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Economic or financial substantiation for smart city solutions: a literature study

Abstract. The research is aimed to find the answer for the research question: *Do the researchers demonstrate economic or financial substantiation for implementation of smart solutions for different dimensions of smart city?* The goal of the research is to determine the publications presenting the economic or financial substantiations for smart solutions for smart city and to determine the type of the provided substantiation. It is very important, since Smart City is becoming our life step by step, though the components of it are introduced without any economic study, estimation and substantiation. This research is done to discover the areas where such substantiations exist, and to estimate the possibility of applying the methods, described in these studies, for smart solutions in smart city.

The study considers the academic articles in English included in Scopus database and available online in full text. The primary selection comprised 927 publications for the period 1993-2020, and only 22 of them contained the comprehensive or close to comprehensive economic or financial analysis. This fact demonstrates the lack of economic and financial researches in the sphere of Smart City. The study allows the scholars to use the reviewed publications as providing the economic and financial basis for smart city; it also demonstrates the areas of smart city and smart solutions where specialists in economy can apply their competences.

Keywords: Smart City; Economic Analysis; Financial Analysis; Cost Efficiency; Cost-Benefit Analysis; Scopus; Bibliometrics; Bibliometric Analysis; Problem-Oriented Database; Literature Review
JEL Classification: A19; O14; R19; R58

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Економічне або фінансове обґрунтування рішень для розумного міста:
вивчення літератури
Анотація. Стаття присвячена пошуку відповіді на дослідницьке питання: *чи дають учені в своїх статтях економічне або фінансове обґрунтування впровадження інтелектуальних рішень для різних вимірів розумного міста?* Мета дослідження – виявити публікації, що представляють економічне або фінансове обґрунтування рішень для розумного міста, і визначити, яке саме обґрунтування представлено. Це дуже важливо, тому що розумне місто крок за кроком стає нашим життям, незважаючи на те, що складові його вводяться без достатнього економічного вивчення, оцінки й обґрунтування. Це дослідження проводиться з метою виявлення областей, де існують такі обґрунтування й розрахунки, і для оцінки можливості застосування методів, описаних у цих дослідженнях, для інтелектуальних рішень у розумному місті.

У дослідженні розглядаються академічні статті англійською мовою, включені в базу даних Scopus, і доступні онлайн у повному тексті. Первинна вибірка містила 927 публікацій за період 1993–2020 рр. за темою «розумне місто», і тільки 22 з них містили всебічний або близький до всебічного економічний або фінансовий аналіз елементів розумного міста. Це свідчить про нестачу економічних і фінансових розробок у сфері «розумного міста». Проведене дослідження дозволяє вченим використовувати представлені публікації в якості економічної та фінансової основи розрахунків для розумного міста й інтелектуальних рішень, а також виявляє ті елементи розумного міста, в яких фахівці в області економіки можуть застосувати свої компетенції.
Ключові слова: розумне місто; економічний аналіз; фінансовий аналіз; економічна ефективність; Скопус; бібліометрія; бібліометричний аналіз; проблемно-орієнтована інформаційна база; огляд літератури.

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Экономическое или финансовое обоснование решений для умного города: изучение литературы

Аннотация. Статья посвящена поиску ответа на исследовательский вопрос: *дают ли исследователи в своих статьях экономическое или финансовое обоснование внедрения интеллектуальных решений для различных измерений умного города?* Цель исследования – выявить публикации, представляющие экономическое или финансовое обоснование решений для умного города, и определить, какое именно обоснование представлено. Это очень важно, так как умный город шаг за шагом становится нашей жизнью, несмотря на то, что составляющие его вводятся без какого-либо экономического изучения, оценки и обоснования. Это исследование проводится с целью выявления областей, где существуют такие расчеты, и для оценки возможности применения методов, описанных в этих исследованиях, для интеллектуальных решений в умном городе.

