The Perception of the Urban Quality of Life Index in the Context of Smart Cities

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ABSTRACT

The implementation of innovations in Information and Communication Technologies (ICTs) in urban areas provides more interconnected and harmonized cities, favoring the development of a new citizen experience with respect to the access and use of public services. The Urban Quality of Life Index (IQVU) of Belo Horizonte, Minas Gerais, is responsible for quantifying the availability of services from the analysis of different variables that identify the spatial distribution of infrastructures. However, even though the index offers greater insight for city management, IQVU does not consider user perception in its measurement. Collaborative mapping initiatives and crowd mapping, are digital cartographic methods capable of collecting and transmitting information about urban behavior, using citizens itself as the observer and regulator of events. This paper aims to validate areas with the highest quality of urban life through the overlap of IQVU information and crowd mapping initiatives in Belo Horizonte. This research focuses on the role of collaborative mapping as a fundamental tool for developing better representations of issues that affect urban planning, as well as for developing solid forms of civic engagement and social innovation.

Keywords: Crowd Mapping, Urban Quality of Life Index and Smart Cities.

1. INTRODUCTION

The concept of "quality of life" has been historically build from approaches concerning social welfare and sustainable development, referring, above all, to components of immaterial nature, that imprint to the concept the focus on the individual and the pursuit for happiness and personal fulfillment. Its conceptual evolution is connected to the economic, social, cultural fields and, subsequently introduced, the environmental field. For those reasons, it is the main concept of sustainable development, since it represents much more than a certain level of private quality of life, demanding, among other aspects, the total availability of social and public infrastructure in the benefit of general welfare (FRANK, 2000).

The discussions on such conception are based on the impacts and social inequality created by the ever-growing urbanization process, specially from the 60's, incorporating the theme to the international political and academical debate as a critical referential in contrast to the negative aspects of the preexisting economic development models (YOUNG E LUSTOSA, 2003).

As a consequence of this debate, distinct methodological processes where used to formulate numerical indexes elaborated as an alternative of qualitatively measuring the general welfare in the cities. One of the products of that process was the development of the Urban Quality of Life Index (UQLI), used in several locations in Brazil to evaluate the efficiency of provided services and to direct the investments and operations of public institutions (FRANK, 2000).

Nevertheless, even if those indexes engage in the attempt of including all of the measurement aspects, such as infrastructure levels, security, education, provision, among other elements offered in the context of urban centers, some elements are not susceptible to measurement, or yet, don't undergo validation from the individual him- or herself. In this way, the UQLI comes as an important tool for urban managers and designers, however, less legitimate, as it's not capable of quantifying, for example, the validation of the population itself concerning the quality of their environment or their general level of satisfaction with services provided (Jacobi, 1999).

If, on the one hand, the levels are not capable of measuring the general perception of the citizens about the city, on the other hand, it could be inferred through the other possibilities, such as the crowd mapping initiatives, that allow collecting information of the citizens in an individual manner, spatialized and in real time. Such actions are a part of what is called Voluntary Geographic System (VGI) according to Goodchild (2007) and represent the engaging of a great number of citizens with little formal qualification in the production of geographical information. The collective and collaborative characteristics of those initiatives that use crowdsourcing represent the possibility of changing in the production of spatial data using the Information and Communication Technologies (ICTs) as secondary tools in the collection and transparency of informational basis relevant to territory management.

City Hall of Belo Horizonte, for example, willing to stimulate the digital competences and make possible the decentralization of the data collecting process of the cartographic information of its governmental institutions, has developed the PBH APP device which allows, among other attributions, the citizen participation in the requiring of demands concerning the quality and access to the urban infrastructures that are offered. In this way, the possibility of the users taking part in the process of urban planning is encouraged through validation or rejection of services provided by public Power, allowing a larger perception of urban space and engaging by a part of the population.

This article intents to investigate the perception of the Urban Quality of Life Index in the city of Belo Horizonte by the citizens and analyze the spatial and qualitative trends of the information obtained in the PBH app since its implementation up to the year 2019.

