotype reasoning [99]. In the case of demographic recommenders, a user model is a list of demographic features that represent a class of users. The representation of demographic information in a user model can vary greatly. For example, Pazzani [139] extracts features from home pages to predict the preferences of users for certain restaurants, while Krulwich [103] uses demographic groups for market research to suggest a range of products and services.

According to the descriptions of the content-based recommendation and the CF methods, in our pair of agents, the second opinion miner provides CBF recommendations based on the opinions of citizens of other cities. Clustering techniques are implemented in order to group the collected opinions [197]. The recommendation task of the agent is to alert regarding the positive or negative opinion of citizens of other cities regarding proposals which are similar to those made in the master plan under preparation. The first agent of the pair, although it also mines opinions, uses collaborative-filtering techniques because of the demographic recommender sub-technology that helps when working with groups. This first demographic recommender agent mines the opinions of citizens concerning their city, focusing on citizens in the demographical group. A survey asking them about their degree of satisfaction with public spaces, facilities and services, the housing market, job opportunities etc., and requesting their ideas and proposals for the city is conducted on-line. To achieve maximum coverage, additional tools besides the website are employed: phone surveys, hard copy questionnaires, etc. All non-digital survey answers are converted into digital text to allow the agent to execute its opinion-mining function. Using the demographic collaborative-filtering functions of the agent, different stereotype groups based on the survey answers are created. Finally, this first agent reports an organized selection of ideas for the plan to its authors. Here, the recommendation task is to select from all the comments and ideas those that apply to planning purposes, and to dismiss those which are not related.

In our pair of agents, both content-based and CF agents will provide their recommendations to the planner based on the principles of consensus, prestige, and confidence. A consensus opinion is generated amongst the agents conforming the pair, and synthesized recommendations are sent to the planner. Consensual will be weighted according to the status of the opinion source (e.g. the reputation of the webpage) and ranked according to the source's credibility (reliability of information).

We are aware that the opinion of citizens changes over time, and have taken this into account in our Model. The first agent, the CF agent, will report recommendations to the planners before design of the master plan starts, and then also throughout the elaboration of the master plan. Similarly, the second, content-based agent will provide recommendations as long as the master plan is under development. Recommendations will be provided until the final approval of the plan, in order to anticipate public reaction to the eventual changes and updates in the plan.

The architecture and protocols of the miner agents in the search of opinions that are relevant to every feature of the Master Plans will be accessed by social search through a web of trust and aggregated with simple weighted averages taking into account again the trust that every agent has declared in its contact list that happens to be a same contact list of citizens participating in the discussion of the Master Plan.

The agents emulate the social features of the human social networks as a sort of social machines, dealing with their own contact lists, handling with requests and interactions in human like language, and supporting their users in their daily operations in and among the open social networks. This is a fully bottom-up approach that contains a design of the types of social machines that will interact similarly to people, under their roles and rules of interaction, sharing their contact lists. The first approaches of social search are 'Sixearch' [111] as a search peer to peer, 'AskNext' [182], search based on agents 'topsy.com' looking for tweets (on twitter), 'factoetum.com' for the automation of contributions to blogs, and heystack.com as an example of collaborative search [165]. In the case of multi-agent referral system (MARS). Yu et al. [213] proposed a P2P application in which agents assist users in obtaining and following referrals to find experts who might answer their questions.

Regarding the contact lists, further works examine the benefits of using social networks like the FOAF (Friend-of-a-Friend) resource description framework (RDF) ontology that has recently gained popularity [94]. FOAF predicates consist of a person's properties such as name, email address, group memberships, employer, gender, birthday, interests, projects, and acquaintances. By 'spidering' the Semantic Web and collecting the information contained in FOAF files, one can build a large collection of data about people and their interests. This information can be used to email people with a given interest, people who know people who know a particular person, and so on.

3.6.4. A concluding example: the redesign of Diagonal Avenue in Barcelona

In March 2010, the Barcelona City Council launched a public consultation process to select one of two designs for the Diagonal Avenue renovation master plan (see pictures below showing designs A and B). Both of these options included new tram lanes to connect with existing lines. The survey made little impression on the citizens, since no opinion and only validation of the options was requested. Participation was only 10%. Interestingly, the option which received most support was a third one, C, which was a rejection of the other two. The victory of option C destroyed any chances that the project would go ahead.

The Diagonal Avenue consultation followed the traditional and unsuccessful public participation process in urban planning, detailed in the problem description section, under which the public gives its opinion of the proposals presented by a master plan at the very end of the design of the plan (when there is no scope for change).

This undemocratic and elitist approach can sometimes lead to extremely long approval processes, or even the rejection of master plans when public reaction is negative, as in the case of Diagonal Avenue in Barcelona. It is quite clear that introducing wider participation during a plan's preparatory and/or design phases would be a step in the right direction for obtaining the opinion of concerned citizens. In non-official blogs and opinion websites created during the Diagonal Avenue case, some people expressed the view that only a bus lane was needed, and that there was not enough financing available to justify a huge investment in new tram lines. Others preferred more investment in basic services and public spaces in the city, rather than spending significant funds on complete renovation of the Avenue.

Following our Model, a public participation survey would be conducted before design of the urban project begins. This extensive survey would involve asking for specific ideas concerning the objectives of the project as well as more general opinions on related urban aspects affecting the project. In the case of the Diagonal Avenue, these related aspects would revolve around the quantity and quality of public spaces and facilities in Barcelona.

Such general opinions would help the planners produce more focused and useful proposals that besides helping design the specific project, would end up satisfying the more general urban needs of citizens.

The first type of agent of our pair, the demographic, collaborative-filtering agent would retrieve the relevant opinions of individual citizens through text-mining from a website created for that purpose doing social search so that the deep web composed of opinions of all kinds would be accessible. Recommendations would be reported to the planner in the form of lists of opinions, positive and negative, ordered by relevance and importance while taking into account the trust and influence of those who are giving their opinion away in the form of comments in open social networks. The planner would develop one or more project solutions based on these recommendations and economic and demographic projections.

Before presenting the project solutions to the public, the second type of agent, the content-based agent, would come into play and mine the Internet for reactions to similar project solutions in other cities following a similar scheme of social search but instantiated with other similar projects. The similarity of projects is assessed by the features of those projects (through the content based filtering process) and will proceed to aggregate the opinions of those projects with the forehead mentioned social search process.

Recommendations on the opinions that similar proposals raised in other cities would be reported to the planner. Armed with this information, the planner can carefully consider and compare actual previous reactions, responses and potential future responses. Finally, the planner can adjust the project solutions being designed before they are public with proper estimates of their opinions and relevance.