В исследовании рассматриваются академические статьи на английском языке, включенные в базу данных Scopus, и доступные онлайн в полном тексте. Первичная выборка включала 927 публикаций за период 1993–2020 гг. по теме «умный город», и только 22 из них содержали всесторонний или близкий ко всестороннему экономический или финансовый анализ элементов умного города. Это свидетельствует о недостатке экономических и финансовых разработок в сфере «умного города». Проведенное исследование позволяет ученым использовать представленные публикации в качестве экономической и финансовой основы расчетов для умного города и интеллектуальных решений, а также выявляет те элементы умного города, в которых специалисты в области экономики могут применить свои компетенции.
Ключевые слова: умный город; экономический анализ; финансовый анализ; экономическая эффективность; Скопус; библиометрия; библиометрический анализ; проблемно-ориентированная информационная база; обзор литературы.

1. Introduction

The processes of globalisation facilitated the urbanisation level and put forward the new requirements for production conditions all over the world. The role of the city has changed, and accordingly the city has started the chain of changes for corresponding to the new conditions and new processes. Therefore, the concept of Smart City appeared. There are numerous definitions and concept formulations, and it is difficult to choose the only one. Moreover, each researcher can find the definition corresponding to his scientific interest and area.

Nevertheless, there are some common components in determining Smart City. For example, according to Bibri (2018), they are the latest communication technologies, smart energy system, advanced systems within many spheres - from construction to research and development. According to Soderstrom, Paasche, and Klauser (2014) it is real monitoring of all the processes within all infrastructure objects. Angelidou (2015) considers sustainability as a constituent part of smart city and some researchers (Martin, Evans & Karvonen, 2018) differ it in developed and developing countries. Sta (2017), Anisetti et al. (2018) and Silva, Khan, & Han (2018) concentrate on the standard of living within the smart city. Lazaroiu & Roscia (2012) speak about the existence of special strategies for city planning. It is possible to continue for very long time, and new and new properties will be reflected in new definitions. Nevertheless, all these definitions have a common feature: the concept of smart city presupposes intensive employment of technologies in all processes within the city.

Therefore, it is quite natural, the technological issues in all spheres are primary in smart city, and this fact is perfectly supported by the content of the scientific publications devoted to the problems of smart city. Nowadays the smart technologies have found their implementation in

everyday life of people. Their practical life is not science fiction but actual situation. As all practical, not only theoretical solutions they have to have some economic terms. All the technologies require certain financial basis, they all have the certain costs, and it is supposed, they must bring certain benefits. In perfect situation these benefits are not only social, environmental, educational etc., but also economic and financial. The circumstances of practical employment of state-of-the-art technologies require the analysis of costs and benefits of each technology implemented in the real life.

The first steps in the area of smart city and smart technologies were devoted entirely to specific technical issues. Nowadays the more developed technologies are represented in the market, the higher is the necessity in the economic basis for these technical solutions. The idea of «costs» and «benefits» becomes more urgent for Smart City the latest decade.

Therefore, current research is devoted to the review of cost analysis of smart solutions, considered in the scientific publications.

This research presents a systemic review of publications related to the research question: ***do the researchers demonstrate economic or financial substantiation for implementation of smart solutions for different dimensions of smart city?*** This approach makes my study different from other literature reviews in the area, since they consider other research questions. The goal of the research is determining the publications presenting the economic or financial substantiations for smart solutions for smart city.

2. Methodology of the Research

The study is organised in correspondence with structure presented by Wee & Banister (2016).

The first stage is planning stage. It comprises developing the plan of the study, setting goal and question of the research, choosing the key words and the criteria of inclusion and exclusion the publications in the research.

Since the conventional economic and financial analysis is based on cost analysis, the following key words were specified as the search words: smart city, costs, cost approach. The query involved the following operators: «smart» OR «smart city» AND «cost» OR «cost approach». The search with these keywords was directed on both the titles and abstracts of the articles.

The following criteria for including the articles were applied: academic articles included in Scopus database; available online in full text; articles in English only; articles relevant to the research goal and research question. Exclusion criteria: the publications not corresponding to the inclusion criteria.