We intend in this way to contribute to the debate arena concerning the questions that involve the future of urban environments, trying to offer a better understanding of the way

the innovations in ICTs corroborate to a better use of the opportunities and improving of quality of life for the citizens, in view of, mostly, the importance of the intelligent systems as enablers of better monitoring and management of the urban infrastructures systems and decision making.

2. ICT IN THE CONTEXT OF SMART CITIES

The development of a smart city comes from the perception that technology is a fundamental factor in providing urban centers a better efficiency in the offer, access and use of the infrastructures that is provided, specially through urban management based on Information and Communication Technology (ICT), which make a potentially significant instrument out of the technological platforms for sensing and monitoring the functionality and performance of the cities. This way it is possible to expand their abilities of managing resources more efficiently and providing connectivity and information in a clear manner to their citizens (TOPPETA,2010).

Such conjuncture was only possible due to the advent of Web 2.0, which has expanded the possibilities of content propagation and information distribution, mostly from the raise in shared data, allowing the users to participate on the creation and manipulation of content. Furthermore, mobile terminals (such as tablets and smartphones) have allowed a broader access to the internet and real-time information production, being integrated to the computer systems and data transmission with global positioning systems (CHOURABI et. al., 2012).

In this way, the digital processes gradually began to have more immediate and meaningful consequences, connecting people, enterprises and the Public Power. Such combination becoming increasingly more effective in integrating capabilities between the sensors and the computer systems are responsible for allowing the creation and identification of limitless opportunities in facing the main problems of the cities (CHOURABI et. al., 2012).

According to Erickson (2006), technological progress that use modular and pragmatical solutions based on open and collaborative architectures have been allowing the Public Power, as well as enterprises, to establish strategies and programs to improve quality of life in the cities, willing to meet interests of all.

3. CROWDSORCING AND CROWD MAPPING

From the development of the Web 2.0 it has been possible to materialize a new scenario of possibilities of interaction between the user and information, which has contributed to the dissemination of a new model of data and events managing in urban centers. Through the conception of the Web 2.0, users have begun to collaborate with content management in a most dynamic and collaborative perspective. In this sense, if previously people where only content consumers, on this new model they also will also begin to generate it in a dynamic and collaborative system (Jarret, 2008; Jones e Weber, 2012), allowing users to create, modify, qualify and share information.

Gómez-Barrón et al (2016) highlighted that the main characteristics of the Web 2.0 systems are great interactivity, interoperability and service-oriented architecture. In this case, those services may be considered software that are built in such a way to allow an easy connection to other components. The construction of computer tools aim, in that way, to favor the reuse, distribution and dissemination of those applications, allowing the emergence of what some researchers have called knowledge "democratization" (Jarret, 2008; Haklay, 2013; Proferes, 2016). In practice, individuals have freedom to modify the available content, give opinion about shared information and validate or invalidate third part actions. Such democratization in the building of knowledge is responsible for the dissemination of a more participative approach in information management and has been affecting the way that public and private organizations interact with the society.

In this sense, crowdsourcing is related to "the forthcoming of websites that use audience/crowd as a source of content or acting manpower that is crucial for its own existence" (SOUSA, 2012, p. 76). The term was created in 2004 to "designate the passage of the web from a mean of consumption to a platform of production" (SOUSA, 2012), being, before, static and unilateral. Crowdmap is the crowdsourcing platform in which citizens participate actively in composing cartographic information online through their own input.

The participation of the population according to Goodchild (2007) can occur in an indirect way, by providing data - such as GPS data by registering traveled route, traffic speed and others - that, compiled, form a database for the public power to study or, directly, trough feedback about the systems, existing urban equipment or pointing local issues that demand public power intervention (MISRA et al., 2014). According to Erickson (2006), the application of geo-collaborative models in city management tends to be effective, promoting data transparency and collaboration of citizens, therefore contributing to the legitimacy of decisions taken by the authorities and the efficiency in targeting public investments.

In the city of Belo Horizonte the direct format for popular participation is exemplified in PBH app developed by City Hall that aims to stimulate the collective participation through personal identification of urban issues. Besides having a democratic feature of citizen participation, it has a great potential for use in urban planning, as following described.