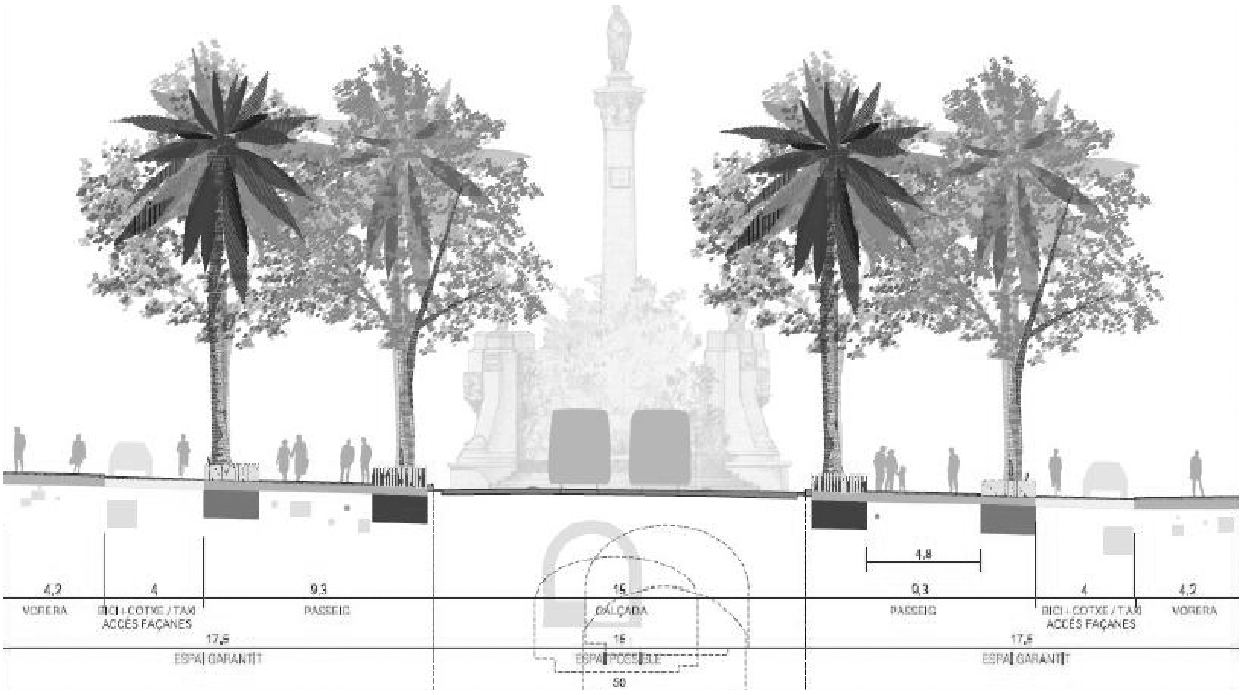


Fig. 15. *Redesign of the Diagonal Avenue in Barcelona. Option A.*

Source: http://w110.bcn.cat/V01/Serveis/Noticies/

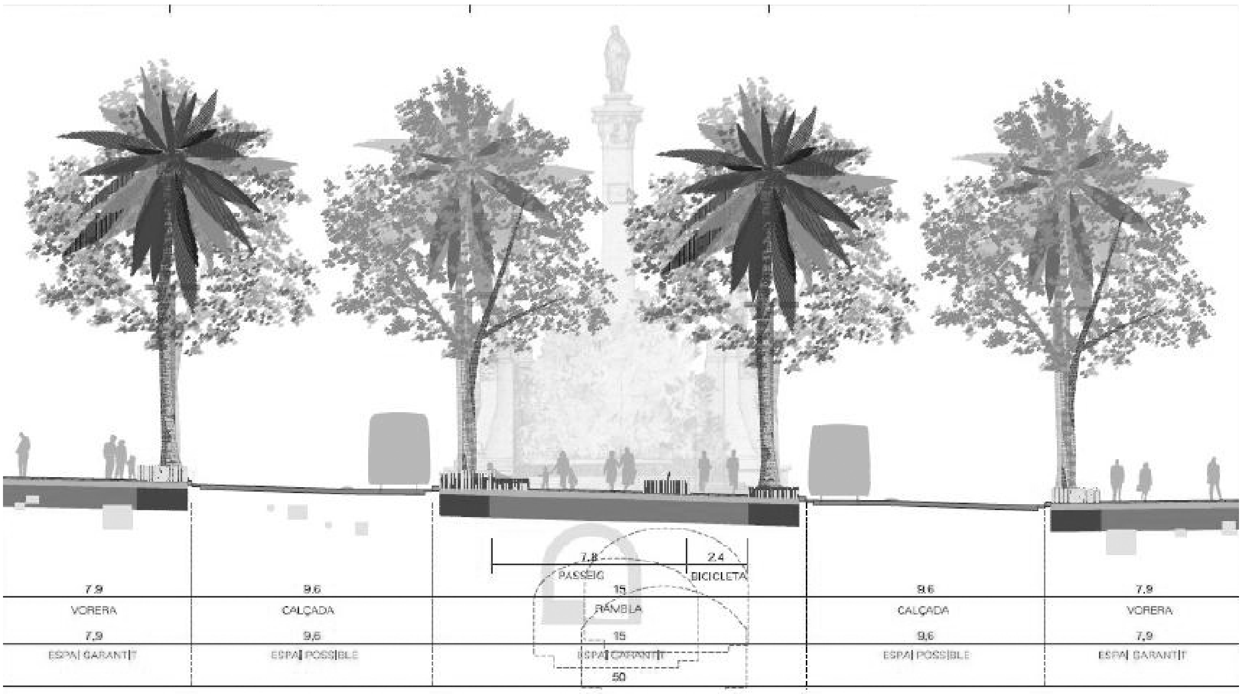


Fig. 16. *Redesign of the Diagonal Avenue in Barcelona. Option B*

Source: http://w110.bcn.cat/V01/Serveis/Noticies/

Returning to our case study in Barcelona, through a key word search using "new tram line, public consultation", the content-based agent would have found that several public consultations had already been conducted on whether or not a new tram line was needed in a given city, and which other design options should be considered. Indeed, there is a great deal of experience in other cities. For example, In Edinburgh, the Scottish Parliament conducted a public consultation in 2003 regarding the new tramway network. The people indicated that only three new tram lines were needed, in combination with feeder bus services or shuttles, to reduce the cost [158]. In Dublin, in December 2005, the Railway Procurement Agency [51] started a public consultation exercise on a new route to connect with the existing Red and Green lines. Citizens were asked about their preferred route for such a connection. Similarly, in London in 2007, the local authority carried out a survey on the route options for the new Cross River Tram (CRT) line. The CRT followed a long route covering four boroughs. It was divided into five sections to facilitate ease of comment during the public consultation [123]. Finally, there is the case of Manchester, where Transport for Greater Manchester worked closely with Manchester City Council to ensure a new tram line fitted in with popular opinion and also fulfilled regeneration aspirations for the area around the new tram line [181]. Interestingly, in all these new tram line consultations, public participation began with consideration of whether a new tram line was necessary in the first place. This differs from the approach in Barcelona.

The agent-based implementation of such model must scale properly to the open nature of comments of citizens about public plans in the social networks. In the end, with the implementation of our agent-based Model for public participation in the Diagonal Avenue case, a more citizen-centered solution would have been possible.

