RANKING OF CROATIAN CITIES ACCORDING TO HELLWIG'S INFORMATION CAPACITY METHOD IN THE SMART ECONOMY DIMENSION

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Abstract

The main objective of this research is to determine whether the size of the city by population is a prerequisite for better economic development and ranking of Croatian cities based on the weighted average z-score of smart economy indicators related to entrepreneurial potential, tourism, information comunication technology [ICT] and research and development [R&D] sector. The sample for this research consists of 127 Croatian cities and ten smart economy indicators. The Hellwig's information capacity method uses only statistically significant indicators, on the basis of which the weights are determined when creating the Smart Economy Indeks. The results of the analyses suggest that the number of positively ranked cities decreases as the city population size decreases: 100 % large cities are positively rated, 48 % medium cities and 6 % small cities.

Keywords: Smart Economy Index, Hellwig's information capacity method, ranking, Croatian cities

1. INTRODUCTION

The concept of the smart city is difficult to define clearly because of its complexity. Today, there is a broad consensus on the adoption of six dimensions of the smart city concept: economy, people, life, environment, governance, and mobility (Griffinger et al., 2007). Therefore, the challenge for city governments is to choose the optimal urban development strategy under the given economic, technological, and social conditions. In this paper, cities in the Republic of Croatia are ranked on the basis of only one smart dimension - the smart economy dimension - based on five statistically significant indicators. The theoretical-methodological understanding of the fundamentals of transformation processes in the smart economy aims to identify the prevailing processes and models in today's global economy and determine the most important indicators for each smart dimension. The review of smart and sustainable city models and indicators identified that appear in almost all models, regardless of their purpose and scale speaks to their importance and influence in representing the level of smartness and sustainability of cities in the smart economy dimension.

Based on the indicators of the observed models, a new ranking model of Croatian cities in the Smart Economy dimension was proposed, which includes indicators such as the share of ICT enterprises, the share of employees in the ICT sector, education and research, indicators from the field of tourism, the research, development and innovation component, the transport accessibility component as a prerequisite for the development of all segments of smart and sustainable cities, and the entrepreneurship component in the form of active business activities of enterprises and trades (Croatian Bureau of Statistics, 2021; Ministry of Finance, 2021; Institute of Public Finance, 2020), which are an integral part of the Smart Economy and are directly linked to a dynamic and growing economy.

Croatian cities are undergoing a certain transformation in terms of the smart economy, which is supported by the construction of roads, schools, sports halls and development agencies. The number of ICT enterprises is constantly increasing, startups are being created, innovation is on the rise, the European Union [EU] provides substantial funding for the development of smart and sustainable cities, and the availability and transparency of data on urban websites is at an enviable level (Ćukušić, Jadrić and Mijač, 2019).

After Croatia became the part of the EU in 2013, the economic development of cities was driven by an increase in exports as enterprises turned to the large international market, resulting in more employment, higher wages, higher private consumption, and an overall increase in economic development. In addition to the aforementioned benefits, Croatia also faces various problems, such as the migration of labor to highly developed countries, economic and demographic challenges, especially in medium-sized and small cities (National Development Strategy of the Republic of Croatia until 2030).

The previous ranking of Croatian cities in the scientific literature focused only on large cities or individual regions. For example, (Jurlina Alibegović,

Kordej-De Villa and Šagovac, 2018) ranked the 25 largest Croatian cities and county centers by Urban Development Index and the Apsolon Strategy (2020) ranked the 20 largest Croatian cities by the Digital Readiness Index. However, it is not clear whether the size of the city in terms of population is a prerequisite for better economic development and ranking of Croatian cities, because this reseasrch has been shown that small and medium-sized cities such as Poreč – Parenzo, Čakovec, Nova Gradiška, Crikvenica, Mali Lošinj, Vodice and others undertake numerous economic development activities. Therefore, this study fills this gap and ranks all Croatian cities based on a weighted average Z-score or Smart Economy Index.

The study was guided by the following research questions (RQ):

RQ1: Do large Croatian cities perform better according to the Smart Economy Index? RQ2: What is the relationship between city size relative to population and statistically significant indicators of the Smart Economy in Croatia?

A correlation analysis of the "information capacity" developed by Hellwig (1969) was conducted to determine the relationship between city size relative to population and ten indicators of the Smart Economy. Based on the value of correlation coefficients, only five indicators were selected and weighted so that the Smart Economy Index could be created by calculating the weighted sum for each city. In addition, a correlation was made between the size of the city measured by the number of inhabitants and the Smart Economy Index of each city.

The weighting of indicators in this method results from the value of the correlation coefficient. The weighting of all indicators is equal to the ratio between the value of the correlation coefficient and the absolute value of the sum of correlation coefficients for the observed indicators. After the correlation analysis, a ranking of Croatian cities was created based on the value of the Smart Economy Index.

2. LITERATURE REVIEW

A new turning point in the field of economy at the beginning of the 21st century is the emergence of the concept of smart economy, a concept based on the diffusion of new smart technologies, with the aim of effective management of economic, social and environmental processes, especially a synergistic effect of these elements on the economic development of smart and sustainable cities. The smart economy refers to the creation of innovation, entrepreneurship development, brands, productivity, labour market flexibility, and greater integration with national and international markets (Griffinger et al., 2007). The definition of smart economy as an essential component of smart and sustainable cities has been the subject of numerous scientific studies by many authors such as Bruneckiene (2014), Sinkiene, Grumadaite & Liugailaite-Radzvickiene (2014), Galperina, Girenko & Mazurenko (2016), Mazurenko (2014), Novotny, Kuchta & Kadlec (2014), etc. Based on the above studies, we can see that some authors consider the determinants of the smart economy from a global and local perspective, i.e. narrow and broad, and emphasise the role of technology in the sustainability of cities.

Bruneckiene (2014) and Novotny, Kuchta & Kadlec (2014) consider the determinants of the smart economy from local perspective and emphasise the role of technology in the sustainability of cities.

In a broader context, Galperina et al. (2016) consider that the development of the smart economy is influenced by the emergence of Industry 4.0, the expansion of technologies and their penetration into the economic system, the continuous growth of quality of life, environmental quality, and the development of innovative networks.