3.1 Crowd Mapping in Belo Horizonte city

According to information collected on City Hall's website (https://prefeitura.pbh.gov.br/ accessed in December 2019), PBH is a free app released in March 2018, developed by Belo Horizonte City Hall, more specifically by the District Planning, Budget and Management Office and Prodabel (District Corporation of Computing and Data Processing of Belo Horizonte), meaning to be a communication channel between district and citizens.

The application of collaborative mapping on the PBH app is available on the tab "Require Services", that allows the citizen to require specific services, including over more than 40 services available, such as requests concerning street lighting, urban cleaning, environment, construction and urban infrastructure, urban regulation and health. Solicitations are made via smartphones Android and iOS with internet connection and GPS insertion, which registers and locates the georeferenced request on the map. In this way information is collected, analyzed and properly forwarded to the responsible public agency to provide the execution of the service. Afterwards it's also possible to follow the solicitation and evaluate the execution of the service after its conclusion. Just until October 2019, roughly 74,000 citizens were registered on the PBH app and have recorded over 120,000 solicitations.

4. URBAN INDEXES

The concept of quality of life has been built historically on the

theoretical plan grounded by dynamic social elements that continually broaden and transform their comprehension according to changes in reality. Their scope involves the economic, social, cultural and later introduced environmental sphere, from the consolidation of terms related to sustainability (YOUNG E LUSTOSA, 2003).

According to Frank (2009), such spheres are the basis to a formulation of indicators such as the concept of "social indicators", which has its origins in the 60's, when the first works in this line took shape initially in the United States, as the government's attempt to address the country's social situation of civic discontent. The situation pointed the fact that economic progress itself was not able to create social welfare. Consequently, it became necessary to seek new social indicators to aspects that could not be captured by the strictly economical approach that was dominant in that time's concept of development.

In the 70's worldwide concern with the environmental issue gains strength, especially due to the quick process of urbanization and subsequent aggravation of global environmental issues. This context stimulated the creation of environmental indicators, seen as instruments to be included in the process of decision making in the public planning sphere, a tendency that gains even more strength in the 80's (FRANK, 2009).

In that same time (between the 70's and the 80's) the debate on urban issues is strengthened by the growth process of cities around the world, particularly in developing countries. Thus, from the focus on the consequences of the development and expansion of urban centers and their social and environmental problems, terms like "quality of life" and "environmental quality" gain strength, fostering the growth of the concept "quality of urban life" (NAHAS, 2005).

Still in the 70's, the Conference of European Statisticians proposed the use of environmental indicators as instruments to monitor the environmental quality of countries and regions. According to Mueller (1991) that Conference established the importance of the creation of environmental indicators, for they are valuable tools to describe and follow environmental conditions of a country or region.

In such a way, throughout the 70's and 80's, statistic representants of international organizations have discussed methodological aspects relative to such indicators having established that, amongst other requirements, they should offer relevant information about the environmental conditions (Guimarães, 1984). The effective formulation of such environmental indexes, however, has not accomplished conceptual and methodological scope, bringing forth criticism about the limitation of the exclusive use of objective measures for analyzing environmental quality. In this way, we can find in the literature the first attempts of proposing new methodologies and experiments concerning the population's perception of environmental quality, including their satisfaction or dissatisfaction about that quality.

In the 90's, however, the progressive increase of poverty, resulting from the very conditions under which society's production processes operate, came to be the center of the decade's structural problems. Simultaneously, the sprawl and growth of urban agglomerates with the environmental degradation as a consequence and the expansion of global environmental issues made sustainability become the main focus of concern on scientific and political international debate. It is precisely in this conjunction of interests and concerns, increasingly focused on cities and the growing expansion of urban agglomerations, that the concept of quality of urban life takes shape. This concept results from the focus on the development of cities and their socio-environmental problems and the need to monitor their development at the local level, a trend that marks the formulation of several social and environmental indicators.

