SMART CITIES EVALUATION APPROACHES

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Abstract: *In addition to planning and organizing, evaluation, which is connected with the control function, is an important managerial function in the concept of building Smart Cities. After the implementation of strategies or models, it is necessary to evaluate performance indicators and, in case of their shortcomings, to identify opportunities for improvement. The aim of the article is to identify approaches to the evaluation of Smart Cities concepts, including frequent methods, indicators or indicators of evaluation. Methods of secondary analysis, summarization, comparison, synthesis, induction and deduction were used to fulfill the aim of the article. The main finding of the article is that currently indicators and management methods, which are supplemented by economic indicators and information and communication technologies, are mostly used for evaluation purposes. Preferred areas are technology, environment, people and economics. In terms of management methods, experts prefer methods to support management and decision-making (AHP, MCD or TOPSIS), SWOT analysis or Maslow's hierarchy of needs, but in a modified form for the needs of Smart Cities in the 21st century.*

Keywords: *management, evaluation, Smart City, ICT*

JEL Classification: *M15, O44, Q01*

1. INTRODUCTION

The trend of building resilient and sustainable cities reflects current natural, technological and social conditions. The adopted strategies, models, projects, plans or concepts need to be evaluated after implementation. The evaluation process should form an essential part of the work of strategic city managers, as it can identify bottlenecks in the form of opportunities for improvement. There is currently no summary of the approaches used to evaluate Smart Cities concepts. The ambition for writing the article was to cover this gap with our own research using a secondary analysis of relevant articles.

2. METHODOLOGY

The aim of the article is to identify approaches to the evaluation of Smart Cities concepts, including frequent methods, indicators or indicators of evaluation. Secondary analysis was primarily used to fulfill the set goal. The search for relevant publications was conditioned by selection using the searched keyword "Smart Cities evaluation" in the Web of Science and Scopus databases. The filtered articles had to meet the following criteria:

- typ Articles,
- Open Access,
- section Sustainability (82 articles),
- top 50 results in WoS and Scopus.

After the elimination of duplicate articles, which were included in both databases, 18 relevant articles meeting all the established criteria were selected and subsequently analyzed. In addition to secondary analysis, the article also contains methods of summarization, comparison, deduction and induction, including synthesis.

3. RESULTS

According to the UN, sustainable smart cities are characterized by economic, environmental and social resilience. Based on this approach, four indicators are to be evaluated in the evaluation [1, 2]:

- city development and GDP per capita (AGPC),
- transport development (PTDI),
- housing and culture (UESI),
- urban environmental sustainability index (UESI).

By calculating the weighted average of these indicators, it is possible to determine the success of the development of Smart City. The calculation is abbreviated CSES and provides important data for the city's planning, prediction and development function [1, 2].

The Mace, Sarate and Moschen survey identified three factors for evaluating smart sustainable cities [3]:

- quality of provided services,
- material well-being,
- environmental protection.

In addition to interviews, factor analysis and linear regression were used. The quality of services reflected satisfaction with the city's infrastructure and social inclusion. This factor depends to a large extent on state support. Material well-being consists of elements of employment, housing levels, work motivation and community participation. Environmental protection reflects the state of limited resources and their conservation for future generations. It was this factor in the survey that achieved the greatest degree of improvement, i. e. the lowest level of satisfaction of citizens with the performance of the city in the area. This method of evaluation through three factors includes the technological, social and environmental aspects of cities [3].

According to Shi et al. the most appropriate PSF evaluation model, which consists of a people-oriented layer, an urban system (management, services, economy) and a flow of resources (basic infrastructure). The weight of the indices is then determined by the analytical hierarchical system (AHP). An innovative element is the AHP-ELM

(Extreme Learning Machine) process, which significantly saves evaluation time and costs [4, 5].

In the European Union, ISO 37120 indicators are used for Smart City evaluation with a focus on sustainability and strategic management of the urban environment [6]. The new evaluation method is called "smart audit" with 70 indicators categorized into 7 areas [6]:

- locality,
- innovative solutions,
- limited resources,
- well-being,
- climate change
- mobility,
- management.

All indicators were rated on a scale from 0 (minimum) to 10 (maximum). In order to meet the sustainability criterion, for some indicators, according to the authors Dall´O et al. better if they reach lower values [6].

Shen et al. they use the PCA and TOPSIS management methods when evaluating Smart City concepts. The evaluation indicators were redistributed into the categories of information and communication technologies (ICT), smart inhabitants, smart management, smart economies, environment. Their evaluation is carried out by allocating points from the Likert scale from 1 to 9, including the evaluation of 10 experts, of which 5 are researchers and 5 specialists in Smart City issues. Their views were sought through semi-structured interviews [7].

