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A new methodology to support smartness at the district level of metropolitan areas in emerging economies: the Case of Santiago de Chile

Francisco Ramirez¹, Pedro Palominos¹, Mauricio Camargo², Didier Grimaldi³

(1), Universidad de Santiago de Chile / Department of Industrial Engineering 3769 Ecuador Ave. Santiago, Chile. PO Box 10233

*(2) Université de Lorraine / ERPI (Equipe de Recherche des Processus Innovatifs), 8, rue Bastien Lepage 54010 Nancy Cedex, France
mauricio.camargo@univ-lorraine.fr*

(3) Universitat Ramon Llull. Sant Joan de La Salle, Department of Business Management, 42. 08022 Barcelona, Spain

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Abstract

According to a forecast by the United Nations, by 2030 one in every three people in the world will live in cities with at least half a million inhabitants. Therefore, enabling smarter and resilient cities is one of the key goals to tackling world challenges and ensuring the citizen's wellbeing in the years to come. Various frameworks of indicators have been proposed to evaluate urban smartness with an aim to improve policymakers' actions. Nevertheless, recent research shows that despite efforts and initiatives, urban policy actions have yet to achieve the expected results, as smartness is evaluated in an aggregated way, while metropolitan areas are very heterogeneous systems. In this paper, the authors propose a methodological approach to evaluate smartness while considering a city not as a homogeneous space, but as a space divided into different districts with different characteristics and dynamics, and therefore different topologies and citizen needs. This methodology is based on Data Envelopment Analysis (DEA), which sets out to measure the performance of decision-making units (districts) by considering the efficiency of each district, measured by the ratio between its allocated resources (input) and the corresponding smartness score (output). Accordingly, the methodology is highly applicable to cities located in emerging countries, which are characterised by a high disparity of human conditions if we compare them district by district. The approach is illustrated in a case study of the smartness of the metropolitan districts of Santiago de Chile.

1. INTRODUCTION

Rural population is decreasing rapidly. In 1950, 30% of the world's population was urban. By 2018, the demographic concentration in urban areas had increased to 55.3%, reducing the population in rural areas to less than one half of the world's population in under 65 years (United Nations, 2018). The most highly urbanised regions include North America, with 82%; Latin America and the Caribbean, with 80%; and Europe, with 73%. In contrast, Africa and Asia are still mostly rural, with 40% and 48% of their respective populations living in urban areas. As stated in the UN World Cities Report, "by 2030, urban areas are projected to house 60 percent of people globally and one in every three people will live in cities with at least half a million inhabitants" (United Nations, 2018). There is no doubt that cities continue to be very attractive for the majority of the world's population, even though there are negative aspects that have not been fully solved, such as traffic congestion, environmental pollution, safety risks, and overcrowding, among others (Joshi et al., 2016; World Bank IEG., 2009). In general, the growth of the urban population does not always go hand in hand with a proportional increase in infrastructure to maintain the quality of the urban services and well-being of the population (Assadian and Nejati, 2013). Indeed, financial resources are limited, and for this reason many cities in the world are looking to develop innovative and smart ways to provide services to their inhabitants. The use of new technologies such as IOT (Internet of Things) has led to a new concept of city that many authors call a Smart City (Angelidou et al., 2012; Grimaldi and Fernandez, 2019; Ylipulli et al., 2014). Nevertheless, (Caragliu et al., 2011) state that not only is the use of ICT in urban services relevant, but that the smartness of cities also requires the holistic integration of systems under sustainable considerations.

As a consequence, at a city level, policymakers need metrics and methodologies to help them to evaluate and manage resources more efficiently and, subsequently, respond to their cities' smartness. A growing number of frameworks of indicators have been proposed to evaluate urban smartness, such as the Smart City Index (IMD, 2019), the Global Cities Ranking (GCR, 2019), the Cities in Motion Index (IESE, 2019), the Global Power City Index (GPCI, 2019) and the Better Life Index (OECD, 2019), among others. In a recent study, (Sharifi, 2020) recorded thirty-four frameworks that have been

proposed in literature since the last decade. These frameworks propose a set of procedures to assess the performance of cities and quality of life objectives. Moreover, when dealing with Smart Cities, it is also relevant to consider the direction taken by cities towards models that foster sustainable development. The smartness of a city includes a more equitable and inclusive social development (Dobbs et al., 2011). Nevertheless, many papers show that despite efforts and initiatives, urban policy actions have yet to achieve the expected results, as smartness is evaluated in an aggregated way, while metropolitan areas are very heterogeneous systems (Khan, 2018; Rodríguez Bolívar, 2018; USA, 1984).

This paper stems from this gap and offers a methodology that urban governments in metropolitan areas can apply to the process in order to harness the value of their actions and improve their decision-making processes (Tran Thi Hoang et al., 2019). More precisely, we set out to evaluate smartness while considering a city not as a homogeneous space, but as a space divided into different districts with different characteristics and dynamics, and therefore different topologies and citizen needs. Moreover, this methodology lets us understand which efforts should be deployed to ensure gradual and profound changes in the city's planning and management at a local scale. It also helps control and mitigate the impact produced by the city's growth, thereby attempting to ensure better living conditions and a potential sustainable development (Orrego, 2017). To achieve this goal, the proposed methodology is based on Data Envelopment Analysis (DEA) (Charnes et al., 1978), which sets out to measure the performance of decision-making units (districts in this case) which convert multiple inputs into multiple outputs. Used as a benchmarking tool, the efficiency score indicates whether the evaluated units are completely efficient or have room for improvement (Ishizaka and Nemery, 2013). Following the same logic, the proposed methodology considers the efficiency of each district measured by the ratio between allocated budget (input) and smartness resulting from the aggregated set of defined metrics of the framework (output). Moreover, the results are compared with citizens' perception evaluated under considerations of the proposed framework.

The proposed approach therefore sets out to be highly applicable to cities located in emerging countries, which are characterised by a high disparity of human conditions if we compare them

district by district. Below is a list of additional reasons that inspired us to develop this specific methodology:

- Most methodologies cover cities in developed countries. The most popular are International Organization for Standardisation ISO 37120: Sustainable Development of Communities (ISO), British Standards Institute Maturity Model (BSI) and International Data Corporation Maturity Scape (IDC). However, the representation of these methodologies in South America is weak. Only Bogota and Buenos Aires are present.
- There are particular issues that make it difficult to apply the same smartness indicators used for emerged and emerging countries. For instance, cities in emerging countries have a higher growth rate and some areas may even be non-urbanised (Marchetti et al., 2019; Theng et al., 2016). As a consequence, the evaluation must be adapted to the local context and meet citizen needs in these countries (Marchetti et al., 2019).
- Moreover, the wealth gap between districts in emerging countries needs analyses and results at district level within a city to activate decisions and actions closer to citizen needs.

The remainder of the paper is structured as follows: after a literature review about smart city rankings, the methodology is presented in Section 3. In Section 4, the authors illustrate it using the case of Santiago de Chile. The relevance of this case study is due to the major heterogeneity of its districts, marked by a high population concentration and accounting for approximately 40% of the national territory (INE, 2017). In Section 5, a discussion takes place to provide academics and practitioners with insights before concluding and exploring ways of improvement.

2. Overview of a Smart City and smartness evaluation

2.1 Smart City definition and smartness dimensions

In scientific literature, the concept of Smart City has a large number of meanings, indicators, and metrics relative to its performance (Ahvenniemi et al., 2017; Albino et al., 2015; Joshi et al., 2016). Hollands (2015) defines 'smart' as a "high-tech" improvement providing a more intelligent, progressive and inclusive city. Wiig (2015) echoes this definition, adding that the term refers to technology will lead to a positive, utopian future, i.e. new expectations about solving long-standing social, economic and environmental urban issues.