The second stage is the stage of making review. The query to the database was taken in June and July 2020. The query was done with the key words: «smart» OR «smart city» AND «cost» OR «cost approach». The primary selection resulted in 927 publications, including 148 publications in Open Access sources and 779 publications in other sources. The time span for the search was 1993-2020. The number of publications by years is presented in Figure 1.

It demonstrates the growth of understanding the necessity to apply the economic or financial substantiation to technical solutions within smart city; at the stage of implementation of smart city concept in practice it becomes absolutely urgent; it also evidences indirectly that the cities
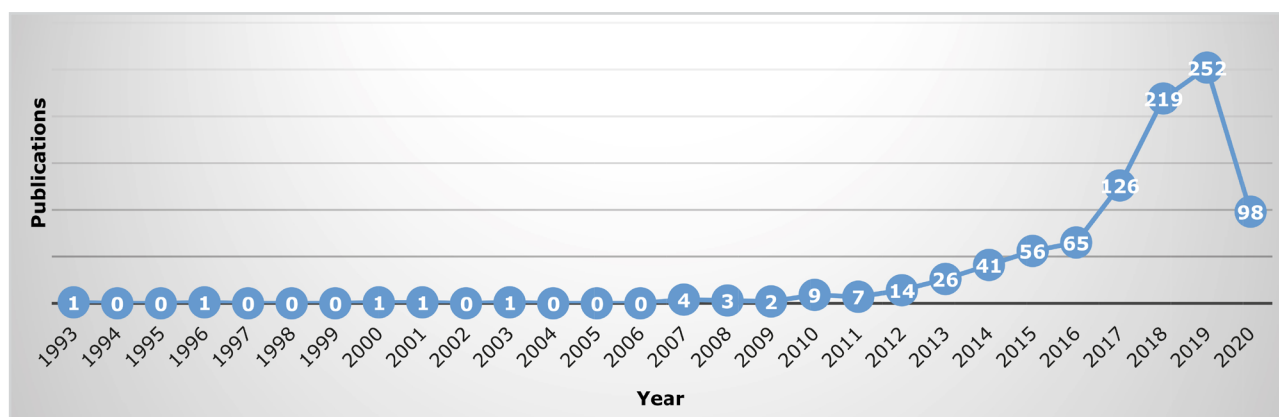

Figure 1:
Choice of publications by year according to the selected criteria (1993 - July 2020)
Source: Compiled by the author using data of Scopus database

are becoming smarter and smarter each year, and more and more solutions must have economic basis.

The publications are devoted to various topics and appeared in various journals. The division of the publications by fields of study is presented in Figure 2
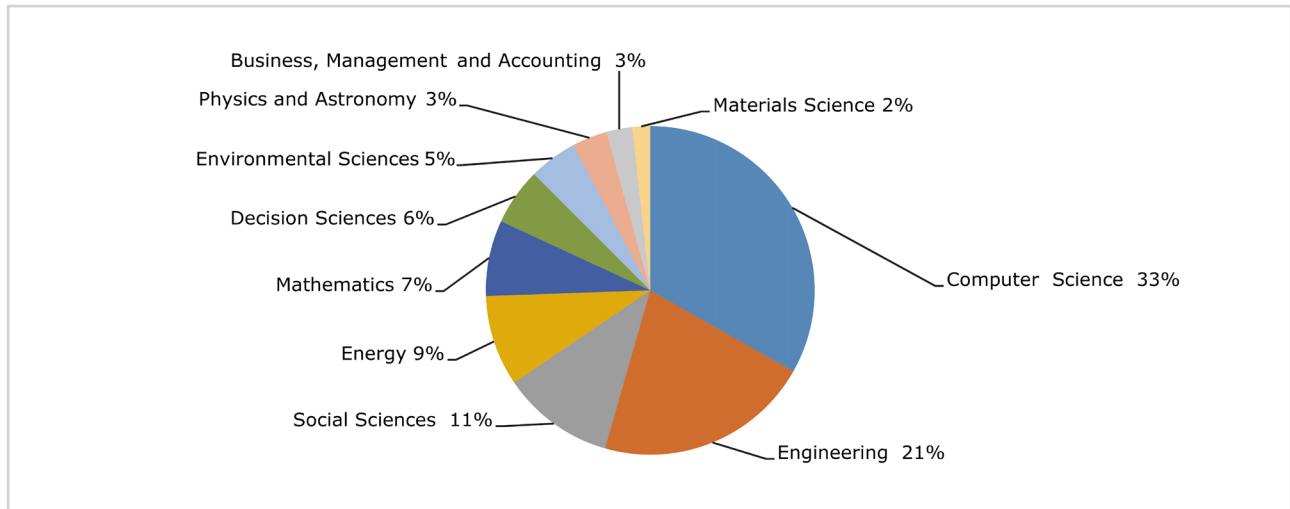