In the social field, in 1990 the UNDP formulated the Human Development Index (HDI), composed by the population's health conditions, education and income indicators, allowing the establishment of a hierarchy between the 104 countries considered the first version, according to the value of the index obtained for each one of them (Pnud, 1992). In the environmental studies field, several institutional meetings, such as the United Nations Conference on Environment and Development, held in 1992, have emphasized the need of strengthening the urban data systems and the formulation of sustainable development indicators (Agenda 21, 1992).

Such initiatives have pointed out a worldwide trend of strengthening governments on a local level and refer to the urge of developing systems to monitor city development. That scenario created a new look for those indicators. On one hand, throughout the 90's, local initiatives to develop so-called "sustainability indicators" have multiplied (NAHAS, 2005), using new technologies of the World Wide Web (Internet) and less academical measurement strategies, aiming to give the city's ability to conceive, draw and implement projects to increase local sustainability. At the same time, since the creation of HDI in 1990, governments and institutions have developed similar initiatives trying to evaluate development, conditions and/or quality of life of distinct spatial areas - states, regions, cities - boosting the elaboration and use of urban environment evaluation indicators.

And so, under that historical context, the concept of quality of urban life is consolidated and configurated: between life quality and environmental quality and through experiences built up by quantification of both (NAHAS, 2005), searching, most of all, better ways of instrumentalizing the planning of public action in cities.

On that same track, the Urban Quality of Life Index of Brazilian districts (IQVU-BR) was created, between November 2004 and December 2005, as a diagnostic tool for the districts, intended to be used as an instrument of aid in district public political planning, as a responsibility of the Ministry of Cities. The proposal to build an index with focus on urban service provision comes from the need of technical apparatus of the systems of district indexes, according to the institutional premises of urban intervention:

> "Guarantee the right to the city for all its inhabitants, promoting universal access to urbanized land and decent housing, environmental sanitation, safe drinking water, traffic and mobility, and a healthy environment, through democratic management. The right to the city implies the formulation and implementation of an urban and regional development policy, with the guarantee of respect for human rights related to urban life, in a sustainable way for present and future generations". (BRASIL, 2003, p.2)

4.1 Urban Quality of Life Index in Belo Horizonte city

The Urban Quality of Life Index of Belo Horizonte was created in 1996 by City Hall and PUC Minas University, and is composed by several variables (urban infrastructure, security, education etcetera), that aim to quantify the availability of public and private goods and services in the city. In this way, its calculation allows us to delimitate priority areas for public investments and a better comprehension of the distribution of

public and private goods and services between the 80 Planning Units (UPs) that currently exist in Belo Horizonte.
The construction of the UQLI-BH methodology began in 1994, being completed in 1996, when it generated a series of accurate results regarding the years of 1994, 2000, 2006, 2010, 2012, 2014 and 2016. Initially, in the denominated Historical Series, 9 variables were considered, as a result of the aggregation of 33 indicators, each one with an assigned weight. In 2006 some modifications were included in the thematic composition of the IQVU, initiating what is called New Series (2006, 2010, 2012, 2014 and 2016), composed by 10 variables and 36 indicators. On both series, variables were grouped, generating the final index value, varying between 0 and 1, being 1 the "ideal", meaning, plain access to public and private goods and services.

Figure 1: Average and Variance of the UQLI/New Series- 2016

VARIABLE	AVERAGE VALUE IN BELO HORIZONTE	VARIANCE
SUPPLY	0,817	0,032
CULTURE	0,428	0,026
EDUCATION	0,756	0,035
SPORTS	0,832	0,017
HOUSING	0,716	0,024
URBAN INFRASTRUCTURE	0,833	0,005
ENVIRONMENT	0,781	0,018
HEALTH	0,627	0,014
URBAN SERVICES	0,517	0,021
URBAN SECURITY	0,411	0,078
IQVU	0,688	0,007