3.6.5. Summary of the advantages of using agent technology in public participation

In this insight we analyze the participation of citizens through crowd sourcing. Specifically, we propose a Model based on agent technology.

Our Model respects the classical three-step participatory process in urban planning, but considerably must reduce the social efforts and the economic costs. Our Model has more social value because it allows real participation and involves citizens in the planning process from the very beginning. And finally, its citizen-friendly approach must be cost-effective and must save resources because it manages opposition and reduces the chances that citizens will object or resort to litigation in response to the final design of a master plan.

The implementation of the Model is as a multi-agent system that do social search for the mining of comments for getting the relevant opinions regarding an on-going design of a master plan. It is useful for scaling up properly at the internet scale and in a modern way, taking advantage of not only the existing discussing happening along the exposition of the current plan, but including preceding discussions of similarly plans all over the world that usually are of relevance for that specific plan.

The Model will have high chances of recommending the proper features of the plans in a way that people might understand and valuate its benefits or drawbacks according to the recommendations of former existing experiences found in the web in an automatic way. The novelty of the approach deserves further work to validate with a proof of concept that is going to be developed as future work.

3.7. Summary

The main goal of this research is to learn about citizens' urban needs through their urban-time-use distribution, to obtain new urban planning values. Our Smart Urban Planning Method does not consider city spaces as simple pieces of land where certain activities can be performed. Our citizen-centered standards revision transforms urban processes into land amounts and their uses. These complex transformations are computer-based and begin with the setting of a "rule of correspondence", fixing a quantitative and also qualitative correlation between urban-time use and urban land use followed by "indicators of equivalence" to set the quantitative correlation between urban-time use and urban land use.

We use a citizen survey to collect data on urban time use. We prove that the use of hypermedia adaptive surveys is the most effective method to collect citizen information. Besides presenting it to the citizen in a friendlier manner, this permits periodical updates that actualize the results and move them closer to real-time data. This proximity to real-time data in urban planning is gained through the easy update functionalities that stereotype and feature based techniques utilized in the proposed hypermedia adaptive survey introduce in the Method. Both techniques capitalize on user profiles. The survey can be conducted by relatively short samples of user profiles, extrapolating results to the overall population, thereby facilitating periodical surveys and the periodical update of urban planning values. This functionality brings the survey and the Smart Urban Planning Method towards real-time accuracy.

To apply the new urban planning values obtained with our Method, it is necessary to consider all available urban data. These are statistics, indicators and indices. Urban data must be combined with urban planning standards to elaborate social, demographical and economical projections. Projections are the basis of urban planning proposals, showed in city master plans. Today, the visualization and representation of urban information has serious problems with redundancies and inefficiencies in general. We propose a Model for integrated urban data representation and visualization which would help solve these problems. Moreover, the proposed Model is constructed in a way that supports the introduction of real-time urban data, a major step forward compared to the use of historical data which currently takes place.

In order to accumulate collective intelligence, in addition to the information collected with the survey included in our Smart Urban Planning Method, we propose the use of an agent-based model as a crowd-sourcing technique. Our agent-based Model is two-tiered. It accumulates opinions of the surveyed population in more specific proposals for the city and provides recommendations to the planners on which proposals should be introduced in the master plan according to citizens' vision. And it mines the web, monitoring the acceptance or rejection that similar urban planning proposals have had from citizens of other cities. The Model deepens the basic Smart Cities principle of increasing public participation, and makes it more citizen-friendly. Moreover, this very efficient Model is strictly based on automated data collection processes.

4. APPLICATIONS OF THE METHODOLOGY

Through our Method, new urban planning design values are obtained. These new values serve as the new urban planning standards, and are more objective and closer to citizens' needs than traditional current ones. Hence, new urban planning standards are satisfaction indices for each of the surveyed urban activities. These satisfaction indices, besides being the new urban planning values, have further applications, such as classification. To illustrate one of these applications, we provide a classification example of municipal self-sufficiency regarding the specific urban subsystem of public services and facilities.

4.1. Decision tree rule learning for municipalities' classification

Once new urban planning design values or standards have been obtained, they can be used to separate municipalities in terms of self-sufficiency for that specific land use. That is, we want to learn classification rules for an automatic classification of any municipality with a similar head-dependency reality. Common urban parameters of the municipalities forming part of our research (such as population, urban surface, facilities surface, number of facilities, etc.,) together with the self-sufficiency threshold already obtained constitute the training data set we run in data mining tools to find rules for an automatic classification of any municipality. This obviates data for all of the parameters contained in the training data set. For instance, classification rules help classify any municipality in terms of services self-sufficiency on the basis of one set of data (such as total surface of facilities, population, etc.). For the purpose of obtaining classification rules of municipal self-sufficiency we use the J48 algorithm[1], as explained below.

[1] J48 is an open source Java implementation of the C4.5 algorithm in the Weka data mining tool

After analyzing the state-of-the art on classification of municipalities or urban areas, we can highlight the novelty of our proposed method for municipal classification. Simply stated, there is no current method for classifying the performance of municipalities on a specific urban matter based exclusively on the level of citizen satisfaction. We have found research on classification methods for municipalities and ranking tasks using fuzzy logic and GIS technology for their visualization [80]. Other classification methods a) impose pre-established conditions to rank the classified municipalities [28], b) extract thematic information from aerial images and land cover evolution to establish classes depending on differences in spectral reflectance [152], c) combine classification results obtained from spectral mixing land cover components within pixels and spectral confusion with other land cover features [69], d) evaluate large regions land cover classification using a multiple-layer characteristics database approach [193], and e) use support vector machines (SVM) as a method for constructing nonlinear transition rules for cellular automata (CA) [209].

We selected algorithm C4.5 to learn classification rules, since it most accurately performs the classification of numeric data [206], that is to say the data where land is allocated. This has been satisfactory tested in the case study provided in chapter 5.

4.2. Improving classification with Knn

It is also possible to generate rules for a specific sub-classification of municipalities based on basic and complimentary levels of services offered in facilities. As an example, according to the municipality’s degree of self-sufficiency regarding services contained in facilities, we propose the following sub-classifications:

1a) Totally Non Self-Sufficient Municipality (TNSSM): the municipality completely lacks one or more basic/universal services, which are education, health, and social services. A minimal sports facility must also exist, either standing alone or as part of education or health services.

1b) Partially Non-Self Sufficient Municipality (PNSSM): one or more basic services are below the average provided by the self-sufficient municipalities.

2a) Partially Self-Sufficient Municipality (PSSM): one or more complimentary services are not covered. Complimentary services include administration, safety and civil protection, culture, transport, and religion.

2b) Totally Self-Sufficient Municipality (TSSM): complimentary services are equal to or above the averages established for self-sufficient municipalities. Also known as “complete municipalities”.