Perboli et al. (2014) say that the majority of Smart City projects are managed in a top-down approach by local government and through partnerships with private companies. Hollands (2015) responds that crowdsourcing solutions have progressively allowed citizens to collectively participate in solving urban issues and spearheading smart initiatives. Furthermore, (Carrasco and Sobrepere, 2015) mention that the open data public policy has changed the urban mode of governance by providing citizens with greater access to information, which also has the positive impact of improving the accountability and transparency of government action. Accordingly, Smart City discussions have recently shifted towards the new concept of Smart Citizens, highlighting the level of education of residents as a driving force behind urban sustainability growth (Meijer and Bolívar, 2016). Referring to this debate, Hollands (2008) recalls that technology is a means for communities connect with each other and develop a human and social capital, i.e. a network of social relations, trust and reciprocity.

The Spanish Association for Standardisation and Certification (AENOR), by means of a synthesis exercise of more than 100 definitions, has proposed the following definition: "*A Smart City is a fair and equitable citizen-centric city which continually improves its sustainability and resilience by leveraging knowledge and available resources, especially Information and Communication Technologies (ICT), in order to improve quality of life, efficiency of urban services, innovation, and competitiveness without compromising future needs in economic, governmental, social, and environmental aspects*" (AENOR, 2016). This synthesis captures the multidimensional character of a system, which is as complex as cities are.

2.2 Frameworks to evaluate urban smartness

In scientific literature, there are several systems of indicators with different objectives, such as benchmarking the transport services developed across megacities such as Sydney, Paris or London (Debnath et al., 2014). Another example comes from Martínez Roget et al. (2005), who propose an European synthetic indicator for Spanish Provinces. Meanwhile, Giffinger et al. (2007) introduce the widely used ‘Smart City Ranking’, proposing a multidimensional approach divided into attributes known as: Smart Economy, Smart Governance, Smart Environment, Smart Mobility, Smart People, and Smart Living. These latter are the common threads when we analyse the frameworks used to assess the smart city (Sharifi, 2020).

Furthermore, the use of Indexes is the dominant format across the registered frameworks (Sharifi, 2020). Carli et al. (2013) developed a framework for classifying performance indicators of a Smart City. Their ranking system is based on two dimensions: the degree of objectivity of observed variables and the level of technological advancement for data collection. Subsequently, Batten and Edwards (2016) developed the Sustainable Cities Index, the OECD released the Better Life Index (OECD, 2016), and Chilean authors published the Index of Quality of Urban Life (Orrego, 2017) and the “*Sistema Nacional de Información Municipal*” (SINIM, 2017).

For developing countries, Manupati et al. (2018) selected from a major literature review and proposed a specific framework composed of seven criteria used to evaluate the ongoing urban renewal in India. However, once the variables of the model had been determined, Rad et al. (2018) argued that it is hard to include their interrelationships in a model, although the integration of the different dimensions is necessary for an all-round smartness evaluation of a city.

More recently, Dall’O’ et al. (2017) proposed a methodology to measure the smartness of small and medium cities in Italy. Their framework is adapted from the ISO 31120 series and simplified to fit the characteristics of cities of less than 50,000 inhabitants. In their paper, they performed a comparative analysis of the most recent frameworks, looking at indicators for each smart dimension. Their analysis

confirmed the relevance of the multidimensional approach of the first Smart City models, proposed by Giffinger et al., (2007). These variables are especially useful for providing a complete and transparent overview of the different systems that coexist in cities. They are also unable to provide a system of management indicators that facilitate decision-making and accountability processes for public or private organisations, citizens, or third parties interested in the public sphere. Figure 1 shows their results, which will be used within the framework of this research paper, after having been adapted by the authors.

Figure 1. Smart City dimensions inspired by Giffinger and Haindlmaier (2010)

2.2 Failure to measure policy actions

As mentioned before, there are various city rankings, but even though most urban regions are composed of medium-sized cities, research has so far focused on larger and global metropolitan administrations (Giffinger et al., 2007). The results are unable to measure administrative efficiency and effectiveness and citizen satisfaction. Moreover, the promise of Information and Communication Technology (ICT) to trigger substantial changes has also failed. In practice, it has been a simple adaptation of offline services but not a new mechanism to increase interaction, transparency of government actions and improvement of services requested by citizens (Paskaleva et al., 2015; Rodríguez Bolívar, 2018).

Smart City frameworks do not include the exact feedback of all citizens in order to comprehensively align policies with social needs. Kontokosta and Hong (2021) state that the problem is due to part of the population being inaudible or misunderstood. Indeed, even if a citizen survey does exist, disparities collected throughout the report lead the government to overestimate or underestimate the complaints of residents. As an example, low-income and minority neighbourhoods usually report

more serious issues than road conditions or nuisance behaviour, even if their neighbourhoods suffer from them.

In other words, with regard to territorial levels (region, city and district), as highlighted by Mattoni et al. (2019), there is a lack of holistic visions of smartness at a district level. Indeed, we believe that at this pinpointed level it is easier for local authorities to work efficiently. In addition, the analyses and solutions defined at this level are flexible and scalable for the entire city, foster a better and more targeted implementation, and achieve effectiveness in terms of social change. This paper addresses this gap. Moreover, as stated by Huovila et al. (2019) in their recent study on how to select indicators for smart and sustainable cities, there is a need for methods to analyse relations between resources invested (i.e. inputs), processes used, and actual outcomes and impacts.

3. Proposed methodology

Based on the discussion above, the proposed methodology sets out to provide a number of stages to integrate the holistic vision of smartness for a metropolitan area, including the district level, the integration of efficiency and the feedback of citizens regarding their own perception about the level of smartness.

Figure 2 describes the proposed methodological approach, which can be summarised by the following steps: (1) Selection of city and districts indicators; (2) Design of a benchmarking methodology for the technical efficiency of districts; (3) Assessment of citizen perception of efficiency; and (4) Data analysis and discussion. We will detail each step below.

Figure 2. Methodological approach to evaluate city smartness at a district level.

3.1 Selection of city and district indicators

Currently, there are many indicators (AENOR, 2016; Cohen, 2015; IESE, 2016; ISO, 2014; Martínez Roget et al., 2005; Orellana, 2017), but many of them are not mutually standardised to make them comparable between cities. The main objective of this stage is the selection of indicators that can evaluate and diagnose districts, setting out to reinforce the public policies based on the Smart Cities model of Giffinger et al., (2007).

For the selection of the city and district indicators, the following systems were considered: *AENOR UNE 178201:2016 AENOR, 2016*, *ISO 37120:2014 Sustainable development of communities - Indicators for city services and quality of life* (ISO, 2014); *Smart Cities Wheel of Boyd Cohen* (Cohen, 2015); and finally, *IESE Cities in Motion Index* (IESE, 2019). These systems contain 135, 100, 62, and 72 indicators, respectively, giving a total 369 indicators to begin the selection.

Exclusions from the indicator selection process were made following the process indicated in Figure 2. The first exclusion sets out to determine the statistical mode between the total indicators, eliminating repetitions. The second exclusion uses the technical assessment criteria proposed by Bonnefoy and Armijo (2005), which comprises the following criteria: belonging, relevance, homogeneity, independence, cost, reliability, simplicity and comprehensiveness, opportunity, and no redundancy, focused on controllable areas and participation. For the whole set of criteria, a group of five experts from the Smart City Lab at the University of Santiago were asked to discuss and reach a consensus in two rounds, aiming to reduce the number of indicators under the set of mentioned criteria. As indicated in Figure 2, the first round obtained 105 indicators. After this, in order to apply them within the districts, they were asked to evaluate the set of indicators regarding their relevance and availability of information, making sure to cover the six dimensions of city smartness and the 24 domains as indicated in Figure 1 (Giffinger and Haindlmaier, 2010).

In this way, the exclusion process provides a total of 40 indicators, classified according to their level of belonging to the six dimensions in 24 themes, which form the final base model of the system and will be used to reach the coverage proposed by each definition. Moreover, we believe that our 40

selected indicators make our methodology scalable to many cities in the world, including emerging areas where the systems fail to provide complex urban information. Table 1 shows the indicators.

Table 1. Indicators selected for the proposed system.

