UDC 711:711.58:351:312:519.8
Preliminary communication
Received: 27.11.2013.

Preliminary identification of residential environment assessment indicators for sustainable modelling of urban areas

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SUMMARY

Increasing population density in urban areas is closely followed by a number of negative aspects, which can significantly affect the quality of housing, as well as its sustainability. The aim of this paper is to identify the most important indicators influencing the quality of residential environment, and to give information for sustainable decision-making and modelling of urban areas. To know the significance of certain indicators presents a very important element in planning and decision making process. This gives the decision-maker an insight into elements to which a proper attention should be given during urban area management. Using a web-based questionnaire, as well as personal questioning, the data for three cities: Brno (Czech Republic), Rijeka (Croatia), and Podgorica (Montenegro) were collected, analyzed, and compared. Results of the performed statistical analysis show that differences among the examined cities exist, and that among indicators, several can be considered very similar, while others differ significantly. The indicators were categorized in three groups (key, important, and marginal) according to their given importance. The conducted research gives a preliminary insight into the population's perception of the importance of indicators, which is established as a necessary element of the sustainable decision-making process in urban area management.

***Key words**: residential environment, housing, urban area, indicators, quality of life, comparative study, decision support, sustainable modelling.*

1. INTRODUCTION

Urban area population is constantly increasing in comparison to rural areas. By 2030, it is expected that *60%* of world population, out of which *84%* of population in developed countries, will have lived in urban areas [1]. Increasing population density in urban areas is closely followed by a number of negative aspects, which can significantly affect the quality of housing, such as increasing level of noise, traffic jams, or air pollution. Those aspects can significantly affect the quality of housing, as well as its sustainability from a long-term perspective.

Quick alterations of a large number of population are often not the result of city expansions, yet wider migration problem, which is confirmed by the fact [1] that every day urban areas take over *160.000* new citizens. The problem of a continuous and abundant growth of population in cities is often solved by a poorly planned, unplanned, and even random construction of residential areas. Such a construction frequently results in decision-maker oversights, where some of them can be seen momentarily while others cannot. Such a way of decision-making is highly unsustainable because one such long-term problem cannot be solved with a lot of short-term, and non-contiguous measures.

The aim of this paper is to identify the most important indicators influencing the quality of residential environment and their implementation in decision-making process. This research has been

carried out as a comparative study of three cities: Brno (Czech Republic), Rijeka (Croatia), and Podgorica (Montenegro) in order to demonstrate which indicators should be given due attention from respective authorities so that sustainable decisions in urban area management can be made.

The paper is structured as follows: Firstly, the literature review is introduced. Secondly, the methodology used in this research is presented. Thirdly, the statistical results on the significance of indicators are presented. Finally, the significance of indicators is discussed with regard to the examined cities.

2. RESEARCH CONTEXT AND LITERATURE REVIEW

From time immemorial, people have wanted to live in pleasant and comfortable premises. Nowadays, housing comfort is influenced by a number of different factors, some of which can be controlled on an individual level (thermal characteristics of the building [2], quality of ventilation [3], presence of elevator [4], quality of sound insulation [5], etc.). Those "indoor factors" are mostly of technical origin, and are subject to the decision-making of investor/resident during the design phase, construction, or operation time of a residential unit. E.g. Bock and Isaac [6] have presented a methodology to support the design of modular buildings that can be adapted more easily throughout their entire life cycle, which is particularly useful for elderly people whose requirements change dramatically in a relatively short time.

On the other hand, since being managed at the governmental or a municipal level, a wide spectrum of factors can be influenced only partially, or even not at all. Bakar et al. [7] have divided the factors into 6 main groups. They have considered environmental, social, economic, site/land use, communication, and transportation aspects from the perspective of the sustainability of housing development. The study presented in this paper examines selected "outdoor/ neighborhood" indicators influencing the quality of housing from the perspective of residential environment.