Authors Kalenyuk and Tsymbal (2021) define the smart economy in a narrow sense as a system of economic relations and connections in a given place, based on technologies developed according to the principles of sustainability and social responsibility, creating safe living conditions for citizens. More broadly, they enumerate key processes for the emergence of a smart economy, specifically intellectualization, digitization, greening, socialisation, institutionalisation, and urbanisation, with the state and other institutions actively involved in regulating research and development, innovation, and entrepreneurship. Authors such as Vinod Kumar and Dahiya (2017) and Manville et al. (2014) point to innovations in creating and implementing the concept of the smart economy through the sharing economy, and Paliaga & Oliva (2018) to better vertical communication with state institutions.

Vinod Kumar & Dahiya (2017) see the smart city as a place that offers a variety of economic opportunities to its citizens because it values creativity and welcomes new ideas, supports and promotes the sharing economy, and focuses on balanced and sustainable economic development. Moreover, the smart economy implies local and global connectivity with physical and virtual flows of goods, services, and knowledge (Manville et al., 2014).

Paliaga & Oliva (2018) believe that smart solutions are key to overcoming administrative barriers as the main obstacle to development and attracting investment, i.e., they are required for interaction between citizens, business, and city government. Only such two-way communication will lead to more successful solutions and the actual application of the concept of smart economy.

Indrawati, Azkalhaq, and Amani (2018) emphasise that the smart economy refers to an open, transparent, and diverse economy that adds value to smart cities. The smart economy fosters a business environment that supports and encourages innovation, regardless of the outcome. It also provides a stable labour market with resources and the ability to adapt and change as needed to ensure the success and economic development of the city and the livelihood of its citizens.

3. OVERVIEW OF MODELS AND INDICATORS FOR RANKING CROATIAN CITIES

In the phase of selecting appropriate indicators for the empirical study, the approach taken was to examine the model, the structure of the indicators, the basic purpose of the model, and the scope of application in order to select individual

indicators in the Smart Economy dimension, and finally to create a ranking of Croatian cities based on the selected indicators.

Annex 1 provides a chronological overview of different models and shows the Smart Economy indicators, authors and main purpose of each model.

Babić (2021b) states that the review of models to measure the achievements of smart cities has a variety of applications, but also different purposes depending on the group of cities observed, such as maturity models, technological readiness and functionality also numerous scientific and practical studies Griffinger et al., 2007; Lombardi, Giordano, Farouh, and Yousef, 2012; Cohen, 2016; Bosch et al., 2016) and different organizations International Telecommunication Unit [ITU], United For Smart Sustainable Cities [U4SSC], World Council City Data [WCCD], International Standardization Organization [ISO] and others coompanies Cisco, Microsoft, Ericsson, IBM, Siemens, Oracle, etc.

The frequency with which certain indicators in the smart economy dimension appear in almost all the models mentioned above speaks to the importance of these indicators and their influence on the representation of the level of smartness and sustainability in the smart economy dimension. For example, the ESCR model was developed only for medium-sized European cities, the U4SSC model adjusted the number of dimensions and specific demand, and the City Keys model used a set of structured data as indicators to monitor the evolution of large cities over time. The ITU focused its indicators on the technical component of a city, i.e., the impact of ICT technologies on all dimensions of highly developed cities.

Most models are described by indicators such as the number of enterprises, the number of ICT enterprises and employees in the ICT sector, education, research and development, indicators for tax revenues, unemployment rate, Gross domestic product [GDP], number of patents and others (see Annex 2).

In this paper, indicators based on the standards ISO 37120 (ISO, 2018) and ISO 37122 (ISO, 2019) were used in comparison with other models mentioned. The selection of these indicators enabled the creation of models for the assessment of Croatian cities, creating a new framework for the comparison of cities based on available indicators for all cities in Croatia.

These indicators are a starting point for the development of smart city strategies in Croatia (Dubrovnik, Rijeka, Kastav, Jastrebarsko Sveta Nedelja and others), but also in the world. The ISO 31720 standard also provides a comprehensive methodology for evaluating cities of any size in terms of their economic, environmental and social impacts compared to other cities. All cities that have been successfully certified according to ISO 37120 are part of the global WCCD network, including the Croatian cities of Koprivnica and Zagreb (WCCD, 2022).

The indicators of the ISO standards were previously used as a starting point for the urban intelligence assessment of the three cities Carugate, Melzo and Pioltello. The proposed methodology was extended and applied to 50 small and medium-sized cities in Lombardy (Dall'O, Bruni, Panza, Sarto & Kayathian, 2017).

Santana, Nunes, Pacos & Santos (2019) consider that the ISO 37120 standard has become an international reference point for smart cities. The same authors used ISO 37122 indicators to develop a new model for assessing the smartness and sustainability of cities in Brazil.

Raspotnik, Grønning & Herrmann (2020) used ISO 37120 indicators to test smartness in the Arctic cities of Anchorage (Alaska), Bodø (Norway) and Oulu (Finland). The goal was to identify areas of success and shortcomings in each city studied.

4. OVERVIEW OF RANKINGS IN CROATIAN CITIES

As for Croatia, recent rankings of Croatian cities in the academic literature have focused only on large cities or individual regions for lack of the necessary indicators. The annual ranking of the 20 largest Croatian cities is based on the Digital Readiness Index, a complex index composed of five individual indices - availability and quality of e-services, service information and unified payment systems, availability of city data, citizen participation in decision-making processes, communication channels between city administration and citizens (Apsolon Strategy, 2020). Paliaga and Olival (2018) conducted a study on trends in the introduction of the concept of smart cities in seven cities in Istria. Jurlina Alibegović et al., 2018) made a ranking of the 25 largest Croatian cities and county towns based on the European Smart City Ranking [ESCR].

This research (Jurlina Alibegović et al., 2018) provided us with a starting point and a solid basis for extending the research to other Croatian cities, as more than 50% of Croatian cities are small cities with up to 10,000 inhabitants, and it has been shown that small Croatian cities take numerous initiatives and implement concrete activities to achieve economic development. In this research, in dimension of smart economy apart from large Croatian cities (Pula, Zadar Rijeka, Velika Gorica, Split, Varaždin, Kaštela, Karlovac, Dubrovnik, Slavonski Brod, Samobor) highly positioned and smaller Croatian towns (Koprivnica, Gospić, Pazin) that represent county centers.