To further classify municipalities according to the described sub-classifications, we need qualitative and quantitative data on facilities for each of the municipalities. In that respect, we use data sets from governmental planning offices for the seventy-six municipalities participating in our Case Study. We expand our original training set for self sufficiency classification with the addition of this new data qualifying and quantifying municipal facilities. From official raw data sets we observe that qualitative data determining the nature of services offered in facilities is complete. However, to the contrary, quantitative data about the specific size of services in the facilities may not be complete. Hence, to conduct the desired sub-classification, we have to deal with missing values techniques to complete the data set.

Different methods for dealing with missing values include: a) deletion, deleting instances containing unknown values, b) maximum likelihood, computing the maximum likelihood of observed data while integrating out the missing values, and c) imputation, replacing missing values with estimated values [62]. A number of learning techniques tolerate and integrate incomplete test data: C5.0, classification and regression trees (CART), linear discrimination (LD) naive Bayes classifier (NBC), Repeated Incremental Pruning to Produce Error Reduction (RIPPER), and support vector machines (SVMs) [187]. But since our number of missing values (57%) is too high to delete or to integrate missing values, we have to proceed with imputation techniques to complete the missing values on the specific attribute of services physical size in our training data set.

There are various imputation techniques, and the choice amongst them must be carefully made, since their underlying mechanisms for missing values vary greatly. The assumption of how the missing values are distributed within the data set is compounded by the fact that for small data sets, it may be difficult to determine mechanism for missing values [166]. Our data set can be considered small, since it has 3966 instances. Sophisticated imputation methods prefer larger data sets. Therefore, we have to select a simple imputation method. Simple methods to impute missing values in small project data sets include Class Mean Imputation (CMI) and K-NN [167, 168]. Some authors sustain that K-NN gives better results [34].

With the K-NN imputation technique, missing values are replaced with estimated values according to the selected k value of most similar cases [90]. Training sets are simulated with different values of k. Related research suggests that a suitable value of k is approximately the square root of the number of complete cases [90]. A K-NN more elaborated technique is K-MSN method, in which imputation is based on the weighted mean of the observed values of the most similar neighbors, where similarity is measured on the basis of the distance in the feature space [145]. Since we obtain good results with the K-NN technique, we not use the more sophisticated weighted mean imputation method. Finally, to complete this short introduction to the K-NN imputation technique, we mention that some research indicates that its accuracy diminishes when the missing data percentage exceeds 40% [159].

The reason why algorithm Knn has been selected to deal with missing values and build an urban planning toolkit is because, as will be shown in next chapter, it has been proven to successfully work with real data.

4.3 Summary

According to the Method explained in Chapter 3, information from citizens may form the basis for setting new urban planning design values for master plans. However, once these new standards have been obtained, they can be further applied to support urban planners in the identification of deficiencies and problems in general in urban planning-related issues. In our application of the Method, data characterizing land uses and services of municipalities, together with the standards for public facilities, are used as input for a learning method, to generate rules for classifying municipalities. Moreover, knn methods are applied to deal with missing data for municipalities. These are two additional applications of the Method, and there are others.

5. RESULTS AND DISCUSSION

We have conducted a proof of concept of our Method in Girona Province (which includes Girona as the main city, with a population of approximately 70.000, plus some two-hundred closely related municipalities). The results obtained are described and discussed herein.

5.1. Survey design on urban time use and citizens' opinions on urban needs

To learn about the covered and uncovered urban needs of citizens of Girona Province, a survey on urban time use was conducted. Respondents were questioned concerning how they are using the city today (which indicates how well their urban needs are covered), plus how they would like to use the city under more ideal conditions (which reveals their uncovered urban needs). A total of 624 responses were collected on-line following the Adaptive Hypermedia Model presented in Chapter 3, and 225 surveys were conducted in person, for collectives who were less familiar with or had limited access to technology. With these different survey modalities we ensured a representative sample of citizens. We established a lower age limit of fourteen, since below this threshold there is little personal autonomy to decide on urban activities, which generally tend to correspond to those of the parents.

Our survey is initiated as a stated-response data to begin classifying the respondents in one of the following four stereotype occupational groups: student, employed, unemployed, and retired. Based only on this initial pre-classification, the survey is constructed as a revealed-choice data section, in which respondents answer a set of questions in free text format.

It is important to mention that advanced surveying methods, such as the so-called “total survey design” [173] combine both of the described techniques. But they initiate the survey with revealed-choice data instead of the stated-response data. And, depending on the respondent’s answers, they offer different customized stated-response data questions. In order to not limit respondents’ answers and thus obtain more accurate results, we took the option of inverting the order of “total survey design” implied techniques.

Other authors have demonstrated that the methodology used to obtain time use data influences the results [172]. This indicates that survey design has important consequences for the attitudes of respondents revealed in the survey. In order to minimize the burden to respondents, our survey was designed as a streamlined version of the traditional time use surveys, which could be completed in approximately ten minutes. Accordingly, we focused on questions concerning the physical allocation of time devoted to urban activities. Moreover, the questions were very carefully selected, and limited to those which obtain information relevant for modeling the urban time use of respondents.

Stylized respondent reports and time diaries are two of the most widely used methods for surveying time use [118]. The former asks respondents to report how much time they usually spend on a specific activity during a certain period of time, while the latter asks respondents to report all activities they perform in temporal order and during a single day. Our survey combines both methods, since we ask for the description of a typical working and non-working day, and the amounts of time spent in all of the involved activities. In our survey the description of a typical day stands for the average time spent on all daily activities, taking recent weeks as a timeline. Presumably, the measures obtained using the two original methods should be consistent with each other at the aggregate level. That is to say, the stylized measure of time spent on a certain activity should be similar to the total time spent on the same activity, as noted in a time diary for the same period [118].

However, many researchers have found inconsistencies between these two measures. In some cases, respondents report higher values in stylized measure, and sometimes they report values which are lower than the total amount of time recorded in time diaries [118]. To avoid such inconsistencies, our combined method asks respondents to report on the time distribution of their activities over a twenty-four hour period, in terms of physical allocation of time. This avoids issues regarding whether or not the time committed to an activity has to be accounted with the activity. Thus, for example, meals at work and training or other events at the work place are counted as time at work, but transportation to work is counted as commuting time.

Through questions on the physical allocation of time, our Method minimizes the burden for respondents, by reducing the number of activities that they have to report. Yet it still preserves the advantages of time diaries, which provide accurate measurement and reduce distortions associated with social desirability bias [172]. However, we must still acknowledge the possibility of inconsistencies derived from the request to describe the twenty-four hour sequence of a typical working and a standard non-working day when respondents do not have routines. This is more likely to be the case for non-working days. Therefore, we assume that respondents are reporting more the activities mode than the activities mean.

5.2. Processing data survey

The Province of Girona has 221 municipalities organized in 8 counties. Girona is the main city in the province. We collected 1000 survey answers from citizens of 163 municipalities.

Before entering into the mining phase of our survey results, a pre-processing task was needed in order to delete a) inconsistent responses (those with less than 50% of the requested answers) and b) noise (non serious answers). In some cases, both tasks were conducted manually, because the answers were too complex and lacked text-mining key words. Once the pre-processing task was completed, the answers were organized by municipality.