All the above-mentioned indicators have a significant economic impact on the price of a real estate. An extensive body of knowledge exists dealing entirely with the effect of spatial dependence on real estate prices. However, these studies take into account technical parameters as well (e.g. wall condition, and roof material [8]; number of bathrooms, and central air-conditioning [9]). On the other hand, several research studies focus solely on the evaluation of criteria significance on sustainability of housing, cities and/or districts. The level of sustainable development is usually measured by means of sustainability indicators categorizable with respect to their basic characteristics.

Shen et al. [10] have, comprehensively, documented a list of urban sustainable indicators classified in 4 main categories (environmental, economic, social and governance), applicable for the comparison on the international level. Nevertheless, individual practices differ since various indicators are applied in different ways. Obviously, authors draw the structure of criteria with regard to the particularity of analyzed location, and the specific purpose of their study. E.g. Zavadskas et al. [11] have evaluated sustainability aspects of Vilnius residential area by 22 indices. In contrast to Zavadskas, Iben and Aduwo [12] have scored 31 housing variables, in order to assess residential satisfaction of inhabitants in public housing. In addition, they have analyzed 9 socio-economic characteristics of respondents. Egger [13] has provided a sustainable city model covered by 15 parameters (e.g. air quality, security, culture and leisure) in order to enable understanding of the interactions between the economy, society and environment. It is clear that the agreement among researchers does not occur even on the aggregated level, e.g. Choguill [14], looks at sets of sustainable criteria from a slightly different standpoint, if compared to Shen et al. [10]. In his study he has presented the category of technical sustainability while Shen et al. classified a set of governance sustainable indicators. Generally, when creating a list of assessment indicators, the selection should be done with regard to their consequent application and measurement/assessment potential. Shen et al. recommend creating a short list of indicators at the beginning, as well as adding or eliminating particular indicators during later revisions [10].

It can be assumed that very different urban areas will achieve considerably different values of evaluation indicators suggesting the satisfaction of residents in housing issues. Iben and Aduwo [12] have investigated the satisfaction with housing conditions in public housing and concluded that most of the residents are dissatisfied. In a similar study on the assessment of residential satisfaction in a newly-designed, public, low-cost housing in Malaysia, Mohit et al. [15] have concluded that residents are moderately satisfied with their residential environment. Dissatisfaction with housing and housing conditions creates the potential for residential mobility, as confirmed by Bekleyen and Korkmaz [16]. They have discovered that most of the residents of Akabe settlement in Turkey would like to move if they had better economic conditions [16]. The dissatisfaction of residents with housing is determined by relocation of wealthier residents and immigration of socially disadvantaged individuals, which has negative consequences on real estate prices. Thus, the quality of residential environment in a particular location is closely related to the structure of the socio-economic background of inhabitants. As proved by Chen et al. [17], on the case of Dalian urban area, residential location, housing characteristics, and residential satisfaction differ significantly according to the

respondents' family income. In order to meet housing needs of individuals (especially of socially deprived citizens), it is necessary to prepare and implement housing policies and strategies. For example, even a small country like Montenegro has its own housing strategy [18]. Those policies can be improved by specific models and by taking expert knowledge into account [19]. So that the future development of particular indicators may be forecast.

However, governmental policies cannot entirely affect the quality of residential environment, as it is also influenced by the real estate market, macroeconomic conditions, or by the financial capability and planning skills of a particular municipality. In any case, the evaluation of the quality of a residential environment is an important element that significantly affects the spatial decision-making of residents meeting their housing needs. Therefore, an appropriate attention should be given to this issue.

3. RESEARCH DESIGN

This research aims to examine the disparities in inhabitants' requirements regarding the quality of residential environment of the cities of Brno (Czech Republic), Rijeka (Croatia), and Podgorica (Montenegro). These disparities have been assessed by means of 22 indicators showing which attributes people consider key, important, and/or marginal. The examinees were not given the possibility to create their own list of indicators. They could only give their individual estimate for each indicator, which was defined by the research team.

3.1 Study Area

The participants of the research conducted and presented in this paper are citizens of three cities: Brno, Rijeka, and Podgorica.