5. METHODOLOGY

Data collection at the national level was challenging, as Croatia still does not have high-quality open databases. Despite these difficulties, most data were collected for the development of the indicators. A detailed description of the indicators for 127 Croatian cities (with the exception of Zagreb[1] can be found in Annex 2, with the note that all data for the creation of the indicators are from 2019

[1] The City of Zagreb as the capital of the Republic of Croatia is excluded from the analysis because in addition to the status of the city, it also has the status of a county and the values of Zagreb indicators are incomparable with those of other cities (Official Gazette (2020). Law on Local and Regional Self-Government consolidated text of the law).

and 2020. These indicators are the number of overnight stays (Croatian Bureau of Statistics, 2021), allocations for research and development (Ministry of Finance, 2021). An official request to the Institute of Public Finance (2020) collected data on tax revenues and direct debt per capita of each city, an official request to the Croatian Bureau of Statistics (2021) collected data on indicators such as the number of enterprises, the number of trades, number of ICT enterprises, number of employees in the ICT sector, number of employees in education and research and development, while the road distance to the nearest airport was measured by the authors using Google Maps.

Prior to the correlation analysis, referred to as "information capacity," (Hellwig, 1969) all indicator values are standardized using the z-transformation method, which determines the universal unit of measurement and the relative position of the value in the overall distribution in relation to the average value, and accordingly, all indices are expressed as positive and negative values according to the formula:

$$z = \frac{x - \mu}{\sigma}$$

6. RESULTS AND OUTCOMES

In the next step, the structure and relationship of the indicator city size based on the number of inhabitants and to ten indicators of the smart economy are studied by means of a correlation analysis calculated with the program Statistica.

In addition to studying the relationship between the above indicators, correlation analysis is also used to assign weights in the ranking process (Booysen, 2002; Organization for Economic Co-operation and Development [OECD], European Union [EU] & Joint Research Center [JRC], 2008; Greco , Ishizaka, Tasiou & Torrisi, 2019). This method uses correlation coefficients to determine the weights of the indicators. This ensures that the indicators with the highest correlation (Table 1) receive the highest weights, i.e., that the weights of the indicators are proportional to the sum of the absolute values of the correlation coefficients from the correlation matrix (Hellwig, 1969; Ray, 2008). This is an objective weighting method that is widely used in scientific research. The main advantage of this method is that subjective judgments are avoided by assigning objective weights (Ray 2008). The basic requirement for the inclusion of an indicator in the weighting procedure is that it must be statistically significant in relation to the assumed significance level of 0.05 (Barańska, 2019; Freudenberg 2003; OECD 2008), i.e. McGranahan, Richard-Proust, Sovani & Subramanian (1970) believe that indicators that are not significant should be excluded from the model. Therefore, the model of this research is based on 5 indicators that are marked as statistically significant in Table 1.

Table 1

Correlation analysis of cities population in 2019 with the ten indicators of smart economy

Correlations (Spreadsheet1) Marked correlations are significant at p < ,05000 N=127 (Casewise deletion of missing data)	
Variable	**Population estimate in 2019.**
Number of tourist nights	0,28
Share of tax revenues	0,11
Direct debt per inhabitant	0,02
Road connection with the nearest airport	-0,31
Number of enterprises	0,96
Number of trades	0,94
Share of ICT employees	0,01
Share of ICT enterprises	0,40
Share of employees in education and I&R	-0,12
Share of budget expenditures for research and development	0,07

Source: authors

According to Ray (2008), there are two ways to determine weight using correlation analysis. The first is based on a simple correlation matrix, where indicator weights are proportional to the sum of the absolute values of each row or column. In another method, known as "information capacity" (Hellwig 1969; Ray 1989), an identifiable variable in the data set is first selected to represent the endogenous criterion. Then, the correlation of each indicator with this distinguishing variable is calculated, as is the case in this study.

The calculated correlations are used as the basis for further calculation of the weighted sums of the z-values. The values are calculated as follows:

$w_i = \frac{|k_i|}{\sum_{j=1}^{5}|k_j|}$, for i = 1, 2,…, 5, where $\sum_{i=1}^{5} w_i = 1$ to obtain weighted sum as a final product.

Then each indicator is multiplied by the weight obtained and we get the weighted sum for each city $y_j = \sum_{i=1}^{5} w_i z_{ij}$ for j=1,…, 127. The result obtained represents the Smart Economy Index for each city and forms the basis for the ranking.

Then, each indicator is multiplied by the obtained weight and we obtain a weighted sum for each city for j=1,..., 127. The obtained result represents the Smart Economy Index for each city and is the basis for ranking.

From the performed correlation analysis, there is a positive correlation between the size of the city, measured by the number of inhabitants and five indicators of the smart economy which were marked as significant and reached the highest correlation for the number of enterprises (0.96) and the number of trades

(0.94). A significant but weaker correlation was found for the share of ICT enterprises (0.40), the city's road connection with the nearest airport (-0.31), and the number of overnight stays by tourists (0.28).

The remaining five indicators from Table 1 were excluded from the correlation analysis and ranking because there is a weak connection and they are not statistically significant in relation to the endogenous variable.

Ray (1989) constructed a Sustainable Development Index (SDI) for 40 countries based on a correlation analysis with 13 indicators of urbanization and industrialization, health status, nutrition, education, and social communication. High intercorrelation coefficients of the variables led to weighting by the correlation analysis method.

Indicator weighting naturally leads to the last step in the formation of a composite index using the aggregation method. All the standardized values of the indicators were multiplied by the weights that resulted from the correlation analysis and were aggregated into an index with positive and negative values. A detailed overview of the z-values of the five smart economy indicators and the values of the Smart Economy Index can be found in Appendix 1.

In order to facilitate the interpretation of the research results, the cities are divided into two classes as positively and negatively ranked cities and into three different sets of cities when it comes to the size of the cities according to the number of inhabitants (more than 35,000, from 10,000 to 35,000 and less than 10,000), such as is shown in Chart 1, while Table 2 contains a list of cities in each of the mentioned groups according to city size.