3.2 Design of a DEA-based benchmarking methodology for the technical efficiency of districts

The indicators selected for the districts under analysis will be the input for the preparation of a global indicator that measures their technical efficiency by means of Data Envelopment Analysis (DEA) (Charnes et al., 1978). Although DEA applications in the construction of synthetic indicators are scarce, they are becoming more frequent. Hashimoto and Ishikawa (1993) and Hashimoto and Kodama (1997) have used DEA for the estimation of an index of social welfare and quality of life in Japan, while Zhu (2001) did the same to compare the standard of living offered by a set of cities. Storrie and Bjurek (2000) used this same technique to construct a synthetic index that reflects the functioning of labour markets in the European Union, while Martínez Roget et al. (2005) created European Synthetic Indicators for Spanish Provinces. Finally, Dzemydaitė and Galinienė (2013) used DEA for the evaluation of regional efficiency disparities by Efficient Frontier analysis.

In general terms, DEA optimises objective agents, known as DMUs (Decision-Making Units), in this case the districts, with the purpose of emphasising their degree of independence at the time of modifying their input and output levels. From the assigned sets, the efficient DMUs determine a linear dotted Pareto border, giving an insight into “how well or badly it operates” (Ishizaka and Nemery, 2013). The proposed mathematical model will be described and the different variables to be used are defined below:

$$\text{Max } \theta_0 \tag{1}$$

s. a.

$$\sum_{j=1}^n X_{ij}\lambda_{j0} \leq X_{i0} \quad ; \quad \forall i \text{ con } i = \{1, \dots, m\} \tag{2}$$

$$\sum_{j=1}^n Y_{rj} \lambda_{j0} \geq Y_{r0} \theta_0 ; \quad \forall r \text{ con } r = \{1, \dots, s\} \quad (3)$$

$$\lambda_{j0} \geq 0 \quad ; \quad \forall j \text{ con } j = \{1, \dots, n\} \quad (4)$$

where

- i. θ_0 represents the technical efficiency of the studied unit;
- ii. X_{ij} represents the inputs i to be consumed by each DMU j ;
- iii. Y_{ij} represents the outputs i to be produced by each DMU j ;
- iv. λ_{j0} represents the weight of each DMU according to the unit observed;
- v. n represents the total number of DMUs evaluated;
- vi. m represents the total number of inputs consumed;
- vii. s represents the total number of outputs produced;
- viii. DMU_0 represents the unit being observed.

It should be pointed out that the output variables of the model present both positive and negative characteristics, i.e. there are indicators under the slogan “the more the better”, categorised as positive, and indicators with the characteristics of “the less the better”, assigned as negative variables. The distinction made as positive and negative is associated with the definition and characteristics belonging to a Smart City. This distinction requires the outputs and the inputs to be normalised under the total sum of the particular data of the indicator for each district (see Table 2). Therefore, the negatives are reversed to achieve an adequate standardisation in which the model minimises the input to maximise all the outputs.

Table 2 Standardisation of indicators

3.3 Evaluation of citizen perception of efficiency

A survey was prepared to measure district-by-district performance based on citizen perception, evaluating the quality-of-life present in each district, and a ranking indicator was prepared. The goal

of finding out perception was to approach the requirements and needs of citizens as a way of complementing the indicators present in the city.

The questions focused on the indicators selected in Step 1 of the methodology, complying with all the characteristics that define a Smart City. The proposed questionnaire was then, designed by a multidisciplinary group of people including psychologists, economist and engineers, and some test realized before deployment. From this process some additional aspects should be considered:

1. It is worth to mention that the questionnaire keeps the same structure and dimensions of the framework of indicators. However, the language of selected questions related to perception, needed to be the more natural and comprehensive as possible for people issue of the different socio-cultural levels of the society.
2. For each dimension of the framework, it was decided to include only 3 or 4 questions. This for methodological reasons. That is, we seek when applying the survey to get a better compromise between relevance and complexity (length).

As a result, a citizen perception survey composed by 43 questions were validated by Smart City experts from the University of Santiago de Chile. The responses of citizens to the survey were expressed on the Likert scale, with a score of 5 for total agreement and 1 for total disagreement with the questions included in the survey.

3.4 Data analysis and discussion

The aim of having access to a global index is to observe the sustainability and smartness level of the city broken down by districts. For that purpose, we used the results of the indicators obtained in Stages (2) and (3) of the methodology, which measure the technical efficiency of the district services an citizen perception of the services provided from the perspective of a Smart City.

The global index consisted of the six dimensions of the Smart City concept used, where the average reached by the six attributes shapes the global index.

4. Case study: Santiago smartness evaluation

4.1 Context

The case study was applied to the Metropolitan Region of Santiago de Chile, which has an area equal to 2% of the nation's area, making it the smallest region in the country. In this context, it is a complex and diverse territory, marked by a high population concentration which accounts for approximately 40% of Chile, with 7,307,000 people (INE; 2017). The region's capital is the city of Santiago, which is also the nation's capital. Administratively, this region comprises six provinces subdivided into fifty-two districts, and the application will be applied to the province of Santiago with thirty-two districts. It does not include rural areas, as this would distort the results. The most populated district is Maipu, with 521,627 people, and the least populated is Cerrillos, with 80,832 people. *Figure 3* shows the districts in the Santiago Metropolitan Region which are considered in the study and *Figure 4* shows the annual budgets for 2016 for the districts under study. For each district, the data needed to calculate the set of indicators to evaluate district smartness (Table 1) was gathered for the same year.

Figure 3. Districts in the Santiago Metropolitan Region

Figure 4. Budget allocation of districts in the Santiago Metropolitan Region

As an analytical tool, case studies are increasingly common in business research (Njie and Asimiran, 2014). This method allows us to study a city in relation to its context and enables us to collect data according to our research question. To ensure the quality of the method, we followed the recommendations made by Yin (2012). External validity is tested in accordance with the principles of analytic generalisation, replicability and comparison between cases, while reliability is ensured by establishing an initial protocol for procedure and creating a full database. Such measures are complemented by a revision of the conclusions using the double-blind peer review method.

4.2 Technical efficiency of the districts

When applying DEA for obtaining the global indicator of technical efficiency of the districts, the current budget of each district was considered as input (X), and all the selected indicators as outputs (Y). To build the model, the authors use the Data Envelopment Analysis program DEAP, Version 2.1.

Table 3 General efficiency for each district in the city of Santiago

As a result, *Table 3* shows that fifteen districts reached the maximum level of overall efficiency in relation to the use of their budget. Meanwhile, the district of Maipú was located at the bottom of the table, with an overall efficiency of 19.7%.

Furthermore, the technical efficiency was also calculated for each of the six dimensions of the proposal by (Giffinger et al., 2007). As an illustration, *Table 4* presents the results of technical efficiency for the dimension of smart economy.

Table 4 Technical efficiency for each district in the city of Santiago

4.3 Indicator of citizen perception

A survey was designed to measure citizen perception (see Appendix 2). To determine the internal consistency and reliability of the instrument, Cronbach's Alpha coefficient was calculated. High values denote that the indicators are adequate to measure the concept by which they were selected. Peterson (1994) suggests 0.7 as an acceptable value. In our case, a value of 0.77 was obtained, representative of the fact that the indicators are correct measures of the phenomenon analysed. The survey was presented in a Google format (<https://goo.gl/forms/KSfSlkcsad9rR43o2>) and a Likert scale was used to answer each question, with 5 being "totally agree" with the question and 1 being "totally disagree". With the purpose of reaching every citizen rapidly via social media, the form was distributed online through WhatsApp, Twitter and Facebook to the largest possible number of users who lived in the Province of Santiago. It received a total of 189 opinions. All thirty-two districts of Santiago were covered. The resulting sample is formed by 52,9% of women and 47.1% of men. Average age (years): 20-29: 56,1%; 29-39: 15.9%; other: 28%. The satisfaction perception index results are presented in *Table 5*.

Table 5 Citizen perception by districts.

4.4 Global index

The global index, which is basically a ranking of the smart districts, considered the average of the efficiency of the six smart dimensions obtained in Stage 2 and the perception of the services obtained by the survey (Stage 3). Thanks to this data, it was possible to generate a ranking by using the DEA technique, where there are only two districts in first places (La Cisterna and Vitacura). These districts achieved this position because they had the highest percentages in technical efficiency and perception. Meanwhile, the districts La Pintana and Peñalolén were in the last places because they had the worst relation between the analysed axes. The results of global index are presented in *Table 6*.