Brno is the second largest city in the Czech Republic, and the historical capital of Moravia. The city now serves as the seat of judicial authority; it is also a seat of a number of state authorities. Brno is also known as a university city with about ninety thousand students creating a specific environment. Forest accounts for a significant portion of the city area, and, in geographical terms, the city is considered partly hilly. A cnsiderable part of the population lives in panel buildings in peripheral residential areas that have been subjects of renovation and modernization during the last decades due to their unsatisfactory initial technical conditions.

Rijeka is the third largest city in the Republic of Croatia, and the largest city in the Primorje-Gorski Kotar County. The city of Rijeka is situated on the northernmost shore of the Bay of Kvarner where the Mediterranean is closest to the countries of Central Europe. Such a favourable geographical location made it a good trading post, i.e. harbour that fuelled the city's development during the 19th and 20th centuries. Today, as the influence of the harbour decreases, Rijeka enjoys the status of a university, cultural and health centre of a wider region (of the neighboring counties as well as neighboring countries such as Slovenia and Italy). Given a high population density, lots of citizens live in skyscrapers and other 5 or more-storey buildings (in the city centre) built during Rijeka's expansion period. During the last couple of decades, on the city's outskirts, smaller buildings have been constructed, as well as family houses. That has followed as a result of the citizens' need for more open spaces, and desire for a better environmental quality of the living area. The present real estate market consists of a large number of quite diverse real estates.

Podgorica is the largest city and capital of Montenegro. Located in the central part of the state, it is an important crossroad that connects all regions, as well as neighboring countries. Podgorica lies in a predominantly flat area, surrounded by rivers and lakes, at the northern end of the Zeta plain. A mixture of architectural styles reflects the turbulent history of the city. There are many examples of Turkish architecture, massive socialist architecture as well as the modern one. The city suffered heavily during World War II when it was almost razed to the ground. After liberation, rebuilding began by erecting massive residential blocks thus strongly influencing a rapid mitigation of population. New residential and infrastructural developments have been made in the last decades with the trend of incorporating contemporary glass-and-steel architecture. In an effort to create a recognizable and modern state capital, city officials made substantial investments in the city's public spaces (wider roads and pedestrian walks, new squares, parks, boulevards, etc.). Today, Podgorica is an administrative, political, traffic, cultural, and educational center of Montenegro, and a home to *30%* of the total country population.

Basic data on the examined cities are listed in Table 1.

Table 1. Basic data on Brno, Rijeka and Podgorica

Data character	*Brno*	*Rijeka*	*Podgorica*
Population [no. of residents]	*384.277 [20]*	*128.624 [22]*	*150.977 [23]*
Total area [km^2]	*230 [21]*	*44 [22]*	*97,5 [24]*
Population density [no. of residents / km^2]	*1.671*	*2.923*	*1.548*
Elevation [m]	*190 to 425 m [21]*	*0 to 441 m [22]*	*44,5 [24]*
Geographic coordinates	*49° 12' N. lat. [21]* *16° 34' E. long.*	*45° 21' N. lat. [22]* *14° 26' E. long.*	*42° 26' N. lat. [24]* *19° 16' E. long.*

3.2 Survey and data

Firstly, the performed literature review has served to the authors as a starting point for creating an appropriate list of criteria according to which the requirements on the quality of residential environment will be evaluated. Afterwards, particular indicators were discussed with the panel of experts in order to:

* Confirm those relevant for the examined cities,
* Remove those assessed as inappropriate or superfluous, and
* Consider others that might be included on the list.

A final list of assessment indicators is given in Table 2. The list of 22 indicators consists of different standpoints, and could be classified into four groups (environmental, social, technical, and transport) based upon their fundamental characteristics.

Table 2. List of assessment indicators

Indicator	Indicator name
C1	Distance from the city centre
C2	Availability of free parking space
C3	Clean air
C4	Safety
C5	Good public transport service to downtown
C6	Well maintained surroundings (environment)
C7	Noise (traffic, close manufacturing, etc.)
C8	Presence of drugs in neighborhood
C9	Drinking alcohol in public places
C10	Homeless people on streets
C11	Architectural appearance of neighborhood
C12	Availability of services (shops, hairdressers, etc.)
C13	Distance from school
C14	Distance from kindergarten
C15	Distance from health facilities
C16	Distance from recreation areas (parks, forests, water areas, etc.)
C17	Distance from cultural institutions
C18	Distance from work place
C19	Distance from pharmacy
C20	Sporting recreation facilities (courts, sports halls, pools, etc.)
C21	Barrier free solution of neighborhood
C22	Traffic fluency

The target examinees in this survey were current and former residents living in the above-mentioned cities, or in a wider urban agglomeration, in order to ensure sufficient personal knowledge of the respective residential environment.