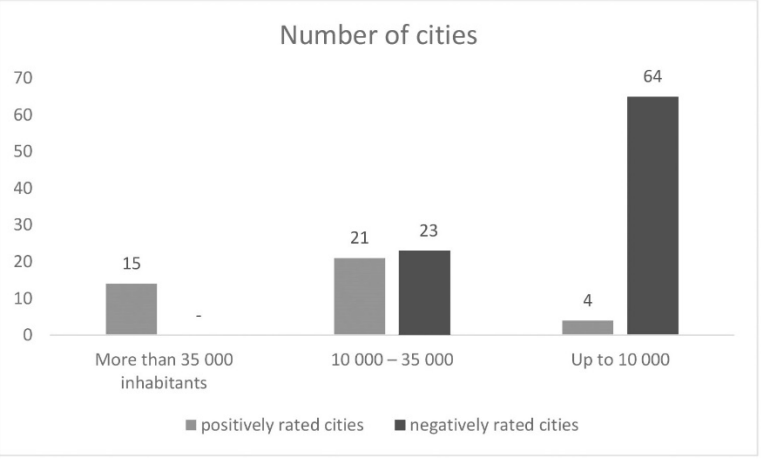

Chart 1 Datasets by city numbers and positively and negatively rated cities

Source: Authors

Table 2

Datasets by city numbers and positively and negatively rated cities

Population	positively rated cities		negatively rated cities	
More than 35 000 inhabitants	15	Split, Rijeka, Osijek, Zadar, Pula - Pola, Dubrovnik, Varaždin, Šibenik, Velika Gorica, Samobor, Slavonski Brod, Karlovac, Bjelovar, Sisak, Kaštela	0	
10 000 – 35 000	21	Rovinj - Rovigno, Sinj, Vukovar, Đakovo, Omiš, Makarska, Solin, Križevci, Trogir, Čakovec, Novi Marof, Duga Resa, Metković, Zaprešić, Umag - Umago, Dugo Selo, Vinkovci, Valpovo, Slatina	23	Krapina, Križevci, Našice, Omiš, Ogulin, Daruvar, Metković, Jastrebarsko, Kastav, Gospić, Slatina, Novska, Trogir, Popovača, Ivanić-Grad, Duga Resa, Petrinja, Dugo Selo, Ivanec, Sveti Ivan Zelina, Sinj, Knin, Valpovo, Novi Marof, Vrbovec
Up to 10 000	4	Mali Lošinj, Ludbreg, Donji Miholjac, Vodice	64	Lipik, Rab, Krk, Pakrac, Korčula, Pazin, Beli Manastir, Garešnica, Lepoglava, Novalja, Đurđevac, Zabok, Ploče, Hvar, Mursko Središće, Čazma, Vrlika, Senj, Novigrad - Cittanova, Pleternica, Oroslavje, Belišće, Buje - Buie, Buzet, Orahovica, Prelog, Varaždinske Toplice, Pregrada, Imotski, Vis, Biograd na Moru, Pag, Hrvatska Kostajnica, Klanjec, Županja, Drniš, Komiža, Opuzen, Donja Stubica, Cres, Kutjevo, Novi Vinodolski, Ozalj, Vrbovsko, Otočac, Zlatar, Čabar, Trilj, Slunj, Skradin, Grubišno Polje, Kraljevica, Supetar, Delnice, Stari Grad, Benkovac, Nin, Ilok, Vodnjan - Dignano, Vrgorac, Glina, Bakar, Obrovac, Otok
TOTAL CITIES	**40**		**87**	

Source: authors

In the first set of cities with more than 35,000 inhabitants, all cities were positively evaluated, which confirms the hypothesis that there is a significant correlation between the size of the city according to the number of inhabitants and the five indicators of the smart economy. This data set includes seven coastal cities and eight cities on the continent, and all of them have high values for all indicators compared to other Croatian cities.

It is important to note that coastal cities have an advantage when it comes to the number of overnight stays by tourists. Tourism is the most important economic activity in Croatia and it ensures higher productivity mainly in coastal cities (Dubrovnik, Split, Pula). On the other hand, continental cities have an average of 59,540 overnight stays, while cities in the Adriatic counties have an average of 819,738 overnight stays.

Continental cities (Varaždin, Osijek, Slavonski Brod) lead the way when it comes to the ICT sector, i.e. the number of ICT enterprises. The ICT sector is recognized as a key driver of digital transformation and the achievement of three dimensions of sustainable development - economic development, ecological balance and social inclusion, but also for promoting innovation in society. The export of ICT activities has grown exponentially in the last few years, and the workforce employed in the ICT sector is one of the main drivers of economic development, increasing labor productivity and increasing international competitiveness through innovative ICT development.

It is important to note that in Republic of Croatia, as in most other countries, in the period from 2007 to 2016, there was a successive growth of this sector (Babić, 2021a). The key challenge for current and future sustainable urban development in the Republic of Croatia is to design an approach to economic, social and environmental challenges, whereby individual benefits will be common drivers. City authorities in Republic of Croatia must shape the future of cities by integrating strategic investments and harmonizing existing capacities with opportunities and needs that are constantly changing. It is a demanding task, but the significant increase in the number of available funds from European funds after Croatia's entry into EU provides a new opportunity to apply the theory of integrated urban development in practice. Despite short-term improvements after joining the European Union in the form of increased growth rates, reduction of the unemployment rate and public debt, more concrete measures and policies are needed in the form of greater trust in public institutions, employment opportunities and higher wages achieve long-term growth, prosperity and quality of life for citizens in such cities (Government of the Republic of Croatia, 2021).

The group of cities with 10,000 to 35,000 inhabitants consists of 44 cities, 21 cities with a positive index and 23 cities with a negative index. This group includes medium-sized Croatian cities located near large Croatian cities, and they achieved their development thanks to agglomeration, better transport connections and the availability of adequate labor force, which is an important prerequisite for development. In these cities, it is necessary to carry out activities that encourage entrepreneurship by establishing legal entities, which can be achieved in several ways: organizing practical education and better information about entrepreneurship, ensuring better financing conditions, renting city business premises under special conditions, various consultations, professional administrative assistance and others (Government of the Republic of Croatia, 2021).