Table 6. Global ranking of smart districts

4.5 Clustering analysis

The results above were used to perform a cluster analysis through the IBM SPSS Statistics software program, according to the general technical efficiency and the perception of the services delivered by the city. *Figure 5* shows the maximum points highlighted above, as represented by La Cisterna (Maximum in efficiency) and Vitacura (Maximum in perception). Meanwhile, La Pintana and Peñalolén are assigned the minimum of the relation. As for the other groups, the blue stands out, considered as a set of districts with a high perception of the quality of services, but with high inefficiencies in the use of resources. Similarly, the green group stands out for its high efficiency in the use of the municipal budget, but with low expectations in product delivery.

Figure 5. Graphic cluster analysis by district (average efficiency)

Moreover, a global analysis of the performance of the thirty-two districts in the six attributes of a Smart City was made, with the results being presented in *Figure 6*, where the setting linked to a Smart

Economy appears as the weakest among the thirty-two analysed districts. On the other hand, Smart People, i.e., the dimension associated with social issues, appears as the strongest dimension in the province of Santiago.

Figure 6. Ranking of districts according to each dimension.

5.- Discussion and policy-making implications

IBM defines the Smart City as a system of systems (Wiig, 2015), based on three cornerstones aimed at planning, managing the urban infrastructure and provide the necessary services for a good quality of life (Söderström et al., 2014). In our study, the definition of a system of urban indicators under the Smart City paradigm has allowed us to put together the present and future characteristics (as a function of a constant updating and feedback) of the city with the opinion or the perception of each citizen on the quality of the delivered services. Marchetti et al. (2019) alerted us that local governments from emerging countries should look for their own model and tools to evaluate their Smart Cities. They added that the idiosyncrasies of South America region usually detract from the methodology used to measure the smartness of cities in North America or Europe. Reasons included the lack of modern infrastructure, the average level of education or the disparity of family incomes between neighbourhoods in the same city. This confirms that a real need existed to find a specific method of data collection and analysis to evaluate the smartness of a developing city like Santiago de Chile.

The difficulty in obtaining the information for this particular case study shows the main specific problem related to the size of a city. Crowdsourcing is not always the solution if the urban area and residents analysed do not have a high enough level of IT literacy (Hollands, 2014). As Giffinger et al. (2007) corroborate, data availability is a major issue for evaluating urban agglomerations at this scale.

As our experience demonstrated, although there are huge advancements in digitalisation and open data in Latin American metropolitan areas, there is still a lot to do to fill the gap regarding European or North American cities. This data availability and heterogeneity of information remains a non-negligible barrier for some cities in developing countries.

However, as mentioned before, this is a first attempt to integrate official data with citizen perception. In this sense, our proposal should be considered as exploratory and that a number of limits exist which certainly open up perspectives for future research.

- The data gathered from citizens is still not significant from a statistical point of view, so a more extensive data campaign should provide more significant feedback for public authorities.
- The questionnaire was distributed via Facebook, Twitter and WhatsApp, which on the one hand potentially enables access to a large number of citizens (young people), but on the other hand restricts the access to others (i.e. ageing citizens). Therefore, a dedicated application with more targeted functionalities and explanation could enhance citizen acceptability, and then increase participation.
- During the implementation of the survey, the citizens consulted suggested incorporating indicators on elderly and disabled people in the future.
- From a methodological point of view, metrics about citizen perception could be improved through focus groups, as suggested by Powell and Single (1996), and open interviews, as suggested by Babbie (2015). These processes are considered to validate the initial results about perceptions, but they take longer than surveys.

It should be noted that "Respect for individual and social rights" has not been considered in the Smart People dimension of a Smart City. From our point of view, this is an important point which should be addressed in further research projects, as issues including cybersecurity, surveillance and tracking systems are considered by several scholars as inherent to modern societies. However, there is still much to do in order to study to what extent people are aware about these issues and how they impact their everyday lives. It is clear

that this area is far from being solved even in the so-called “developed countries”. In the case of emerging countries, it has far from been a priority for most citizens.

The proposed case study of the city of Santiago also confirms the research of Marchetti et al. (2019), which argues that the particular context and idiosyncratic factors in Latin American countries implies adapted frameworks to assess the smartness of local cities. In that sense, the proposed methodology is a step forward as the authors claim the lack of empirical studies to enrich the body of knowledge in this area.

The alignment that the proposed methodology could have with the strategies and objectives of the city provides the possibility of application to other regions or particular districts, after making some adaptations. Furthermore, the results provided thanks to the generated Global Index give an insight into the weaknesses and strengths present in each district, providing the possibility of imitating the actions performed by districts with higher scores. The advantages of the application of the designed system lie chiefly in solving the problems mentioned above, where all the city’s flow of information from participating entities and citizens is unified under the emerging concept of Smart City, thereby satisfying the need for information for a correct municipal management. Also, the citizens become participants, or at least know about the problems related to their districts, which generates greater transparency levels (Grimaldi and Fernandez, 2017).

The implementation of the proposed methodology, where each stakeholder (citizens, districts, government, governmental entities and private agencies) is able to carry out the assigned task, is still pending. In practical terms, the implementation would be led by a governmental entity devoted full-time to the research, compilation, modification, and constant delivery of data and information to the different links that form part of a city. This would require constantly updating the data that keeps citizens informed on the condition of the city, and the districts on the result and evolution of its management. In essence, this is achieved by looking at the designed set of smartness metrics, where the strategies and objectives can be modified as needed. This transparency should drastically improve citizen satisfaction as it is one of the main issues usually reported by opinion polls (Paskaleva et al., 2015; Rodríguez Bolívar, 2018).

Regarding managerial implications, the general index approach helps practitioners and policymakers support urban strategy design a much more inclusive way by considering metropolitan heterogeneity, taking into account the poorer and richer districts of the city at the same time. Hollands (2008) reveals that the cities can be economically, socially or culturally polarised and we believe our study could help decrease these divides, especially for the poor and blue-collar workers, by providing a fine-grained analysis capable of supporting a district-based action plan. This more pragmatic approach allows for specific actions and roadmaps that identify and cover the most important aspects for citizens. Making decisions about urban investments that really matter will help politicians justify the efforts to become a smart city and make their actions much more audible and visible.

6. Conclusion

This paper proposes a methodology for assessing the smartness of cities in emerging countries, which is applied at a district level to take into account the city's heterogeneity. A DEA-based approach is applied integrate efficiency of resources for each district.

The aim of the proposed approach is to explore means to align local authorities' decisions with communities to effectively implement social innovations, so citizen engagement is just as critical. To achieve this, integrating citizen and community perception is vital for confirming and validating results from metrics and indicators issued by public sources, i.e. tackling quantitative and qualitative approaches of the same phenomenon.

Finally, as future research, the authors consider it necessary to incorporate new themes associated with the same six Smart dimensions into the proposed system. For example, indicators on the elderly and disabled adults, with both topics experienced daily by citizens, but without a specific solution. The idea also arises of adding a third axis to the citizen survey, covering the level of happiness, interaction between neighbourhood communities, citizen participation in the definition of the various

indicators, and weighting to Smart City dimensions to give some importance or prioritisation to the city's work.