In order to assess indicator grades, the examinees could express their stances by assigning a number from 1 to 5 to each indicator (1 - negligible indicator, 2 - indicator of little significance, 3 - significant indicator, 4 - very significant indicator, 5 - key indicator).

Besides assigning grades to indicators, the examinees were questioned about their age (age groups: *15-25, 26-35, 36-45, 46-55, 56-65, >65*), location of their dwelling (close center, wider center area, or boundary city area), and the type of their dwelling (house or flat).

The data were collected using a web-based questionnaire, as well as by personal questioning. At the end, *445* questionnaires were collected, out of which *165* in Brno, *132* in Rijeka and *148* in Podgorica.

4. RESULTS AND DISCUSSION

All examinees were aged *15* or older. In total there were six age groups, each with a *10* year span. As this was a preliminary research, all collected data were grouped by their location of conducted examination, i.e. city. The collected data, in form of grades from *1* to *5*, are given in Table 3.

Table 3. Collected data (grades)

Indicator	Brno	Rijeka	Podgorica
C1	3,079	2,985	3,149
C2	3,867	4,008	3,635
C3	4,103	4,076	3,838
C4	4,424	4,356	3,993
C5	3,952	3,932	3,405
C6	3,861	3,841	3,507
C7	4,170	3,818	3,547
C8	4,176	4,000	3,554
C9	3,600	3,212	3,264
C10	3,873	3,394	3,203
C11	3,194	3,227	3,142
C12	3,455	3,409	3,581
C13	3,509	3,545	3,804
C14	3,449	3,121	3,777
C15	3,321	3,568	3,791
C16	3,388	3,583	3,466
C17	2,628	2,621	2,973
C18	3,321	3,485	3,466
C19	2,776	3,129	3,264
C20	3,018	3,409	3,277
C21	2,806	3,409	3,081
C22	3,449	3,939	3,405

Overall grade by each city was *77,42* in Brno, *78,07* in Rijeka, and *76,12* in Podgorica. As each city's examinees had their own value scale which they applied on predefined indicators and grades, these data could not be directly compared. In order to make comparison relevant, the collected data (grades) has to be normalized for each indicator [25].

Normalization of each indicator has been conducted by following expression:

$$w_i = \frac{g_i}{\sum_{i=1}^{22} g_i} \qquad (1)$$

where w_i stands for the weight of each indicator, and g_i stands for the grade of each indicator.

Data from Table 3 has been normalized for the purpose of comparison, and the final output is presented in Table 4.

Table 4. Indicator weights

Indicator	Brno	Rijeka	Podgorica
C1	0,0398	0,0382	0,0414
C2	0,0499	0,0513	0,0478
C3	0,0530	0,0522	0,0504
C4	0,0571	0,0558	0,0525
C5	0,0510	0,0504	0,0447
C6	0,0499	0,0492	0,0461
C7	0,0539	0,0489	0,0466
C8	0,0539	0,0512	0,0467
C9	0,0465	0,0411	0,0429
C10	0,0500	0,0435	0,0421
C11	0,0413	0,0413	0,0413
C12	0,0446	0,0437	0,0470
C13	0,0453	0,0454	0,0500
C14	0,0445	0,0400	0,0496
C15	0,0429	0,0457	0,0498
C16	0,0438	0,0459	0,0455
C17	0,0339	0,0336	0,0391
C18	0,0429	0,0446	0,0455
C19	0,0359	0,0401	0,0429
C20	0,0390	0,0437	0,0430
C21	0,0362	0,0437	0,0405
C22	0,0445	0,0505	0,0447

With all indicators being normalized, a relevant comparison regarding each city, as well as among cities, is possible. Sum of all indicator weights by each city is one (1,00). Weights comparison between cities is shown in Figure 1. Each indicator weight for each city is presented by its own bar, as well as average weight of each indicator.