Source: https://prefeitura.pbh.gov.br, 2018

5. METHODOLOGY

After the research previously presented, whose purpose was to carry out the construction of the bibliographic survey on themes related to the urban context, specially crowd mapping and urban indexes, now practical research on the themes described is presented. For this purpose, the Arqgis Software was used for the elaboration of 3 maps comprehending data from the PBH app, the UQLI-BH and the overlap of both datasets. The methodology used in both cartographic confections can be described in three steps.
Step one comprises the gauging of the data set related to the requests made by the users of the PBH app about services of Urban and Infrastructure Work and, more specifically, maintenance services of squares, sites, green areas and whole fixing. Such data was made available by the Undersecretary of Management Modernization which covers the District Office of Planning, Budget and Management and beholds a set of 79.181 data referring to solicitations under that theme and distributed among the 80 Planning Units (UP) of the city of Belo Horizonte.
For the map, the classification method used to systematize the numeric fields is the "Natural Breaks", which is based on natural groupings inherent to data. So, the class breaks are identified, separating the data between five levels: low, medium low, medium, medium high, high. That classification is based on the algorithm of Jenks Natural Breaks, as described in the text Univariate Classification Schemes in Geospatial Analysis - A Comprehensive Guide.
Step two consists in the measurement of the data set regarding the Urban Quality of Life Index performed by Belo Horizonte's City Hall, above all, on the indicator that represents the possibility of access to paving in the last year of measurement (2016). The data constitutes a set of information offered in open format through the City Hall's website (https://prefeitura.pbh.gov.br/ accessed on December 2019), with the final number index about each of the 80 Planning Units. The methodology used for turning such data into a map is the same as the described above.
Finally, step three is the overlap of the two previous information as a fundament for the analysis of possible trends. This required the transformation and reclassification of the numerical information from the Multicriteria Analysis and Combinatorial Analysis methodology, which may be understood as:

> The Multicriteria Analysis works with layers of information that has already been judged concerning their meaning for the goal of the investigation, represented as a numerical value as to the degree of relevance according to the purpose of investigation (from the numerical coding of elements that before were in ordinal, quantitative and selective or nominal scale) (MOURA, 2007; MOTTA, 2017).

The classifications were based on the five subgroups established in the previous maps and were re-grouped in a matrix as indicated in Figure 02. Through it, it became possible to know the possible territorial coincidences of the agreement variables according to the purpose in order to locate the junction between the levels of manifestations of the UQLI-BH and the PBH app.

Figure 02: Methodological matrix

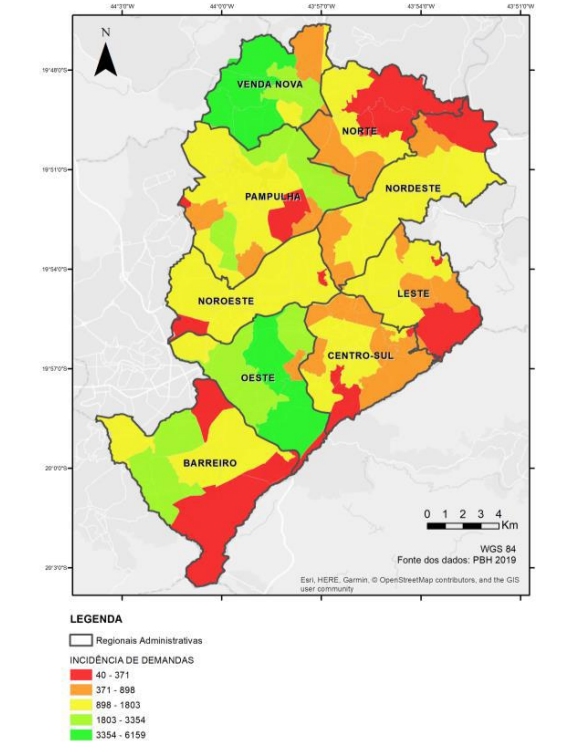
		Low		IQVU		High
		10	20	30	40	50
Low	1	11	21	31	41	51
PBH APP	2	12	22	32	42	52
	3	13	23	33	43	53
	4	14	24	34	44	54
High	5	15	15	35	45	55

Source: Prepared by the author

6. RESULTS

Figure 03 pictures the incidence of solicitations collected by the PBH app, distributed throughout the 80 Planning Units and grouped by circumscription of administrative regions of the city. Its data represents the requests in relation to urban works and infrastructure, specifically maintenance requests in squares, flowerbeds, green areas and plugging holes, made between 01/01/2018 and 11/24/2019.