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Appendix 1 Metrics for smartness and sources in the case of Santiago

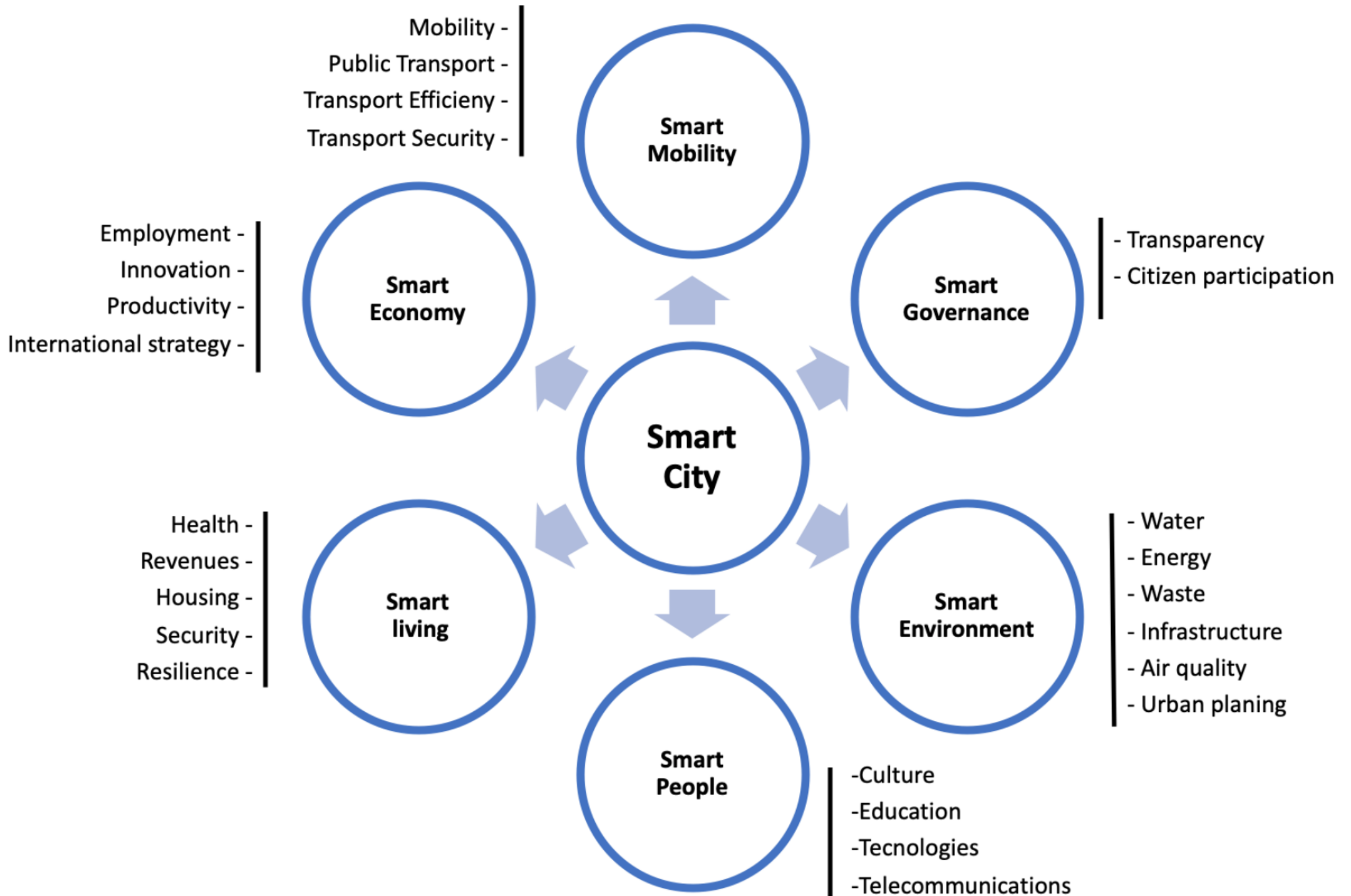
<i>Attributes</i>	<i>Indicators</i>	<i>References</i>
Smart Environment	Percentage of population with access to potable water supply services.	www.sinim.gov.cl
	Fine PM2.5 particulate matter concentration.	www.ine.cl
	PM10 particulate matter concentration.	www.ine.cl
	Total per capita electric power residential consumption (kWh).	www.sec.cl
	Number of buildings with LEED Silver certification per 100,000 people.	www.chilegbc.cl
	Green areas with maintenance per 100,000 people. (m ²)	www.sinim.gov.cl
	Percentage of the population potentially exposed to more than 65 dBA.	www.mma.gob.cl
	Collected solid residues per 100,000 people (Ton).	www.gobiernosantiago.cl
Smart Governance	Number of district employees per 100,000 people.	www.sinim.gov.cl
	Number of inhabitants per km ² .	www.sinim.gov.cl
	Percentage of women employed by districts.	www.sinim.gov.cl
	Own income as percentage of total income.	www.sinim.gov.cl
	Capital investment as percentage of total expenses.	www.sinim.gov.cl
Smart Living	Percentage of the population living in poverty.	www.sinim.gov.cl
	Number of fire stations per 100,000 people.	www.bomberos.cl
	Mortality rate of children younger than 1 year per 1,000 born alive.	www.sinim.gov.cl
	Number of public physicians per every 100,000 people.	www.sinim.gov.cl
	Per capita medical service and health expenses (M\$).	www.sinim.gov.cl
	Number of public nursing professionals per 100,000 people.	www.sinim.gov.cl
	Number of violent crimes per 100,000 people.	www.ine.cl
	Number of crimes against property per 100,000 people.	www.ine.cl
	Number of families living in camps.	www.techo.org
Smart Mobility	Number of personal automobiles per 100,000 people.	www.ine.cl
	Number of two-wheel motor vehicles per capita.	www.ine.cl
	Number of deaths in traffic accidents per 100,000 people.	www.mtt.gob.cl
	Number of electric power vehicle charging stations per 100,000 people.	www.enel.cl
	Number of metro stations per 100,000 people.	Maps.google.cl
	Total number of buses per 100,000 people.	www.ine.cl
Smart People	Percentage of the district budget allocated to culture.	www.sinim.gov.cl
	Expenses in recreation programmes per capita in pesos.	www.sinim.gov.cl
	Number of students per classroom teacher.	www.sinim.gov.cl

	Rate of premature school dropout.	www.sinim.gov.cl
	Expense in education per district student in thousands of pesos.	www.sinim.gov.cl
	Percentage of school age population in schools.	www.sinim.gov.cl
	Number of Internet connections per 100,000 people	www.subtel.gob.cl
Smart Economy	Number of dependent workers per 100,000 people.	www.sii.cl
	Number of R & D centres per 100,000 people.	www.sii.cl
	Number of active companies per 100,000 people.	www.sii.cl
	Number of small and medium-sized companies per 100,000 people.	Innovacion.cl
	Number of hotels and restaurants per 100,000 people.	www.sii.cl

Appendix 2. Survey on citizen perception of district performance

SURVEY ON DISTRICT PERFORMANCE	
Sex:	
Age:	
District of residence:	
Questions	
1.	In your district of residence, do you have many opportunities to get a job?
2.	In your district of residence, are innovative proposals performed to improve your neighbourhood and surroundings?
3.	In your district of residence, are there employment opportunities in companies?
4.	In your district of residence, are there many small and medium-sized companies?
5.	Is tourism promoted in your district of residence through the development of restaurant and accommodation services?
6.	In your district of residence, is there a continuous supply of potable water, without outages or interruptions?
7.	In your district of residence, is there usually a low level of car and bus traffic?
8.	In your district of residence, do fires occur infrequently?
9.	In your district of residence, does your neighbourhood have access to electricity supply?
10.	In your district of residence, are there buildings with sustainability seals?
11.	In your district of residence, are there enough green areas such as parks, groves and / or squares?
12.	Are you constantly noise-free in your district of residence?
13.	In your district of residence, is waste constantly collected?
14.	In your district of residence, does the number of community personnel respond to community needs?
15.	In your district of residence, are you and your neighbours not overcrowded?
16.	In your district of residence, are women included in public office?
17.	In your district of residence, are waste collection services, primary healthcare, education, etc. carried out correctly?
18.	In your district of residence, does the district constantly invest a significant part of its resources into infrastructure?
19.	In your district of residence, are there few people living on the streets?.
20.	In your district of residence, are firefighters effective in fire situations?
21.	In your district of residence, is emergency care timely for children under 1 year of age?
22.	In your district of residence, do you have good public healthcare?
23.	In their district of residence, do hospitals and public care centres provide quality medical services?
24.	In your district of residence, do the nursing staff respond to community needs?
25.	In your district of residence, are no assaults observed on a recurring basis?
26.	In your district of residence, is property crime rare?
27.	In your district of residence, are there few camps?