There are 68 cities in the group of cities with up to 10,000 inhabitants, and only 4 cities have a positive index, while 64 cities have a negative index. We have already stated that coastal cities are focused on tourism, while continental cities have turned to traditional production, i.e. sustainable and ecological production with preservation of natural resources and added value to products and services. The economic development of the Republic of Croatia is based on exports, primarily tourism, with a share of 70%, and the export of other activities related to transport, construction, the ICT sector, financial services is growing, so it is

necessary to implement strategies and activities that favor exports. growth more decisively, and will ultimately affect the achievement of higher productivity and the development of smart and sustainable cities (National Development Strategy of the Republic of Croatia until 2030). As for the development of medium-sized, and especially small, cities, the situation is very worrisome because they face uneven distribution of cities, uneven economic development, depopulation, lack of financial resources, lack of educated workforce and concentration of power in the metropolis (Perišić, 2013).

Having an insight into the values of the indicators in this set of cities, positively rated cities have slightly higher tax revenues that are the result of increased entrepreneurial activity, i.e. the number of enterprises and trades, while negatively rated cities face problems such as insufficient financial and human resources, traffic and telecommunications infrastructure, attracting investments, population structure, but also the lack of cooperation with local self-governments (Svirčić Gotovac, 2016).

In all cities with a negative index, the number of enterprises and trades is very small, the share of ICT enterprises is low, transport connections are weak and the number of overnight stays by tourists is low.

Ćorić & Šimić (2020) believe that after the Covid-19 pandemic, Republic of Croatia will experience a deep recession and be on the verge of another economic disaster, similar to the global and financial crisis that engulfed the world in 2007-2008, if it fails to find an adequate response and avoid its disastrous consequences effects on the domestic economy.

A polycentric and balanced approach with the establishment of an even system of central settlements is needed for the development of medium and small towns. In addition, some counties do not have cities that strongly gravitate to the surrounding settlements, and county centers have different influence and economic and social significance (Klarić, Kranjčević, Kušen & Lukić, 2014).

7. CONCLUSIONS AND IMPLICATIONS

The main objective of this research is to choose the appropriate methodology, model and data for ranking all Croatian cities by the smart economy dimension, to determine whether the size of the city by the number of inhabitants is a prerequisite for better economic development in the smart economy dimension, and to propose a ranking model of Croatian cities based on the Smart Economy Index. According to the study, all large Croatian cities with more than 35,000 inhabitants, 21 out of 44 medium-sized cities between 10,000 and 35,000 inhabitants and four of 68 small cities up to 10,000 inhabitants recorded growth.

It is necessary to carry out significantly more activities in all indicators and achieve higher values of the indicators in order to position the city on the scale as well as possible. In addition, large cities have the potential for even greater and

more balanced growth according to plans and strategies that usually lack the financial and human resources to implement. For small and medium sized cities, there are a number of strategies, policies, and plans aimed at finding ways to maintain the vitality of life in small and mid-sized cities and their surrounding areas.

Given the current status and timing of this study, i.e., using data from 2019 and 2020, the plan is to conduct a similar study in 2023 using the same indicators to compare and assess the progress of each city.

The main scientific contribution of this study is the first comprehensive analysis that includes all Croatian cities, as well as the methodological guidelines for conducting such a study.

In addition, the study also provides a practical contribution, it is possible to propose measures to local decision makers to promote the smart economy, increase entrepreneurial activities, self-employment and new enterprises in cities, develop digital skills and even more investments in the ICT sector.

This papaer has the added potential to serve as a basis for new similar studies, such as analysing existing models with new indicators, new dimensions, new regional units (municipalities), or other appropriate methods to determine the maturity and functionality of smart and sustainable cities.

The limitations of the study are that certain data that should have been included in this study were not available for all cities (number of patents, number of start-up enterprises, unemployment rate, etc.). In addition, for future research on this topic, it would be useful to compare the analysis and results obtained with different methods as Principal Components Analyses [PCA], Cluster analyses, Data Envelopment Analyses [DEA] to determine if there is a significant change in the ranking position or if the current stability of the ranking is maintained.

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APPENDIX

Annex 1 Detail of model, authors and indicators of Smart econmoy dimension

Models/authors/year	Description	Indicators for smart economy
The European Smart Cities Ranking [ESCR] Giffinger, R., Fertner, C., Kramar, X.X., Milanović, N., Meijers, E. (2007)	This model was developed for Central European cities. For the first time, this model defined the dimensions and indicators for 70 medium-sized cities according to the number of inhabitants.	The ratio of the number of employed to the number of unemployed persons in the city Share of R&D and patents in the total value of assets of all enterprises in the city Patents Share of employees in knowledge-intensive industries (ICT, R&D) Number of registered patents in the city Share of self-employed in the total number of employees in the city Share of start-ups in the total number of enterprises in the city. Share of plant and equipment of all enterprises in the city Share of unemployed persons in the city in the total population Number of recognized international trademarks of enterprises in the city 9The ratio of value added and the number of employees in all enterprises based in the city Share of part-time employees in the total number of employees in all enterprises in the city The number of enterprises in the city is listed on the national stock market Share of export revenues in the total revenues of all enterprises in the city Ratio of revenues of enterprises with a share of foreign capital greater than 49% and the total revenues of all enterprises based in the city Value of foreign direct investment (enterprises)
Triple Helix Approach [THA] Lombardi, P., Giordano, S., Farouh, H., Yousef, W. (2012)	To explore the concept of a smart city, this authors proposed the with a focus on producing university and government knowledge and producing innovations patented by industry and universities as an index of intellectual capital.	Research and development expenditure Education expenditure Percentage of residents working in the education and research sector City government debt per capita Unemployment rate GDP per capita Average one-time annual household income Energy intensity in the economy (gross energy consumption / GDP) Percentage of projects funded by civil society
The Smart City Index Master Indicators [SCIMI] Cohen, B. (2014)	This model presents an initiative of the Smart Cities Council to enable the ranking of cities in terms of living conditions, feasibility and sustainability indicators.	Number of new opportunities (startup / year) % Of GDP invested in research and development in the private sector % of full-time persons Innovation Index Gross regional product per capita (in USD $, in EU €) % GRP based on technology exports Number of international congresses and fairs
ITU - ITU -T Y.4901 / L.1601 International Telecommunication Unit [ITU] (2016)	This authors identified Key Performance Indicators (KPIs) to establish criteria for assessing the contribution of ICT to the creation of smarter and more sustainable cities, and to provide cities with the means for self-assessment.	Percentage of GDP for ICT, research and development Share of employees in the ICT sector among the employees of each city The share of R&D and ICT enterprises among all enterprises in the city Investing in information systems, smart solutions, platforms, IoT Number of e-commerce transactions via electronic and mobile payment Share of enterprises providing e-commerce, e-learning, e-entertainment, cloud, etc. services. The share of enterprises that offer software solutions in the cloud, and serve the public, enterprises, government and other organizations