Zhang et al. used an interesting method of evaluation in their research work, taking into account the needs of the population. In the evaluation process, they used knowledge from the Maslow hierarchy of needs and modified it with an evaluation model based on the Fuzzy Analytic Hierarchy Process method. During the evaluation, 21 indicators were identified through a questionnaire survey conducted in 29 Smart Cities [8]. This method maximally reflects the social aspect and the focus on the needs of the population, thus reflecting centrist-oriented models.

In addition to the TOPSIS management method, multicriteria decision analysis (MCDA) is also used, the advantage of which is the elimination of uncertainty in the evaluation of Smart City projects, strategies, models and criteria. An innovative method that combines the two previous ones, the so-called Decision-Making And Trial Evaluation Laboratories (DEMATEL) [9, 10]. Chakraborts, Ghosh and Agarwal add the MABAC comparison method to the DEMATEL method [10].

An alternative to evaluating and assigning weights to individual criteria is the CV-CRITIC method, which takes into account the critical decision-making method and the Coefficient of Variance method. The approach is accurate, simple and reliable [11].

SWOT analysis is also a frequent method of Smart City evaluation. Based on her results, Bach and Kim proposed an evaluation model that consists of management, economics, environment and housing. It also takes into account vision, participation, challenges and existing legislation [12]. Wang et al. recommend the implementation of an evaluation system based on the Cloud computing platform for the given method, as it can streamline the evaluation process [13].

Angelakoglou et al. prefer an evaluation framework composed of performance categories in the area [14]:

- technology,
- legislation,
- the environment,
- economics,
- social aspects.

Decision tree methods (Threshold), monitoring, planning, scalability and replicability analysis are used in the evaluation [14].

As part of the Smart City evaluation process, there is a single evaluation framework (USE) that evaluates project performance metrics, the impact on the sustainability and resilience of the city, and a comprehensive evaluation taking into account the views and expectations of all stakeholders [15, 16].

In 2021, Oh and Seo introduced the Structural Equation Model (SEM), which is based on the Population Satisfaction Index, reflecting centrist orientation and social preference [17]. Innovative methods of new evaluation approaches are, for example, Moving Target Defense (MTD) techniques, for the protection of shared data, which form the basic level of the evaluation process [18].

4. DISCUSSIONS AND CONCLUSIONS

The following Table 1 summarizes and at the same time compares the common and different elements that are used in the different approaches to the evaluation of Smart Cities concepts.

Based on the summary of findings from Table 1, indicators that appear in all evaluation approaches are considered to be among the most used elements. It is important that they reflect not only the technological aspect, but also the social, managerial, environmental and economic aspects, including the legislative requirements of a particular country. Most approaches favor only four of them, namely the technological, social, economic and environmental aspects. Although the economic aspect is found in the vast majority of approaches, only three of them use economic indicators (UN, Mace, Sarate, Moschen and ISO 37120). The creation of complex models is unique, with technologies such as Cloud computing platform and data protection through Moving Target Defense being preferred. The management methods use the method supporting management and decision-making (AHP, MCDA or TOPSIS), analysis (SWOT, scalability, replicability), comparison (MABAC) in the evaluation of Smart Cities concepts. The authors consider the inclusion of Maslow's hierarchy of needs, which reflects individual, collective and systemic requirements, as an important element, thus being able to have a positive effect on trust, culture and development.

Table 1 Common and different elements of Smart City concept evaluation approaches

Evaluation approach	Used elements				
	Economic indicators	Indicators	Management methods	Model	Technologies
OSN [1, 2]	Yes	Yes			
Mace, Sarate and Moschen [3]	Yes	Yes			
Shi et al. [4, 5]		Yes	AHP, AHP-ELM	PSF	
ISO 37120 [6]	Yes	Yes			
Shen et al. [7]		Yes	PCA, TOPSIS		
Zhang et al. [8]		Yes	Maslow's hierarchy of needs		
Chakraborty, Ghosh and Agarwal [9, 10]		Yes	MCDA, DEMATEL, MABAC		
CV-CRITIC [11]		Yes	Coefficient of Variance		
Bach and Kim [12]		Yes	SWOT	Yes	
Wang et al. [13]					Cloud computing platform
Angelakoglou et al. [14]		Yes	Threshold, scalability and replicability analysis		
Unified evaluation framework (USE) [15, 16]		Yes			
Oh and Seo [17]		Yes		Structural Equation Model (SEM)	
Moving Target Defense (MTD) [18]		Yes			Yes

Source: own processing according to section Results

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