Figure 2:
Publications by subject areas
Source: Compiled by the author using data of Scopus database, Statistical Analysis

Quite expectable, the greatest deal of studies was done in such areas as Computer Science and Engineering. Nevertheless, the fact that such type of query resulted in inclusion of the researches from Business area demonstrates that the interest to smart city appears among scholars concerned with business, finance and economics as well.

Next step was reading the abstracts of the detected articles for understanding whether they correspond to the set criteria or not. As a result, 159 articles were chosen for detailed analysis after admitting them as accurately and consistently corresponding to the research goal. The most important reasons for excluding 768 publications from the analysis after reading the abstracts were as follows: it is denoted that cost efficiency is determined due to the price/cost of one device; many researchers wrote about costs for consumers, practically, in this case the study is devoted to the price-decrease for clients, not costs; many studies are devoted to time, transparency, environmental or social costs; considered only cost of one resource for one device/process, but not for the entire smart solution; costs is just one part of multiple-component function.

The time span for these selected publications is 2012-2020. No articles, published before the year 2012, were selected due to the reasons, shown above. The relation between the publications chosen before and after reading the abstracts is demonstrated in Figure 3.

As Figure 3 evidences, the growth of the number of publications on the topic leads to corresponding increase in papers considered as relevant for the study. In the latest years, each 4th or 6th
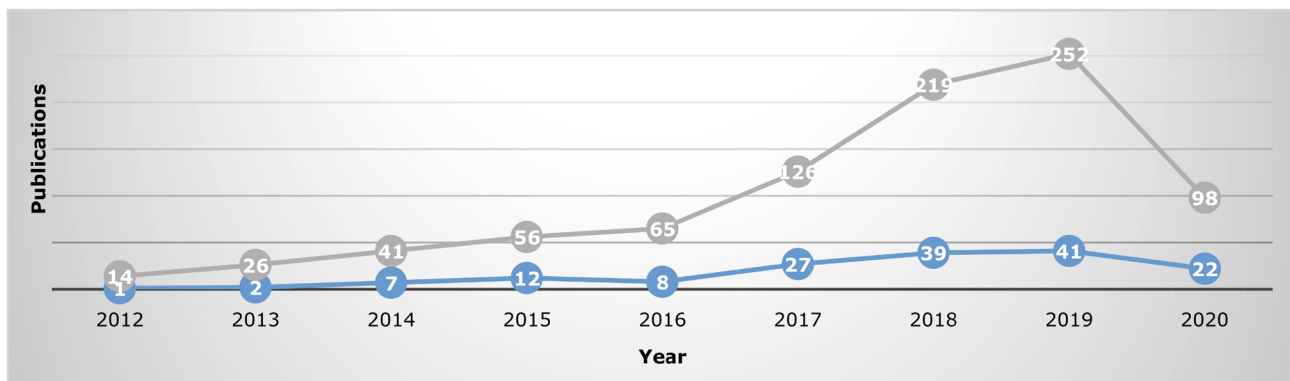

Figure 3:
Publications selected before (in grey) and after (in blue) reading the abstracts, by years
Source: Compiled by the author using data of Scopus database

publication considers costs in some way. This fact indirectly proves that the time of economic and financial estimation of smart projects has come.