28. In your district of residence, do citizens use non-automobile means of transport to get to work?
29. In your district of residence, do citizens use motorcycles as a means of transport?
30. In your district of residence, are there few traffic accidents resulting in death?
31. In your district of residence, do your neighbours own electric vehicles?
32. In your district of residence, do you have easy access to a subway station?
33. In your district of residence, does the number of buses meet people's needs?
34. In your district of residence, are there regular cultural events financed with resources?
35. In your district of residence, are there public spaces for leisure and recreation?
36. In your district of residence, do educational establishments meet the demands of school-age people?
37. In your district of residence, do all your school-age neighbours regularly attend an educational establishment?
38. In your district of residence, do educational establishments have quality infrastructures?
39. In your district of residence, are there sports, cultural, or recreational programmes for children?
40. Does your home have Internet-enabled devices?



Step 1
Selection of city and municipalities indicators

- Literature review and relevant frameworks: n=369 indicators
- Elimination by redundancy; n= 257
- Technical selection assessment (Bonney & Armijo, 2005); n=105
- Second round of selection assessment; n=40

Step 2
Design of a benchmarking methodology for districts' technical efficiency

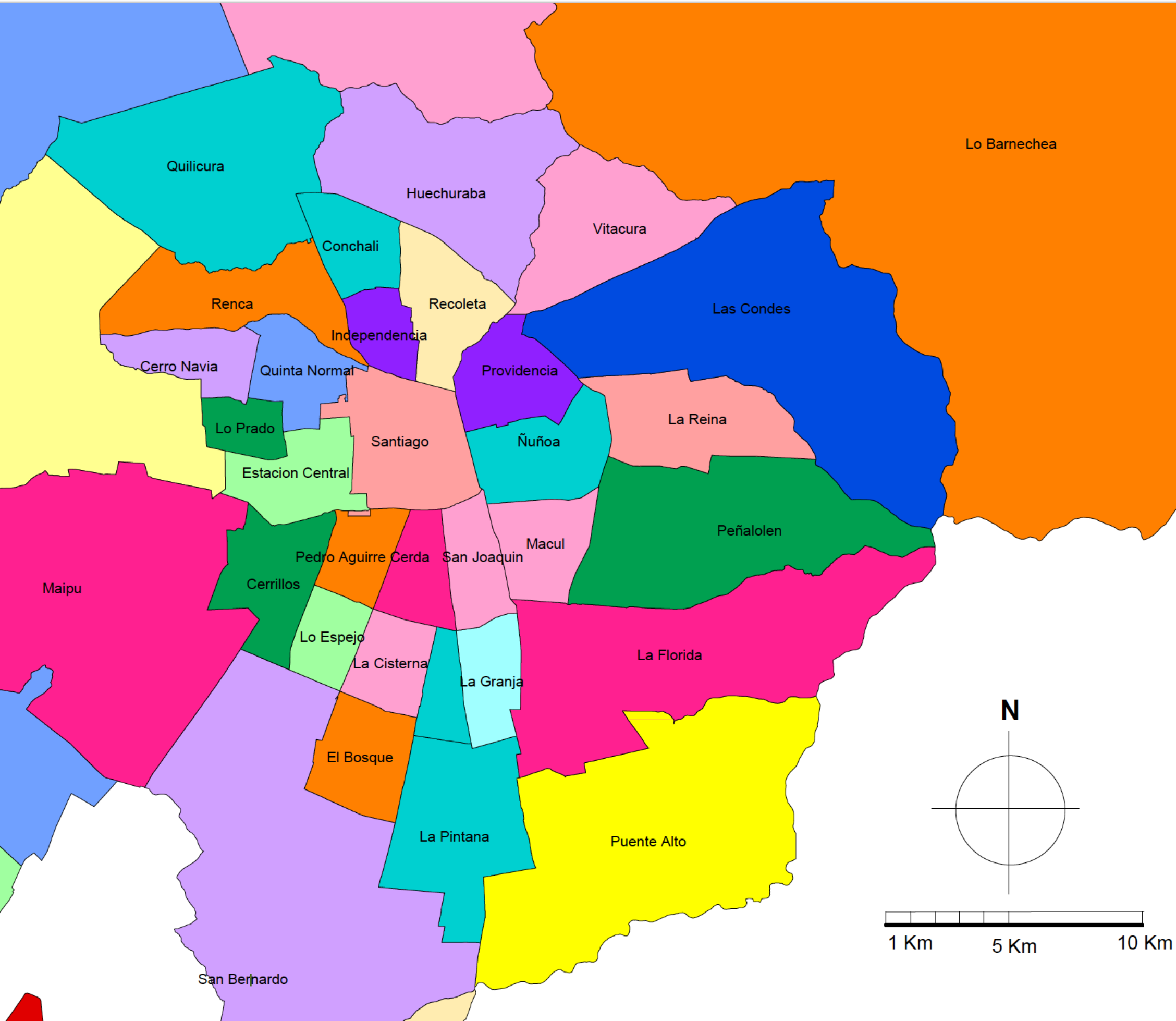
- DEA (Data Envelopment Analysis) to measure each district efficiency, regarding the set of selected indicators and dimensions.

Step 3
Citizen's perception survey

- Based on the set of selected indicators an on-line survey, a Likert-scale survey of the perception of satisfaction regarding each indicator is applied. This survey covering citizens of all the city districts