According to the examinees of all compared cities, the safety indicator (*C4*) is the most significant one, while distance from cultural institutions (*C17*) is the least significant. It is clear that the issue of safety is one of the key demands of the population, because damages to health, life and personal property are perceived as personal and as significantly affecting human lives. Towards other indicators, the examinees had different attitudes (as shown in Figure 1), but the clean air (*C3*) is one of more important ones.

In Brno, indicator (*C4*) is followed by the presence of drugs in neighborhood (*C8*) and noise indicator (*C7*). Drug problem is, to a large extent, associated with a high number of university students, and thus strongly affects only citizens in Brno. Monitoring the student drug scene at Masaryk University in Brno it has been discovered that *45%* of examinees consumed marijuana more than ten times in life [26]. Regarding the significance of noise, it should be mentioned that some districts suffer from traffic noise coming from the highway (Bohunice, Starý Lískovec and Bosonohy), as well as other city districts that are located near the airport (Turany and Chrlice). Precisely for this reason, noise is a factor of a particular interest in Brno.

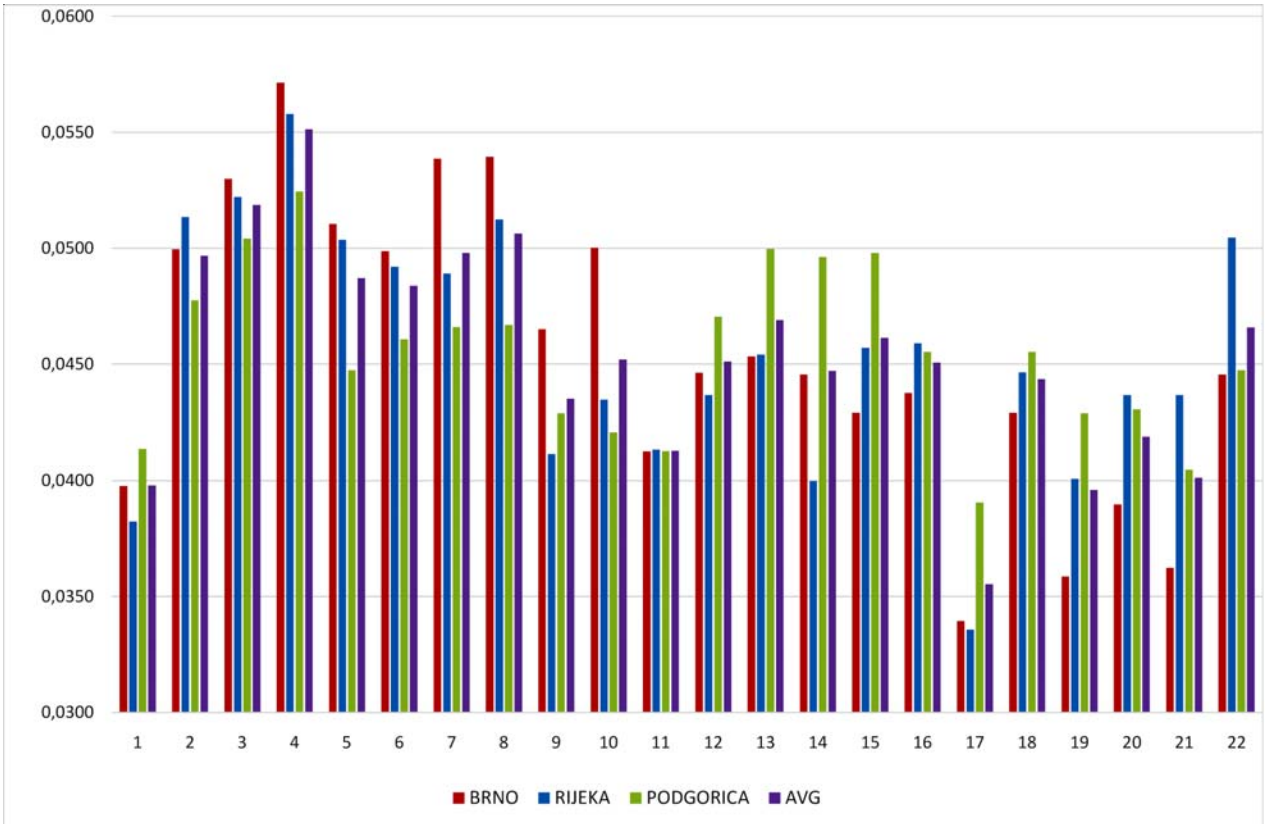

Fig. 1 Weights comparison between cities of Brno, Rijeka and Podgorica

In Rijeka, indicator (*C4*) is followed by the presence of clean air (*C3*) and availability of free parking space (*C2*). During Rijeka's industrial period, air quality was not taken into account so residential buildings were settled close to industrial areas and the city centre. As the industry abated, citizens sought for more open spaces and air quality, which resulted in migrations to the city outskirts forming today's settlement rings. To overcome the distance from the outskirts to the city centre, the significance of transport indicators such as availability of free parking space (*C2*), good public transport service to downtown (*C5*), and traffic fluency (*C22*) are not unexpected.

In Podgorica, indicator (*C4*) is followed by the presence of clean air (*C3*), distance from school (*C13*), distance from kindergarten (*C14*), and distance from health facilities (*C15*). These indicators are directly related to the demographic situation in Podgorica. It is not unexpected if the information from census [23] is considered (*84,8%* of citizens are younger than *60*). The citizens of Podgorica periodically visit cultural events, assessing the distance from cultural institutions (*C17*) indicator as insignificant. With Podgorica being a transit crossroad, the significance of transport indicators is one of the more important ones.