The survey text answers were numerically converted into a twenty-four hour time distribution for both working and non-working days. Activities performed in the city of residence were positively accounted in the municipality, and activities performed in a non-residence city were negatively accounted. Thus, we were able to track exported and imported hours between municipalities. This also served as an initial correction factor to design a fair rule of correspondence between urban time use and urban land use at both municipal and regional levels.

We created tables for each municipality from which dependency answers were obtained (municipalities importing hours). These municipalities are called “head municipalities”. Subsidiary or “dependent municipalities” export hours to the head municipalities. We observed that municipalities exporting the main occupation activity (work, studies, etc.) are also exporting minor activities (shopping, leisure, etc.). In our Case Study, 163 municipalities, 7 of them are head and 156 are dependent.

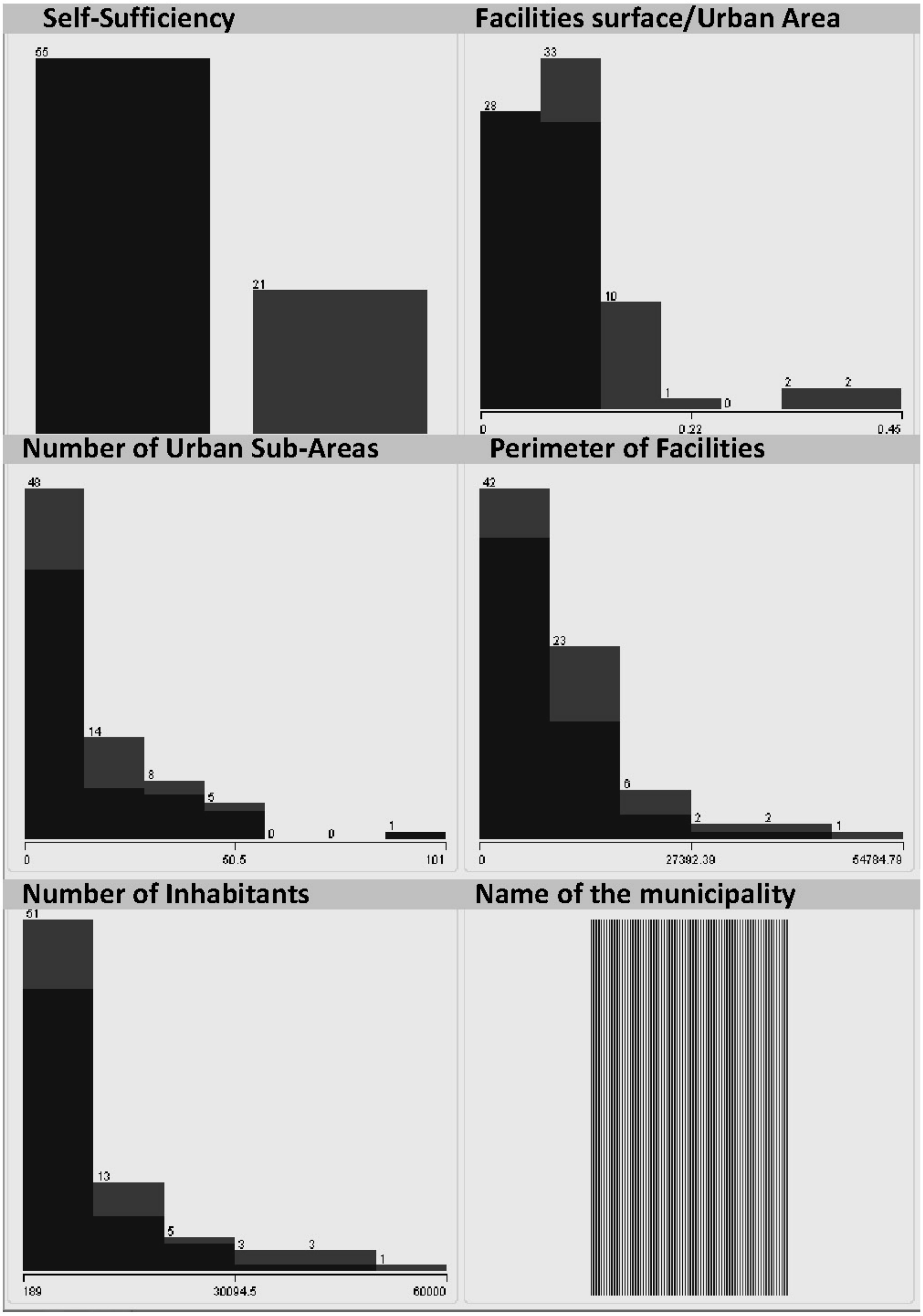
5.3. Obtaining a new standard

Limiting our Case Study in Girona Province to the urban sub-system of public services in facilities, we find that the land percentages for the use of facilities corresponding to the time desired to be spent using public services should be at least 11,2% of the total urban area of a given city. In other words, citizens are satisfied with the amount of services offered in facilities when land for those facilities in the municipality is equal to or above 11,2%. This value means that the proportion between total urban land and land specifically designated for the use of facilities (which is a part of the total urban land) is 11,2%. We propose to use this threshold not only as the design value for facilities planning but also as the cut-off for citizen satisfaction, and thereby classify municipalities into self-sufficient and non-self-sufficient, with respect to the services offered through facilities.

It is extremely important to mention that the value of 11,2% is above the minimum level urban planning standard of 5% set by the Catalan Urban Planning Law, and applicable to the Case Study area. In the Case Study, proportion between land for facilities and urban land ranges from 0% to 44%. One-hundred eleven municipalities are below the satisfaction threshold (11,2%) while fifty-two are above.

5.4. Outcomes of the classification of municipalities

For the purpose of finding classification rules for our services and facilities Case Study in Girona Province, we processed a file containing values on the already mentioned urban parameters included in our training set. The file contains ten attributes relevant to determining the self-sufficiency of municipalities in the urban sub-system of services offered in facilities. This includes urban land surface, population, facilities area, number of services contained in facilities, etc. The attribute “self-sufficiency” is the class. The seventy-six municipalities participating in the classification pilot are the number of instances. Weka tool has been used as the data mining software [70], where C4.5 is implemented (named J48 in Weka). To learn classification rules, we first need to identify which of the attributes is the most discriminating, and therefore delineates the class. We did not find one completely discriminating attribute, but the proportion between “facilities area/urban surface” appears to be the most indicative (see Figure 17). Therefore, additional attributes are taken into account for classification purposes, in order to obtain successful rates in the classification rules.