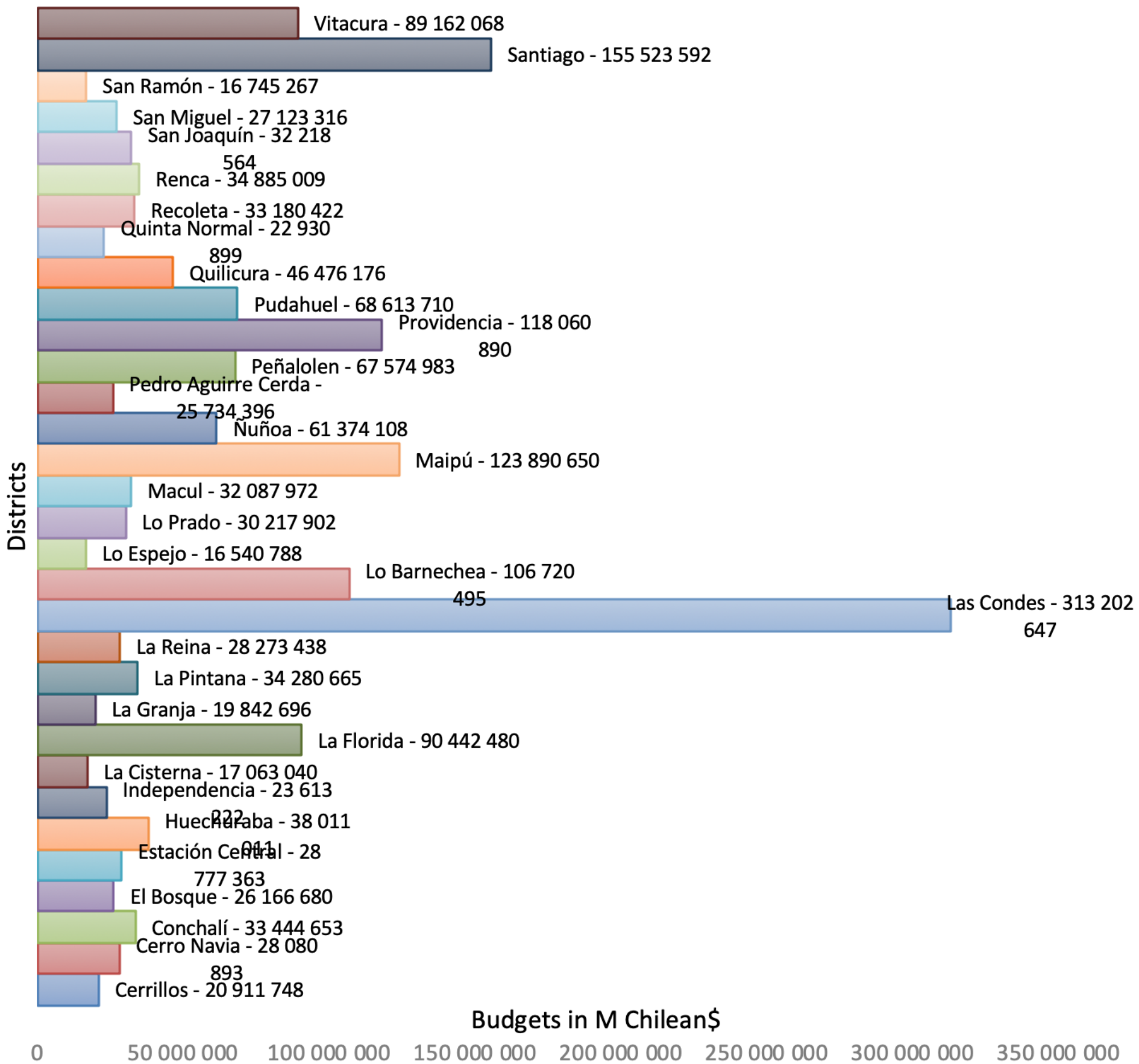
Step 4
Results analysis and discussion

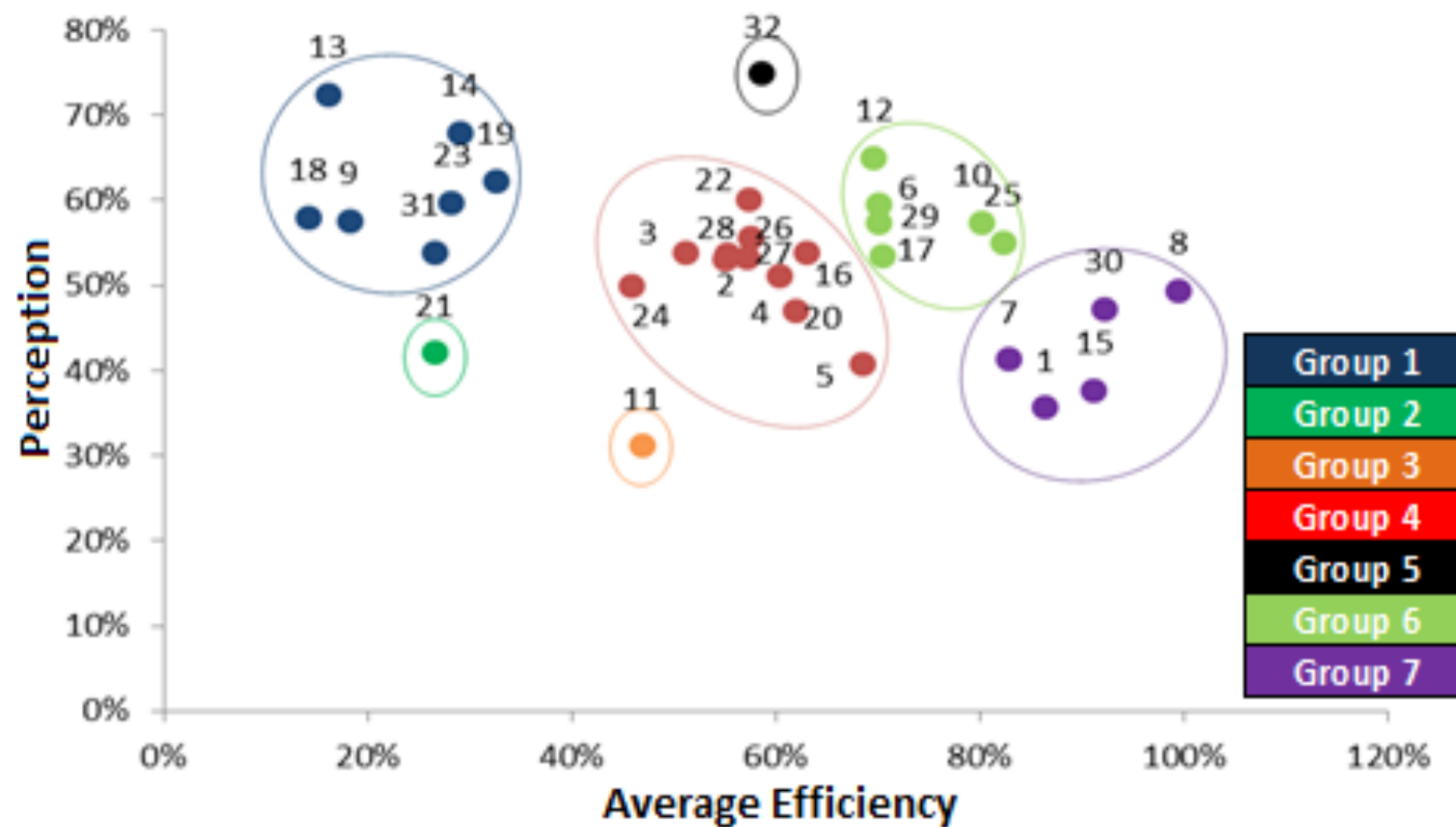
- Clustering analysis of the districts' efficiency vs. citizen perception.
- Analysis by districts smartness dimension



SANTIAGO DE CHILE

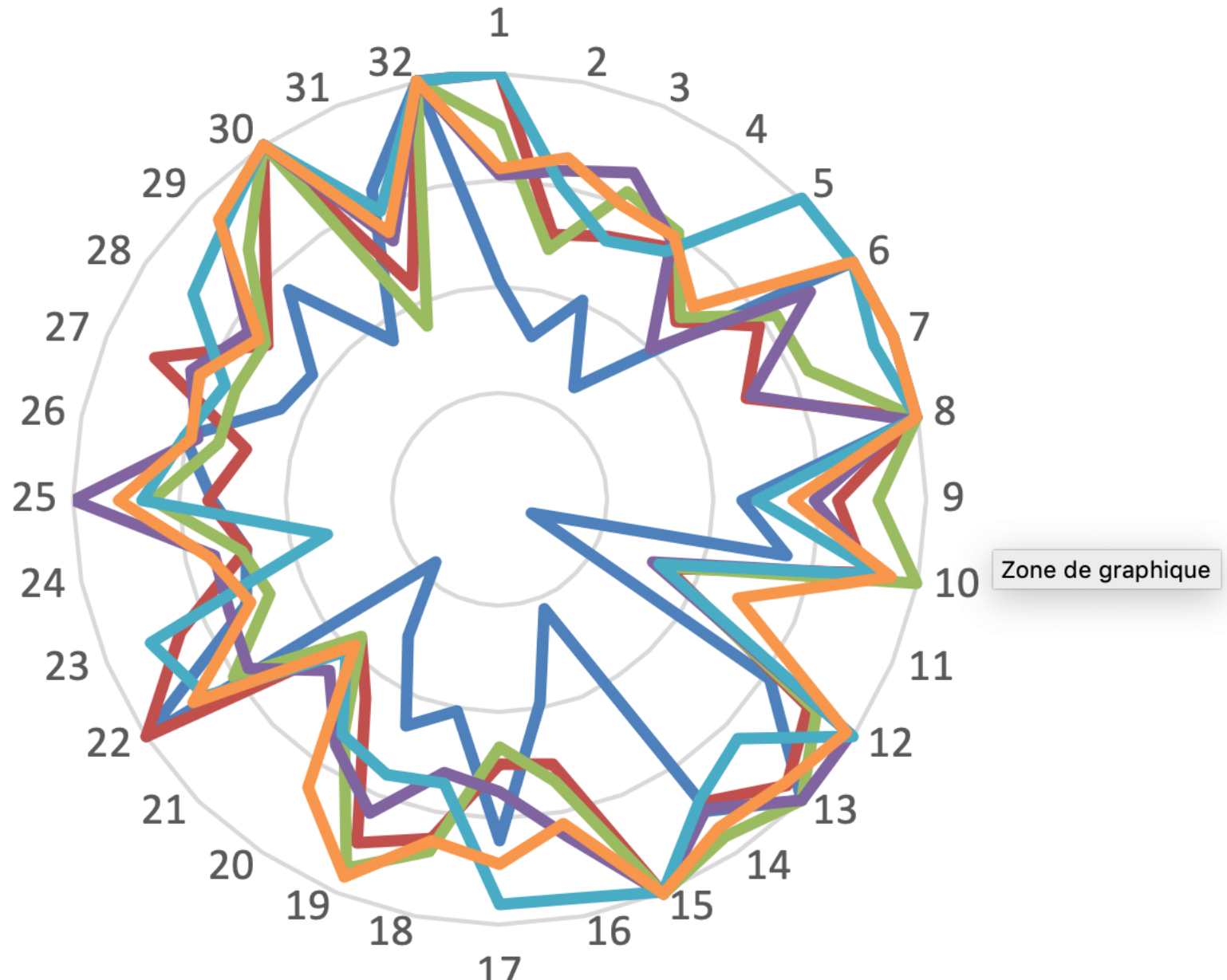






Ranking of district by dimension

Economy Environment Gobernance Living Mobility People



Zone de graphique

Table 1 Indicators selected for the proposed system.