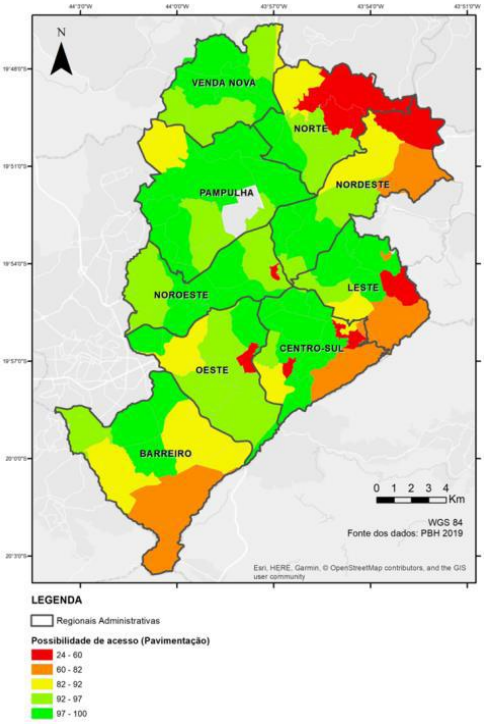
Figure 03: The Incidence of PBH app requests (2018-2019)



Source: Prepared by the author

Figure 04 pictures the spatial distribution of Pavement and Access Possibility Index, being one of the evaluation criteria from the UQLI-BH. This data is located inside the 80 Planning Units and grouped by circumscription of administrative regions of the city and represent the last UQLI measurement, in 2016.

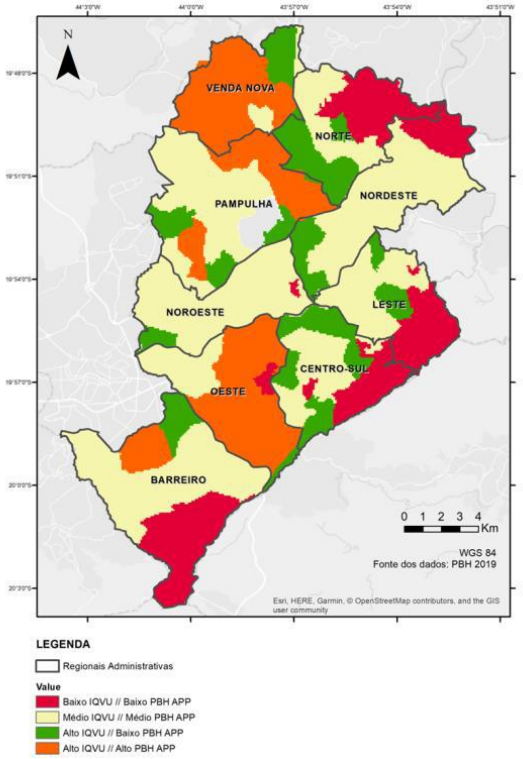
Figure 04: Access possibility (pavement) - UQLI (2016)



Source: Prepared by the author

Figure 05 pictures the confluence of both maps shown above, containing the spatial distribution of information relative to UQLI-BH and PBH app. The data is placed by Planning Units and grouped by circumscription of administrative regions of the city.

Figure 05: Relation between UQLI and PBH app requests



Source: Prepared by the author

7. DISCUSSION

The proposed investigation resulted in the spatial diagramming of the UPs of Belo Horizonte including complementary information, both about UQLI levels and the solicitations requested through the PBH app.

Concerning Figure 03 it's necessary to highlight that, amongst the 2.501.576 residents as estimated in 2019 by the Brazilian Geography and Statistics Institute (IBGE), 74.000 are registered in the PBH app, which corresponds only about 2,95% of the total population.

Concerning distribution of requests throughout the urban territory, it occurs in a heterogeneous way, showing a great disparity between the quantity of requests by UP, containing some locations with only 40 requests and others, more than 6 thousand occurrences.