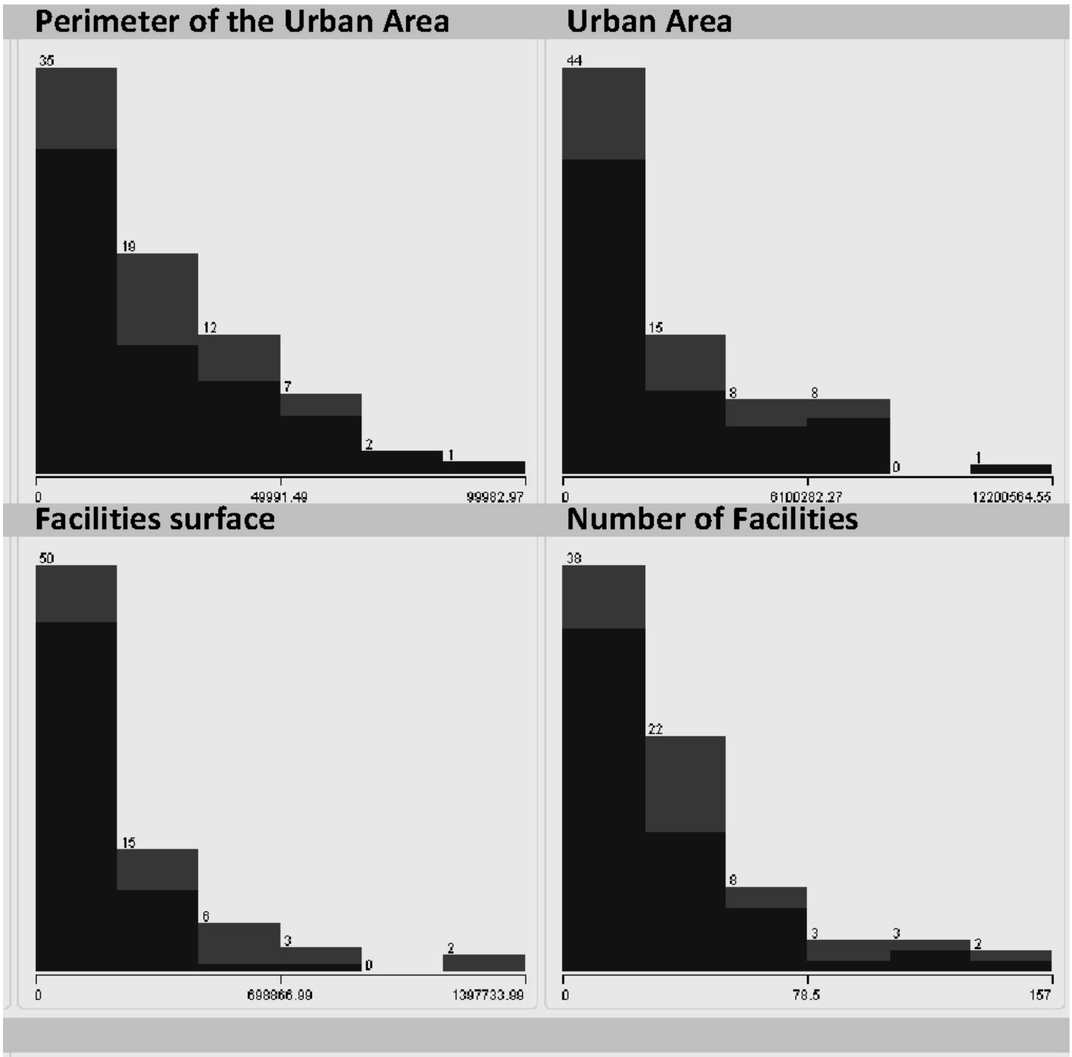


Fig. 17. *Depiction of potentially discriminating attributes. "Facilities area/urban surface" (second graphic) most accurately separates the "class" (first graphic). Own elaboration using WEKA software.*

We use stratified cross-validation to estimate the validity of the rules learned. We test both the 5 and 10-fold, which means that the technique is processing the instances by grouping them in 5 and 10 folders. This estimates the predictive capacity of the rules. We observe no differences in results between the two tests.

In order to learn classification rules to classify instances when the class and the most discriminating attribute are missing, we eliminate both and run the J48 algorithm with the training data. We run the J48 algorithm under different parameters to select the best classification result:

a) J48 unpruning, meaning that the algorithm is able to learn rules to correctly classify 100% of instances

b) J48 pruning, allowing rules to classify about 90% of instances

c) J48 reduced error pruning, a variation of pruning which is based on one of the folders of cross-validation