Several indicators (distance from city centre (*C1*), clean air (*C3*), the architectural appearance of neighborhood (*C11*), distance from recreational areas (*C16*) and distance from work place (*C18*)) are considered equally important among the examinees in the observed cities. On the other hand, there is a big discrepancy in examinees' answers on several indicators (noise (*C7*), presence of drugs in neighborhood (*C8*), drinking alcohol in public places (*C9*), homeless people on streets (*C10*), distance from school (*C13*), distance from kindergarten (*C14*), distance from health facilities (*C15*), distance from cultural institutions (*C17*), distance from pharmacy (*C19*), barrier free solution of neighborhood (*C21*) and traffic fluency (*C22*)).

According to the examinees of all compared cities, tendency of grouping of the indicators was done by visual method. These were grouped as key indicators (*C4, C3, C8, C7, C2, C5, C6*), important indicators (*C13, C22, C15, C10, C12, C16, C14, C18, C9, C20, C11*), and marginal indicators (*C21, C1, C19, C17*). Difference in the citizens' perception among key and marginal indicators is slightly over *30%*. Such a difference represents a key point of interest which can yield significant economic benefits, if a decision-maker decides to implement the presented way of collecting, and taking into account information during his decision-making process.

Descriptive statistics of indicator weights is given in Table 5. It is clear that the range among weights is similar for the cities of Brno and Rijeka, while Podgorica differs from both. That means that the citizens of Brno and Rijeka have perceived the importance of some indicators over some others, while the citizens of Podgorica have demonstrated less diversity in the preference indicators.

Table 5. Descriptive statistics of indicator weights

	Brno	*Rijeka*	*Podgorica*
Mean	*0,04545*	*0,04545*	*0,04545*
Std. Error	*0,00136*	*0,00114*	*0,00077*
Median	*0,04459*	*0,04503*	*0,04553*
Mode	*0,04455*	*0,04367*	*0,04473*
Std. Dev.	*0,00636*	*0,00534*	*0,00360*
Sample Var.	*4,04E-05*	*2,85E-05*	*1,3E-05*
Range	*0,0232*	*0,0222*	*0,0134*
Minimum	*0,0339*	*0,0336*	*0,0391*
Maximum	*0,0571*	*0,0558*	*0,0525*
Sum	*1*	*1*	*1*

Regression analysis of the cities resulted in the highest correlation beeing the one between Brno and Rijeka ($R^2=0,6724$), and the lowest between Brno and Podgorica ($R^2=0,4043$). Correlation between Rijeka and Podgorica is slightly higher than between Brno and Podgorica, with amount of $R^2=0,4421$.