With regard to the UPs with less requests in the PBH app, they were located in a concentrated manner in the North, Northeast regions and Barreiro and in a sprayed and reduced manner by the other regions, contemplating, mostly, UPs with a low purchasing power or urban agglomerates, such as Zilah Spósito, Granja Werneck, Capitão Eduardo, Conjunto Paulo Vl, Barragem Santa Lúcia, Taquaril, Baleia, among others. The areas of environmental preservation, part of the Mangabeira's neighborhood and Serra do Curral are also included in this concentration.

On the other hand, it is possible to measure that places that hold the biggest request rates by the app are the regions Venda Nova,

including UPs Mantiqueira, Rio Branco and Céu Azul and West region, including UPs Calafate, Nova Suíça, Estoril and Buritis.
Concerning Map 04 it's possible to deduce that most part of the Planning Units has an UQLI equal or superior to 92, which means, according to indicators provided by City Hall, that the city has mostly locations with the possibility of access to pavement. On the other hand, UPs with a low UQLI are equally concentrated on North and Northeast regions and on urban agglomerates spread randomly over the city.
Map 05 is a result of the overlap of the previous maps, indicating the citizens perception of urban indicators, highlighting, mostly, that trends are placed in a distributed and heterogeneous way on the map, not showing significant spatial overlay related to the obtained data. We can also deduce that the places where the UQLI is low constitute, occasionally, locations of a low index of requests through PBH app and represent mostly low social class neighborhoods, including agglomerates and slums. In that same way, it is possible to deduce that West and Venda Nova regions represent the places where there is a high level of requests and a high UQLI, which shows a trend of higher social engagement in relation to the use of urban infrastructures in such locations.
However, on the results mapped, there are no places that have simultaneously a low UQLI and a high PBH level of requests and that conclusion becomes an important point of the present work, since, as previously described, most part of UPs with a low UQLI are urban agglomerates. So, considering places with low levels of paving and access possibility, they should be, as a consequence, the areas with a higher ratio of requests for repair or bigger investments, it is possible to deduce that there is no linear trend towards those predictions, which makes the analysis of the results still broader, making it necessary to explore other layers of information. It's necessary to consider, beyond presented data, other interferences such as access to cell phones or to the app, digital knowledge of residents and, most of all, the social activism and engagement in those places.
And so, in relation to the investigation presented it is necessary to highlight the importance of the development of urban indexes as essential tools to make possible a better comprehension of the operation and location of several parameters of the urban infrastructure, which makes possible more effectiveness in the urban planning operations, facilitating decision-making by managers and a better distribution of investment from public and private initiatives. However, even if those initiatives are beneficial for society as a whole, they still show some flaws. The difficulties discussed are centered in the dynamism itself under which the concept is updated, considering the complexity of economic, environmental and social transformations present in a urban context, which also demands constant update of the indicators themselves. In that same way, it was possible to analyze the gap present in the indicators because they are unilateral and unable to measure their applicability to society.
About the conceptual references about crowd mapping, it is an important instrument capable of promoting a higher level of activism and social engagement through citizen collaboration in a collective and democratic manner. The discussion around the ICTs as percussionists and enablers of smart cities contemplates exactly the role of users in the construction of more inclusive and efficient spaces. In that way, the concepts presented hook the development of technological applications in favor of the social sector. That correlation, however, is cyclical and continuous, since the dynamic and spontaneous aspect of society produces several changes that also bring about changes in technological apparatus, in values and in the use of technology, demanding constant attention for those changes and their unfolding.

8. FINAL CONSIDERATIONS

The present work aims to make a summary of the coverage that involves the urban context unfolding both its conceptual aspects as well as the practical aspects, mostly through studying the initiatives adopted by the public sphere and by the citizens for a better understanding and usage of the resources available in the cities, such as measurement of urban quality of life indexes and crowd mapping initiatives.
Regarding the practical aspects discussed, this article investigated the overlapping of information collected on two sets of data: UQLI-BH and PBH app, which made it possible to analyze the spatial distribution and the several demands for infrastructural improvements. As a consequence of that process we have come to realize that the systematization of information and data analysis are important tools for a better understanding of the distribution of the population's demands, alongside with the urban quality of life index, and that the interpretation of the results doesn't happen in a predictable way, becoming insufficient if they are not considered together with social, economic, environmental and other aspects.

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