CITY KEYS Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.M., Airaksinen, M. & Huovila, A. (2017)	This indicators are aimed at monitoring the development of the city towards an even smarter city. The time component - "development over the years" - is an important feature.	Increased use of local labor Creating local jobs Encouraging an innovative environment New start ups Involvement of extraordinary experts Energy costs Housing costs Certified enterprises involved in the project (ISO 14001) Green public procurement Cost-effectiveness of CO2 reduction Financial benefit to the end user Net present value (NPV) Quality of open data Improved interoperability Reduced travel time
United for Smart Sustainable Cities [U4SSC] (2017)	This is a publication that provides cities with a methodology for collecting KPIs for Smart Sustainable Cities (SSC).	Research and development expenditure Patents Small and medium enterprises Unemployment rate Employment in the tourism industry Employment in the ICT industry Youth unemployment rate
International Standardization Unit [ISO] 37120 - Sustainable cities and communities - indicators for city services and quality of life (2018)	The World Council on City Data (WCCD) enabled the certification of smart cities based on the guidelines and methodology of the ISO 37120 and ISO 37122 standard for smart and sustainable cities (WCCD, 2022).	Unemployment rate in the city Number of enterprises per 100,000 inhabitants Number of new patents per 100,000 inhabitants per year Youth unemployment rate
International Standardization Unit (ISO) 37122 - Sustainable cities and communities (I2019)		Annual number of new start-ups per 100,000 inhabitants Percentage of labor force employed in the sector (ICT) Percentage of labor force employed in the sectors of Education, R&D Debt service ratio (debt service as% of city revenue) Annual number of overnight stays per 100,000 inhabitants Commercial air connectivity Revenues from own source as a percentage of total revenues Estimated value of commercial and industrial real estate as a percentage of the total estimated value of all real estate Percentage of full-time persons Economic profile indicators Capital expenditure as a percentage of total expenditures Tax collected in% of calculated tax

Source: authors

Annex 2. Detailed description of 10 indicators included in the model

SMART ECONOMY				
	Indicators	**Unit of measurement**	**Year**	**Source**
1.1.	Number of tourist nights	The indicator is expressed as the exact number of overnight stays.	2019	Croatian Bureau Of Statistics CBS https: //www.dzs hr / Hrv / publication / FirstRelease / results asp? pString = Cities % 20u% 20stat & pSearchString =% Cities % 20u% 20stat%
1.2.	Share of Tax Revenues / Total Revenues	The indicator is expressed as the ratio of revenues collected from taxes and total revenues of an individual city.	2019	Ministry of finance - https://mfin.gov.hr/istaknute-teme/lokalna-samouprava/financijski-izvjestaji-jlp-rs/pr-ras-i-ras-funkc-za-razdoblje-2014-2019/3107
1.3.	Direct debt per capita	The indicator is expressed as the ratio of direct debt per capita.	2019	INSTITUTE OF PUBLIC FINANCE (official inquiry)
1.4.	Road connection to the nearest airport	The indicator is expressed by the number of kilometres of each city to the nearest airport..	2020	Google Maps
1.5.	Number of **enterprises**	The indicator is expressed as the exact number of active **enterprises**.	2019	Croatian Bureau Of Statistics CBS (official inquiry)
1.6.	Number of trades	The indicator is expressed as the exact number of active trades in the Smart Economy dimension.	2019	Croatian Bureau Of Statistics CBS (official inquiry)
1.7.	Share of ICT **enterprises**	The indicator is presented as a share of active ICT / total number of **enterprises** and trades	2019	Croatian Bureau Of Statistics CBS (official inquiry)
1.8.	Employees in the ICT sector	The indicator is expressed as a share in the total number of employees in legal entities	2019	Croatian Bureau Of Statistics CBS (official inquiry)
1.9.	Employees in education, research and development	The indicator is expressed as an exact number for each city (National Classification of Activities: 75, 82).	2019	Croatian Bureau Of Statistics CBS (official inquiry)
1.10.	Allocations for R&D	The indicator is expressed as an exact number, ie the sum of all 10 areas of allocation for research and development in the city budget.	2019	Ministry of finance - https://mfin.gov.hr/istaknute-teme/lokalna-samouprava/financijski-izvjestaji-jlp-rs/pr-ras-i-ras-funkc-za-razdoblje-2014-2019/3107

Source: authors

Appendix 1. Z-values of five indicators and Smart Economy Index for 127 Croatian cities (in descending order)

Cities	Number of population (2019)	Number of tourist nights	Road connection to the nearest airport	Number of **enterprises**	Number of trades	Share of ICT **enterprises**	Smart Economy Index (descending)
Split	169577	0.29	- 0.13	2.46	1.94	0.12	4.68
Rijeka	115995	0.00	- 0.13	1.60	1.43	0.13	3.04
Osijek	101117	- 0.03	- 0.15	0.96	0.96	0.40	2.14
Zadar	75627	0.20	- 0.17	0.79	1.12	0.01	1.94
Pula - Pola	56349	0.21	- 0.18	0.84	0.82	0.11	1.79
Dubrovnik	44743	0.48	- 0.14	0.59	0.85	0.01	1.79
Varaždin	46269	- 0.04	0.04	0.56	0.42	0.41	1.40
Šibenik	44275	0.15	0.05	0.24	0.63	0.01	1.09
Poreč - Parenzo	17833	0.34	- 0.03	0.28	0.39	- 0.02	0.96
Velika Gorica	62550	- 0.04	- 0.19	0.44	0.55	0.18	0.94
Samobor	37905	- 0.04	- 0.09	0.32	0.38	0.30	0.86
Slavonski Brod	53083	- 0.04	0.10	0.24	0.44	0.06	0.80
Čakovec	27757	- 0.04	0.09	0.31	0.04	0.35	0.75
Karlovac	51063	- 0.04	- 0.01	0.25	0.30	0.11	0.60
Rovinj - Rovigno	14464	0.43	- 0.09	0.11	0.22	- 0.11	0.56
Umag - Umago	13993	0.25	0.05	0.18	0.15	- 0.09	0.54