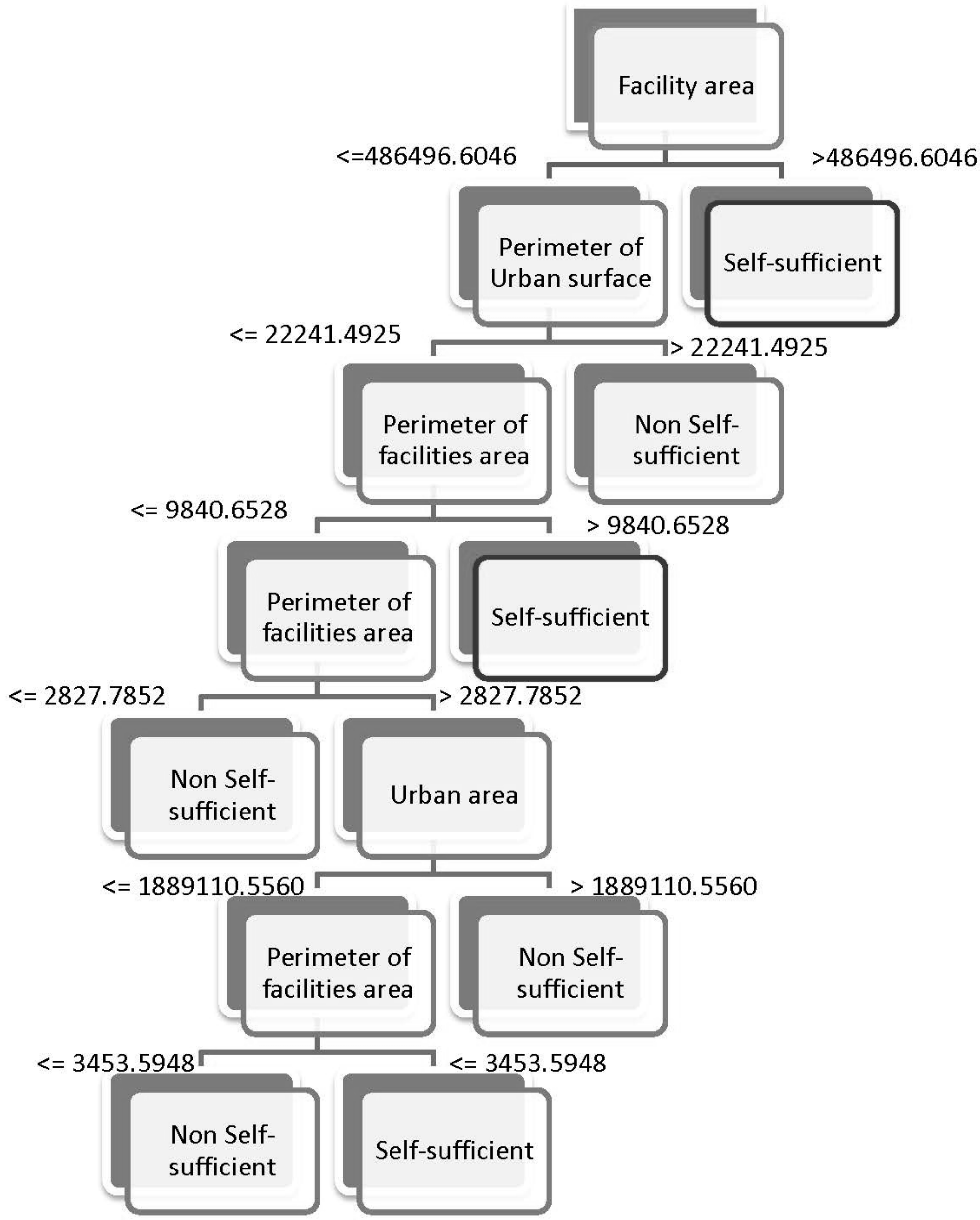


Fig. 18. *Experiment a) and b) decision tree. Own elaboration*

In the two first experiments, a) and b), the most discriminating attribute is "facilities area". However, in the third one, c), the attribute "number of facilities" is most discriminating. In a) the unpruning context increases precision and therefore generates over-fitting. However, we do not observe very significant differences between the three experiments.

Figure 18 shows one of the decision trees learned with J48, from which the rules are derived, showing the tree from the roots to leaves. Each leaf corresponds to the class, while nodes in the tree are the attributes, and edges the attribute values. The following insight classification rules can be extracted from the tree of Figure 18:

1) For a facilities area <= 486496.6046 m2 a municipality will be self sufficient if:

    Perimeter of Urban surface is <= 22241.4925 m2

        And

    Perimeter of facilities area is <= 9840.6528 m2

    (...)

2) For a facilities area > 486496.6046 a municipality will be non-self sufficient

Although it has more classification error due to increased accuracy, it is worth mentioning experiment c) decision tree and its classification rules. Based on the most discriminating attribute for experiment c), "number of facilities":

1) For a number of facilities <= 14 municipality will not be self-sufficient

2) For a number of facilities >14 municipality will be self-sufficient if:

    Perimeter of Urban surface is <= 51006.1098 m2

        And

    Perimeter of facilities area is <= 9840.6528 m2

    (…)

5.5 Sub-classification outcomes with knn

In our Case Study, quantitative missing values for services' physical size are 57% of the total number of instances. Hence, to conduct the desired sub-classification, we have to deal with missing values techniques to complete the data set.

When applying the K-NN algorithm to deal with missing values on services physical size, we understand that the high percentage of missing values might diminish the accuracy of our results, according to [167]. Accordingly, since we may be outside of the supposedly optimal parameters, we begin by testing different values of k, aside from the square root of the number of complete cases (1705 instances).

We start with a K-NN=1, and analyze three different scenarios:

a) Select the closest cases according to population
b) Select the closest cases according to population and facility ownership (public or private)
c) Select the closest cases according to population, facility ownership, and kind of service (specific type of basic or complimentary categories, such as education, culture, etc.)

Best results are expected in scenario (c), since it contains the largest combination of attributes and better defines a service. We understand best results as more meaningful, closer to reality, and with fewer repeated values. For K=1, best results are obtained in combination (b). Therefore, we continue testing with K=5, now obtaining the best results in the combination of attributes (c). For K=10, best results continue being obtained in combination (c). For K=20, best results still reside in set (c), and in addition they are more realistic and have fewer repetitions than in K=10. For K=30 and K=40, best results are found in combination (b). This leads us to stop testing for k values. According to the findings of recent research, the best k values should be obtained from the square root of the number of complete cases, which is 26 for our Case Study of 1705. When testing K=26, we find that the best results still remain in K=20. We attribute this small deviation from the rule of the square root to the elevated number of missing values with respect to the supposedly optimal accuracy threshold.

After completing our data training set missing values with results obtained from K=20, we start essaying to obtain classification rules to sub-classify the previously obtained two groups of self-sufficient and non-self-sufficient municipalities into four groups, namely 1a) Totally Non Self-Sufficient Municipalities (TNSSM), 1b) Partially Non-Self Sufficient Municipalities (PNSSM), 2a) Partially Self-Sufficient Municipalities (PSSM), and 2b) Totally Self-Sufficient Municipalities (TSSM).

We apply the same classification method as for the self-sufficiency classification to sub classify the first pair (1a/1b), namely algorithm J48, under unpruned and pruned parameters. We obtain the same classification results under both J48 parametrizations, with the same decision tree. Next, classification rules have been generated, allowing us to sub-classify municipalities when most discriminating attributes are missing, and we need to predict the totally or partially non-self sufficiency class. We observe that there is no discriminating attribute, and therefore we run the algorithm to learn classification rules by only eliminating the class. A unique classification rule is obtained: municipalities with fewer than 3993 inhabitants are sub-classified as Totally Non-Self Sufficient, and municipalities above 3993 inhabitants are sub-classified as Partially Non-Self-Sufficient. Under this rule, seven municipalities are sub-classified as Totally Non-Self-Sufficient, while twenty-six pertain to the subgroup of Partially Non-Self-Sufficient.

We proceed with the same method to sub classify the self-sufficient pair 2a/2b. But the results are different, and we can not obtain sub-classification rules. This makes our previous task of completing missing values much more relevant, and leads us to sub-classify with a sole method of services identification. Thus, a municipality will be Partially Self-Sufficient when one or many complimentary services are not covered, and Totally Self-Sufficient when offer exists for all circumstantial services, and in values which are equal to or above the average defined by self-sufficient municipalities. Out of the one-hundred thirty-four self-sufficient municipalities, thirty-tree are Totally Self-Sufficient, while one-hundred one are classified as Partially Self-Sufficient.

5.6. Summary

In this Chapter we prove the Method through a Case Study in the Girona province. Among the different outcomes, first it is interesting to highlight that the Method goes beyond providing an accurate answer to the current urban needs of citizens by also discovering future and uncovered needs as revealed through desired urban use. Second, the Method's rule of correspondence processes citizens' targeted urban time use distribution, and through the indicators of equivalence previously found between current urban time use and urban land use, the corresponding land allocation is found. In our Case Study in Girona Province, new planning values for the public services offered in facilities were obtained. This is also possible for other urban land uses such as public space, transport infrastructure, retail sales, housing, etc.

Third, with the new planning values obtained for the specific land use of public facilities, municipalities participating in the Case Study were also classified. Therefore, the Method not only updates municipal planning standards, it also establishes a regional classification of municipalities according to the new indicators obtained, which are also the satisfaction thresholds of citizens for the specific land use. Hence, the new indicators or satisfaction thresholds of each land use constitute, in turn, the level of municipal self-sufficiency for this specific land use. Sufficiency will be achieved if municipal levels of a specific use are above the satisfaction threshold of citizens. Below the threshold, municipalities must be considered non self-sufficient, because there is insufficient quantity of the specified use, and citizens must to commute to the next municipality offering that specific use.