This can be interpreted as the citizens of Brno and Rijeka sharing a more similar attitude towards *22* predefined assessment indicators in contrast to the citizens of Podgorica.

Even the fact that all indicators have not got the same weight points to the fact that the examinees (citizens of Brno, Rijeka and Podgorica) are aware of their difference in importance. This presents a valuable information for decision-makers to implement in their decision-making process. This research has given a answer to the questions seeking to determine which indicators are important for the quality of residential environment and which indicators due attention from respective authorities should be given in order that sustainable decisions are made in the urban area management.

5. CONCLUSION

The aim of this paper was to identify the most important indicators influencing the quality of residential environment. Using a web-based questionnaire, as well as by personal questioning, a total number of *445* questionnaires has been collected, analyzed, and compared among the citizens of three cities: Brno, Rijeka and Podgorica. This preliminary research has shown that, out of *22* predefined indicators, the most significant indicator for the examinees from all three cities is safety (*C4*), followed by clean air (*C3*) and presence of drugs in neighborhood (*C8*), while the distances from city centre (*C1*), from pharmacy (*C19*), and from cultural institutions (*C17*) are the least significant.

Differences among examined cities were further analyzed. Several indicators were considered very similar while other indicators were assessed differently. These similarities and disparities are listed in the

previous chapter. Regarding the similarity of the results between cities, it has been observed that the citizens of Brno and Rijeka have a similar attitude toward *22* predefined assessment indicators, as opposed to the citizens of Podgorica. Furtermore, the citizens of Brno and Rijeka have perceived a greater importance of some indicators with respect to some others, while the citizens of Podgorica have revealed less diversity in preference for the given indicators.

Apart from being classified according to their importance, the indicators could be additionally grouped in three groups (key, important and marginal), and the difference between the key and marginal indicators can be up to *30%*. All presented gives valuable information and a clearer picture for decision-makers to make greater efforts regarding key indicators, as well as in implementation of all indicators and their preferences into decision-making process. This can be a trigger for making long-term and sustainable decisions, as well as for achieving sustainable solutions in the urban area management.

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PRELIMINARNA IDENTIFIKACIJA UTJECAJA INDIKATORA STAMBENOG OKRUŽENJA ZA POTREBE ODRŽIVOG MODELIRANJA URBANIH PODRUČJA

SAŽETAK

Povećanje gustoće stanovništva u urbanim područjima je usko povezano s brojnim negativnim aspektima koji mogu značajno utjecati na kvalitetu stanovanja, ali i na njihovu održivost. Cilj ovog rada je identificirati važnost indikatora koji utječu na kvalitetu stambenog okruženja te dati informacije za održivo donošenje odluka i modeliranje urbanih područja. Poznavanje važnosti pojedinih indikatora predstavlja vrlo važan element u procesu planiranja i donošenja odluka pri čemu se donositelju odluka daje uvid kojim bi se elementima trebala posvetiti posebna pažnja prilikom upravljanja urbanim područjima. Koristeći web upitnik kao i direktno anketiranje, podaci su prikupljeni, analizirani i uspoređivani između triju gradova: Brna (Republika Češka), Rijeke (Hrvatska) i Podgorice (Crna Gora). Rezultati provedene statističke analize ukazuju na postojanje razlika između promatranih gradova te da se među promatranim indikatorima neki mogu smatrati sličnima, dok se drugi značajno razlikuju. Prema utvrđenim važnostima, indikatori su kategorizirani u tri grupe (ključni, važni i marginalni). Provedenim istraživanjem dobio se preliminarni uvid u percepcije stanovništva o važnosti indikatora kao nužnog elementa u procesu održivog odlučivanja pri upravljanju urbanim područjima.

***Ključne riječi**: stambeno okruženje, stanovanje, urbani prostor, indikatori, kvaliteta života, usporedna analiza, donošenje odluka, održivo modeliranje.*