<i>Traits</i>	<i>Themes</i>	<i>Indicators</i>
<i>Smart Environment</i>	<i>Water</i>	Percentage of population with access to potable water supply services.
	<i>Air quality</i>	Fine PM2.5 particulate matter concentration.
		PM10 particulate matter concentration.
	<i>Energy</i>	Total per capita electric power residential consumption (kWh).
	<i>Infrastructure</i>	Number of buildings with LEED Silver certification per 100,000 persons.
<i>Urban planning</i>	Green areas with maintenance per 100,000 persons. (m ²)	
<i>Smart Governance</i>	<i>Residues</i>	Percentage of the population potentially exposed to more than 65 dBA.
		Collected solid residues per 100,000 persons (Ton).
	<i>Citizen participation</i>	Number of municipal employees per 100,000 persons.
		Number of inhabitants per km ² .
	<i>Transparency</i>	Percentage of women employed by districts.
Own income as percentage of total income.		
<i>Income</i>	Capital investment as percentage of total expenses.	
<i>Response to emergencies</i>	Percentage of the population living in poverty.	
<i>Smart Living</i>	<i>Health</i>	Number of fire stations per 100,000 persons.
		Mortality rate of less than 1-year old children per 1,000 born alive.
		Number of public physicians per every 100,000 persons.
	<i>Safety</i>	Per capita medical service and health expenses (M\$).
		Number of public nursing professionals per 100,000 persons.
<i>Housing</i>	Number of violent crimes per 100,000 persons.	
<i>Smart Mobility</i>	<i>Mobility</i>	Number of prime against property per 100,000 persons.
		Number of families living in camps.
	<i>Transport safety</i>	Number of personal automobiles per 100,000 persons.
		Number of two-wheel motor vehicles <i>per cápita</i> .
	<i>Efficient transport</i>	Number of deaths in traffic accidents per 100,000 persons.
Number of electric power vehicle charging stations per 100,000 persons.		
<i>Public transport</i>	Number of metro stations per 100,000 persons.	
<i>Smart People</i>	<i>Culture</i>	Total number of buses per 100,000 persons.
		Percentage of the municipal budget meant for culture.
		Expenses in recreation programs per capita in pesos.
	<i>Education</i>	Number of students per classroom teacher.
		Rate of premature school dropout.
<i>Telecommunication and Technology</i>	Expense in education per municipal student in thousands of pesos.	
<i>Smart Economy</i>	<i>Employment</i>	Percentage of school age population in schools.
		Number of internet connections per 100,000 persons.
	<i>Innovation</i>	Number of dependent workers per 100,000 persons.
		Number of R & D centres per 100,000 persons.
	<i>Productivity</i>	Number of active companies per 100,000 persons.
<i>International projection</i>	Number of small and middle-size companies per 100,000 persons.	
		Number of hotels and restaurants per 100,000 persons.

Table 2 Standardization of indicators

Standardization	
Positive	$\frac{\textit{Particular data}}{\textit{Sum of the particular data}}$
Negative	$1 - \frac{\textit{Particular data}}{\textit{Sum of the particular data}}$

Table 3 General efficiency for each district of the city of Santiago

Districts	Efficiency	Districts	Efficiency
Cerrillos	100.0%	Recoleta	81.5%
Estación Central	100.0%	Quilicura	79.4%
Huechuraba	100.0%	San Joaquín	79.0%
Independencia	100.0%	Cerro Navia	74.3%
La Cisterna	100.0%	Pedro Aguirre Cerda	74.1%
La Granja	100.0%	El Bosque	71.7%
La Reina	100.0%	Lo Barnechea	67.1%
Lo Espejo	100.0%	Conchalí	64.7%
Lo Prado	100.0%	La Pintana	64.5%
Macul	100.0%	Santiago	58.9%
Providencia	100.0%	Ñuñoa	55.5%
Quinta Normal	100.0%	Pudahuel	47.5%
Renca	100.0%	Peñalolén	45.0%
San Ramón	100.0%	Las Condes	31.7%
Vitacura	100.0%	La Florida	29.2%
San Miguel	98.7%	Maipú	19.7%

Table 4 Technical efficiency for each district of the city of Santiago

Districts	Efficiency	Districts	Efficiency
Huechuraba	100.0%	Lo Espejo	40.0%
Independencia	100.0%	San Joaquín	39.8%
La Cisterna	100.0%	Renca	36.8%
Providencia	100.0%	La Granja	35.5%
Macul	84.3%	Pedro Aguirre Cerda	34.3%
San Miguel	76.1%	Conchalí	33.6%
Recoleta	74.2%	Lo Barnechea	28.9%
Quinta Normal	73.7%	El Bosque	28.2%
Vitacura	65.3%	La Pintana	25.1%
Cerrillos	61.0%	Lo Prado	24.9%
La Reina	59.8%	Las Condes	23.8%
Estación Central	58.3%	Cerro Navia	22.5%
Santiago	48.9%	Pudahuel	17.3%
Ñuñoa	46.9%	Peñalolén	13.8%
San Ramón	46.7%	La Florida	11.8%
Quilicura	40.9%	Maipú	7.5%

Table 5 Citizen's perception by districts.

Districts	Mean	Standard deviation
Cerrillos	2.405	1.128
Cerro Navia	3.093	0.915
Conchalí	3.137	0.795
El Bosque	3.010	0.856
Estación Central	2.561	1.152
Huechuraba	3.361	0.551
Independencia	2.624	0.734
La Cisterna	2.990	0.664
La Florida	3.297	1.094
La Granja	3.341	1.023
La Pintana	2.224	0.453
La Reina	3.634	0.572
Las Condes	3.976	0.768
Lo Barnechea	3.761	0.300
Lo Espejo	2.507	0.534
Lo Prado	3.117	0.786
Macul	3.143	0.810
Maipú	3.337	1.019
Ñuñoa	3.524	0.801
Pedro Aguirre Cerda	2.888	1.036
Peñalolén	2.698	1.093
Providencia	3.423	0.887
Pudahuel	3.332	0.861
Quilicura	2.927	0.656
Quinta Normal	3.151	0.739
Recoleta	3.098	0.704
Renca	3.180	0.693
San Joaquín	3.161	0.679
San Miguel	3.285	0.830
San Ramón	2.971	0.730
Santiago	3.122	0.932
Vitacura	4.015	0.451

Table 6 Global ranking of smart Districts

Districts	Results of DEA	Ranking
La Cisterna	100.00%	1
Vitacura	100.00%	1
La Reina	97.30%	3
Las Condes	96.90%	4
La Granja	96.40%	5
Quinta Normal	95.40%	6
San Ramón	93.90%	7
Huechuraba	92.60%	8
Lo Espejo	91.70%	9
Lo Barnechea	90.80%	10
San Miguel	90.70%	11
Macul	87.40%	12
Cerrillos	86.80%	13
Providencia	85.90%	14
Lo Prado	83.60%	15
Independencia	83.40%	16
Ñuñoa	83.30%	17
Renca	82.10%	18
Pudahuel	80.00%	19
Recoleta	79.80%	20
El Bosque	79.60%	21
San Joaquín	79.10%	22
Cerro Navia	78.50%	23
Maipú	77.60%	24
Conchalí	77.00%	25
La Florida	76.90%	26
Pedro Aguirre Cerda	76.90%	27
Estación Central	74.90%	28
Santiago	72.00%	29
Quilicura	70.40%	30
Peñalolén	56.20%	31
La Pintana	54.20%	32