Fourth, for the purpose of municipal classification on self-sufficiency, we prove that the J48 algorithm provides good results, as we obtain useful automatic rules for classifying municipalities beyond sufficiency values. Therefore, a municipality can be easily classified without knowing the class (self-sufficiency). Typical urban databases containing only basic information such as municipal population or quantities of a specific land use are enough to classify the municipality for that land use.

And fifth, subsequent classification on self-sufficiency for a specific land use is possible with larger land use data bases detailing land use characteristics. However, urban data bases can have a number of unknown values, and this is more problematic with larger datasets. In our Method, we prove that sub-classification is possible by completing missing values of urban databases using the K-NN technique. With this technique we successfully sub-classify the self-sufficiency condition on public services and facilities into four subgroups, making a distinction between self-sufficiency in basic and complimentary services.

Summarizing, we can claim that the ICT-based method is proved to help urban planners to obtain citizen-centered values for conducting their activities.

6. CONCLUSIONS AND FURTHER RESEARCH

The main objective of this work is to review and update urban planning values in a more objective and citizen-centered manner. To that end we elaborated the Smart Urban Planning Method, based on the use of ICT. It has been proven that the Method successfully obtains new urban planning values, and has many further applications. We have implemented one of these applications by classifying a set of municipalities on the basis of self-sufficiency. Furthermore, we accompanied the dissertation of the Method with additional explorations on significant and related topics. A description of the three main contributions of this work: *objective, application of the methodology and exploratory insights*, follows.

6.1. Contributions

OBJECTIVE: TO ELABORATE A CITIZEN-CENTERED METHOD TO UPDATE URBAN PLANNING VALUES

Urban planning methodologies require urgent revision because they are based on obsolete and subjective planning values for urban design. As part of this revision, the role of citizens should also be updated, so they can contribute more meaningfully to master plans proposals. In our Smart Urban Planning Method, ICT technologies constitute the basis for gathering and processing objective data regarding urban time use of citizens, using web-based surveys and data mining tools.

Our Method constitutes a way to update obsolete urban planning values with new values coming from data about citizens' actual use and desired use of their cities. Therefore, the new planning values obtained with the Smart Urban Planning Method guarantee an urban land offer and urban uses which perfectly meet citizens' urban needs.

The Smart Urban Planning Method goes beyond providing an accurate answer to the current urban needs of citizens, by also discovering future and uncovered needs as revealed through desired urban use. The Method's rule of correspondence processes citizens' targeted urban time use distribution, and through the indicators of equivalence previously found between current urban time use and urban land use, the corresponding land allocation is found.

APPLICATION OF THE METHODOLOGY: METHODS TO CLASSIFY MUNICIPALITIES

For the purpose of municipal classification on self-sufficiency, we obtain useful automatic rules for classifying municipalities beyond sufficiency values, thanks to the use of inductive learning methods (C4.5). Therefore, a municipality can be easily classified without knowing the class (self-sufficiency). Typical urban databases containing only basic information such as municipal population or quantities of a specific land use are enough to classify the municipality for that land use.

Subsequent classification on self-sufficiency for a specific land use is possible with larger land use data bases detailing land use characteristics. However, urban data bases can have a number of unknown values, and this is more problematic with larger datasets. In our Method, we prove that sub-classification is possible by completing missing values of urban databases using the K-NN technique. With this technique we successfully sub-classify the self-sufficiency condition on public services and facilities into four subgroups, making a distinction between self-sufficiency in basic and complimentary services.

EXPLORATORY INSIGHTS OF THE METHOD

The Smart City concept uses ICT technologies within the urban fabric to make our cities more efficient and optimize the use of natural resources. This results in significant economic savings, protection of the environment, and higher living standards and quality of life. Under this perspective, the pioneering Smart Urban Planning Method uses ICT technologies to develop more informed and objective planning, and thereby better achieve the main urban planning goal, which is to cover the needs of citizens. The Smart Urban Planning Method fills the existing gap of smart solutions in the urban planning arena.

The Smart Urban Planning Method learns about the needs of citizens through a survey on urban time use. To make the survey Method more sophisticated, and increase accuracy and readiness in the responses, we propose an adaptive hypermedia survey.

In addition to the benefits of the Method in the areas of municipal and regional planning, The Smart Urban Planning Method improves public participation in the urban planning approval process. As an extension of the Method we propose the use of agent technology to obtain collective opinion on urban proposals in which urban planning values obtained with our Method materialize.

Finally, it is important to mention that the Smart Urban Planning Method contributes to the Smart City Initiative in the urban planning context, providing planning innovation at municipal and regional levels. We identify inefficiencies in the presentation of urban data which make it difficult to get maximize the utility of the Method. We present an insight concerning a model for integrated urban data visualization and representation, which could help solve these inefficiencies.

6.2. Next research steps

SMART CITY ASSOCIATED BENEFITS OF BUILDING AN URBAN REAL- TIME USE DATA-COLLECTION SOLUTION FOR MORE STRATEGIC UPDATING OF URBAN PLANNING VALUES

Further research can be done on opinion-mining of citizens at the time of the survey, and on real-time data mining as long as new data is available. To obtain real-time data on the urban time use of the city, the Smart Urban Planning Method needs adaptive hypermedia survey techniques, agent-based models, and integrated urban data presentation, and to cooperate with Smart City technological solutions already operating in our cities.

Cooperation between the Smart Urban Planning Method and the existing Smart City data collection solutions would contribute to more complete success of the Smart City Global Initiative. The Smart Urban Planning Method provides a perfect platform for coordinating sensing technologies for urban data collection, which are already making our cities smarter, with both urban development strategies and growth policies proposed by master plans in light of the new planning values obtained with our Method.

The Smart Urban Planning Method can lead a new generation of urban master plans, based on ICT, which make possible to coordinate data captured in the city through the deployment of sensing technologies with Method's new planning values. This, in turn, permits real updating of planning values, plus more strategic action in the specific city aspects controlled by sensors, by expanding their sensitive capacities to actuation functionalities. For instance, a sensor controlling traffic pollution with actuation functionalities could report to drivers to adjust the speed limit in coordination with the planning values obtained for the transport sub-subsystem. Thereby, real-time data captured by the urban sensors together with real-time data which citizens report via mobile phones would constitute an innovation that moves beyond the opinion survey used in this Case Study. This needs to be explored, and will constitute the basis of our future research.

Real-time data poses challenges associated with big-data. The term ‘big data’ refers to data sets which exceed standard software capacities to gather, process and manage data in a reasonable time frame. Indeed, we will have to consider the difficulties and challenges real-time data generates when developing future implementations of our Method, and especially because we aim to process real time data which will mean not only to have big data sets but to process them continuously. In the area of big data analytics, the Senseable Lab at MIT is leading a number of projects on big data analytics. Here, we highlight The Urban Code project, analyzing how big data is impacting the various facets of urban living, a reference to look at when developing next research steps.

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