The third stage included the detailed reading of the selected 159 articles, answering the research question and making conclusions about the degree of inclusion of cost analysis in scientific publications devoted to smart city. Very important part of this stage is writing the review report on the selected articles. The research uses mostly the descriptive analysis for obtaining the answer for the research question and writing the review of literature on the subject for achieving the goal.

3. Results

The word «cost» appears in numerous researches. The aim of this study is to review the degree of development of «cost» analysis which is promised by the scholars in the abstracts for their scientific publications.

After the detailed analysis of the published papers, it becomes obvious, that the cost analysis (or economic or financial analysis) is very rare in the presented papers. The majority of analysed researches use the sum of costs of separate components of the device or system or process. This approach is quite general for researchers involved in engineering process. Nevertheless, the concept of cost analysis is substantially wider than just summing up the cost of resources.

It presupposes recognising the different types of costs, first of all. For example, costs of installation are usually quite substantial, but they present one-time expenditure. The operational costs appear during the whole period of device/system exploitation. Any process has indirect costs, and sometimes these indirect costs are even bigger than the direct ones. Another issue is opportunity costs, which sometimes are more significant for the decision making about employing the device/system/project.

The cost benefit analysis which is often declared in the abstract for the publication is another very important type of economic analysis. It presupposes monetary form of benefits, moreover, it concerns the future cash flows which will be the result of some activities taken today. Therefore, it is important to consider the value of money today and tomorrow. So, it requires not only determining the volume of future cash flows but also periods of their coming in, and then the process of transformation of future value to the present value (discounting process) or vice versa for comparing the incoming and out-coming cash flows.

Quite often the introduction of new device/system/process results in not monetary benefit, but in some other gain - for example, time, efforts, convenience. If it is possible to express these changes in terms of monetary units then it is also part of cost benefit analysis. Nevertheless, cost effectiveness analysis is used to find out whether the outcome worth of investment or not, and it can include the effects which are not usually expressed in monetary form. However, we have the tools for transferring almost all values into monetary form, and if it is done, then we face the cost-benefit analysis.

The authors quite often write about cost efficiency analysis. The difference between effective and efficient is clear: effective - achieving the result, while efficient - achieving the result in the most economical way. It is possible to assume that the authors of researches should compare the implementation of two projects in terms of cost-benefit analysis. If it is said that the device/system/process is cost-efficient, it is assumed, that the researcher has produced the cost-benefit analysis or at least cost analysis and compares the results of implementation of two devices/systems/processes.

It is short terminological introduction necessary for understanding the economic analysis in any form within the concept of smart city.

After analysis of the publications selected for analytical reading on the purpose to estimate the level of economic or financial analysis contribution, *the following findings could be mentioned*.

Only 22 researches out of 159 studies under consideration present the full or partial cost analysis or cost benefit analysis. They are quite approximately divided into such fields as «Energy», «Utilities», «Population Living», «Smart Devices» and one study is devoted to Robots and artificial intellect. Certainly, the division is very conditional, the areas are overlapping, and the boundaries between the fields are blurred. Nevertheless, the general division allows grouping the researches. The results are presented in Figure 4.