Bjelovar	37948	-0.05	0.04	0.21	0.12	0.08	0.40
Koprivnica	29758	-0.05	0.09	0.08	0.14	0.08	0.34
Sisak	42326	-0.04	-0.05	0.11	0.22	0.09	0.33
Makarska	14362	0.14	0.07	0.00	0.18	-0.09	0.30
Kaštela	40894	0.03	-0.18	0.11	0.32	0.01	0.28
Sveta Nedelja	18558	-0.04	-0.11	0.16	0.02	0.22	0.24
Zaprešić	25033	-0.05	-0.09	0.13	0.04	0.20	0.22
Opatija	11042	0.12	-0.08	0.08	-0.02	0.09	0.19
Đakovo	25063	-0.05	-0.05	-0.03	0.25	0.06	0.18
Virovitica	19689	-0.05	0.22	-0.03	-0.02	0.03	0.15
Požega	23155	-0.05	0.14	-0.03	0.07	0.01	0.15
Nova Gradiška	12287	-0.05	0.26	-0.11	-0.05	0.05	0.12
Vinkovci	33489	-0.04	-0.09	0.05	0.14	0.01	0.07
Kutina	20359	-0.05	0.03	-0.05	-0.03	0.15	0.05
Mali Lošinj	7876	0.19	0.11	-0.07	0.00	-0.20	0.05
Labin	10794	0.13	-0.09	-0.01	0.02	-0.02	0.04
Ludbreg	8631	-0.05	0.08	-0.11	-0.13	0.23	0.03
Crikvenica	10692	0.18	-0.14	-0.06	0.06	-0.01	0.02
Vukovar	22401	-0.04	-0.13	0.01	0.07	0.12	0.02
Donji Miholjac	8432	-0.05	0.01	-0.13	-0.16	0.35	0.01
Solin	26578	-0.04	-0.15	0.09	0.06	0.04	0.01
Vodice	9345	0.11	0.01	-0.07	0.06	-0.09	0.00
Lipik	5038	-0.05	0.41	-0.16	-0.22	0.01	-0.02
Rab	7850	0.11	0.01	-0.11	0.12	-0.15	-0.03
Krapina	11816	-0.04	0.01	-0.07	-0.06	0.13	-0.03
Krk	7030	0.11	-0.13	-0.08	0.04	0.02	-0.04
Križevci	19769	-0.05	-0.01	-0.00	-0.06	0.07	-0.05
Našice	15180	-0.05	0.00	-0.09	-0.04	0.13	-0.05
Pakrac	6607	-0.05	0.29	-0.15	-0.19	0.03	-0.06
Korčula	5533	0.00	0.22	-0.12	-0.06	-0.10	-0.06
Omiš	14661	0.07	-0.00	-0.08	0.05	-0.10	-0.07
Ogulin	12717	-0.04	0.15	-0.11	-0.07	-0.01	-0.08
Pazin	8423	-0.04	-0.06	-0.06	0.02	0.06	-0.09
Daruvar	10371	-0.04	0.17	-0.11	-0.15	0.04	-0.09
Metković	16296	-0.05	0.14	-0.07	-0.03	-0.10	-0.10
Jastrebarsko	14996	-0.04	-0.06	-0.05	-0.01	0.06	-0.10
Beli Manastir	8235	-0.05	-0.06	-0.13	-0.18	0.31	-0.11
Garešnica	8831	-0.05	0.09	-0.11	-0.19	0.16	-0.11
Lepoglava	7450	-0.05	0.05	-0.15	-0.21	0.24	-0.12
Novalja	4109	0.16	0.08	-0.10	-0.05	-0.20	-0.12
Kastav	11021	-0.04	-0.10	-0.02	-0.08	0.12	-0.13
Gospić	11761	-0.04	0.12	-0.10	-0.14	0.02	-0.14
Slatina	11925	-0.05	0.13	-0.11	-0.07	-0.05	-0.15
Đurđevac	7686	-0.05	0.12	-0.13	-0.20	0.11	-0.15
Zabok	8766	-0.05	-0.04	-0.09	-0.09	0.11	-0.16
Ploče	8841	-0.04	0.16	-0.14	-0.13	-0.01	-0.17
Novska	11455	-0.05	0.10	-0.14	-0.06	-0.02	-0.17
Hvar	4493	0.04	0.06	-0.12	0.01	-0.17	-0.19
Trogir	12944	0.02	-0.19	-0.04	0.10	-0.10	-0.20
Popovača	10860	-0.05	-0.02	-0.14	-0.16	0.16	-0.21
Mursko Središće	5985	-0.05	0.14	-0.12	-0.21	0.03	-0.21
Ivanić-Grad	13705	-0.04	-0.10	-0.04	-0.13	0.10	-0.21
Duga Resa	10552	-0.04	0.02	-0.12	-0.12	0.05	-0.21
Čazma	7190	-0.05	-0.02	-0.13	-0.21	0.18	-0.22
Petrinja	20423	-0.05	-0.05	-0.08	-0.04	-0.01	-0.23
Dugo Selo	18114	-0.05	-0.14	0.03	-0.07	-0.02	-0.24
Ivanec	13080	-0.05	0.03	-0.09	-0.11	-0.03	-0.24

Sveti Ivan Zelina	14799	- 0.05	- 0.10	- 0.02	- 0.06	- 0.02	- 0.25
Vrlika	1714	- 0.05	0.03	- 0.18	- 0.25	0.19	- 0.25
Sinj	24348	- 0.04	- 0.06	- 0.07	0.04	- 0.11	- 0.25
Senj	6162	- 0.00	- 0.05	- 0.14	- 0.09	0.02	- 0.27
Novigrad -	4752	0.09	0.01	- 0.04	- 0.13	- 0.20	- 0.27
Knin	11513	- 0.05	0.10	- 0.15	- 0.12	- 0.05	- 0.27
Pleternica	9382	- 0.05	0.13	- 0.14	- 0.17	- 0.05	- 0.29
Oroslavje	5951	- 0.05	- 0.01	- 0.13	- 0.15	0.04	- 0.29
Valpovo	10339	- 0.05	- 0.07	- 0.13	- 0.17	0.11	- 0.30
Novi Marof	12071	- 0.05	- 0.01	- 0.11	- 0.09	- 0.05	- 0.32
Belišće	9435	- 0.05	- 0.05	- 0.14	- 0.18	0.10	- 0.32
Buje - Buie	4878	- 0.02	0.03	- 0.05	- 0.17	- 0.11	- 0.32
Buzet	6083	- 0.04	0.05	- 0.09	- 0.10	- 0.14	- 0.32
Orahovica	4586	- 0.05	0.06	- 0.16	- 0.17	- 0.01	- 0.33
Prelog	7546	- 0.05	0.09	- 0.08	- 0.21	- 0.08	- 0.33
Varaždinske	5729	- 0.04	0.01	- 0.15	- 0.20	0.05	- 0.33
Vrbovec	14063	- 0.05	- 0.09	- 0.07	- 0.11	- 0.02	- 0.33
Pregrada	5988	- 0.05	0.02	- 0.15	- 0.17	0.00	- 0.34
Imotski	9972	- 0.04	0.01	- 0.09	- 0.15	- 0.06	- 0.34
Vis	2068	- 0.03	0.04	- 0.14	- 0.19	- 0.03	- 0.35
Biograd na Moru	5878	0.07	- 0.12	- 0.09	- 0.04	- 0.19	- 0.36
Pag	3731	0.05	- 0.02	- 0.15	- 0.15	- 0.09	- 0.36
Hrvatska	1967	- 0.05	0.05	- 0.17	- 0.25	0.05	- 0.36
Klanjec	2628	- 0.05	0.00	- 0.16	- 0.21	0.06	- 0.36
Županja	9558	- 0.05	- 0.03	- 0.11	- 0.13	- 0.05	- 0.36
Drniš	6126	- 0.05	0.11	- 0.14	- 0.17	- 0.12	- 0.38
Komiža	1484	- 0.03	0.07	- 0.17	- 0.19	- 0.06	- 0.38
Opuzen	3111	- 0.05	0.12	- 0.16	- 0.22	- 0.09	- 0.40
Donja Stubica	5948	- 0.04	- 0.07	- 0.14	- 0.17	0.02	- 0.41
Cres	2907	0.06	- 0.06	- 0.14	- 0.15	- 0.14	- 0.42
Kutjevo	4985	- 0.05	0.09	- 0.16	- 0.20	- 0.12	- 0.44
Novi Vinodolski	4783	0.03	- 0.12	- 0.14	- 0.11	- 0.10	- 0.44
Ozalj	5993	- 0.05	0.01	- 0.14	- 0.17	- 0.09	- 0.44
Vrbovsko	4063	- 0.05	0.01	- 0.16	- 0.20	- 0.07	- 0.46
Otočac	8842	- 0.04	0.06	- 0.12	- 0.14	- 0.23	- 0.48
Zlatar	5586	- 0.05	- 0.07	- 0.14	- 0.18	- 0.03	- 0.48
Čabar	3131	- 0.05	0.02	- 0.16	- 0.21	- 0.10	- 0.50
Trilj	8251	- 0.05	- 0.05	- 0.15	- 0.16	- 0.09	- 0.50
Slunj	4070	- 0.03	0.15	- 0.16	- 0.22	- 0.23	- 0.50
Skradin	3064	- 0.04	0.01	- 0.16	- 0.20	- 0.10	- 0.50
Grubišno Polje	5381	- 0.05	0.16	- 0.16	- 0.22	- 0.23	- 0.51
Kraljevica	4412	- 0.02	- 0.14	- 0.14	- 0.21	0.01	- 0.51
Supetar	4457	0.02	- 0.13	- 0.12	- 0.10	- 0.17	- 0.51
Delnice	5437	- 0.04	- 0.07	- 0.13	- 0.16	- 0.11	- 0.52
Stari Grad	2887	- 0.02	0.01	- 0.15	- 0.19	- 0.19	- 0.54
Benkovac	8724	- 0.04	- 0.10	- 0.14	- 0.17	- 0.10	- 0.54
Nin	2943	0.09	- 0.05	- 0.15	- 0.20	- 0.23	- 0.55
Ilok	5256	- 0.05	- 0.02	- 0.16	- 0.19	- 0.13	- 0.55
Vodnjan -	6360	- 0.01	- 0.15	- 0.11	- 0.15	- 0.13	- 0.56
Vrgorac	5570	- 0.05	0.01	- 0.15	- 0.20	- 0.19	- 0.56
Glina	6718	- 0.05	- 0.01	- 0.15	- 0.22	- 0.18	- 0.60
Bakar	8160	- 0.04	- 0.16	- 0.09	- 0.18	- 0.16	- 0.63
Obrovac	3649	- 0.04	- 0.02	- 0.16	- 0.22	- 0.23	- 0.67
Otok	5056	- 0.05	- 0.05	- 0.17	- 0.23	- 0.23	- 0.73

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RANGIRANJE HRVATSKIH GRADOVA PREMA HELLWIGOVOJ METODI INFORMACIJSKOG KAPACITETA U DIMENZIJI *SMART ECONOMY*

Sažetak

Glavni je cilj ovoga istraživanja utvrditi je li veličina grada s obzirom na populaciju preduvjet za bolji ekonomski razvoj i rangiranje hrvatskih gradova na temelju prosječnog z-score modela pametnih ekonomskih pokazatelja u odnosu na poduzetnički potencijal, turizam, informacijsko-komunikacijske tehnologije (ICT) te istraživanje i razvoj (R&D). Uzorak na kojemu je provedeno istraživanje sastoji se od 127 hrvatskih gradova i deset pametnih ekonomskih pokazatelja. Hellwigova metoda informacijskog kapaciteta koristi se samo statistički značajnim pokazateljima, na temelju kojih se određuju težine pri sastavljanju indeksa pametne ekonomije. Rezultati analiza pokazuju da se broj pozitivno rangiranih gradova smanjuje usporedno sa smanjenjem populacije u gradu: pozitivno je rangirano 100% velikih gradova, 48% srednjih gradova I 6% manjih gradova.

Ključne riječi: Indeks pametne ekonomije, Hellwigova metoda informacijskog kapaciteta, rangiranje, hrvatski gradovi.

JEL klasifikacija: O18, O31, O33, R58.