The biggest number of studies are in «Energy» field. It is quite expectable result, since solutions in the area of energy supply and consumption are the most vivid for calculations. Moreover,
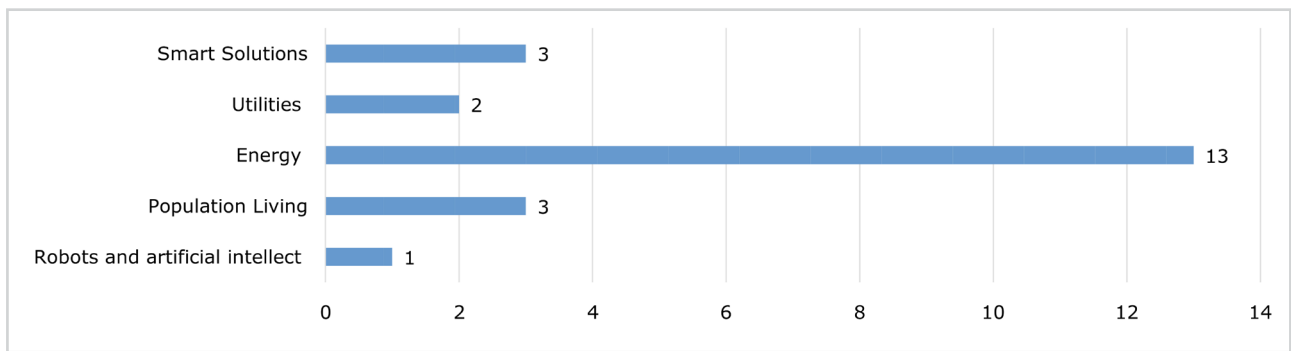
Figure 4:
Distribution of the selected 22 studies by the research areas
Source: Compiled by the author using data of Scopus database

energy sphere requires substantial investments, and it presupposes the detailed calculations for decision making. Another factor is comparatively easy prediction of the future cash flows as well as very accurate calculation of investment amount. Since the calculation of WACC is not a problem for the projects with accurate calculation of investment, and the predicted cash flows are also possible for accurate calculations, this fact allows the process of discounting and therefore the calculation of NPV, IRR, discounted payback period.

If to consider the years of publishing for the selected researches, the situation is as follows (see Figure 5).
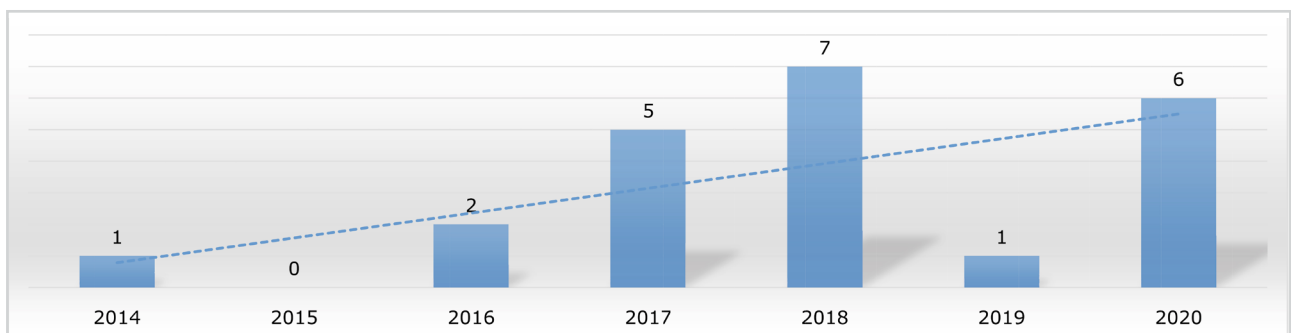

Figure 5:
Number of the selected publications by year
Source: Compiled by the author using data of Scopus database

The trend shows that the number of publications with detailed implementation of economic or financial analysis increases in the latest years. The necessity in comprehensive economic or financial analysis with wide implementation of smart solutions in life is evident. It opens great opportunities for the scholars in the nearest future.

The summary of these researches is presented in Table 1.

The studies shown in Table 1 are devoted to technical solutions, the authors do not set the cost analysis or cost benefit analysis as a goal of the research; nevertheless, they complete a very important task of giving the economic or financial substantiation for the technological solutions. These publications evidence the significance of the aforementioned approach.

In general, the researches dealing with smart city concentrate on the technological or engineering part of the smart device/system/process. They use the terms «cost-efficiency» or «cost analysis» as one of the argument for employing the innovation which they describe. For supporting their idea, they use very simple summing up of the costs of the components. Nevertheless, from economic point of view it is not enough for decision making. They often do not differ one-time investments and operational costs, which can result in quite serious mistake; they do not consider the indirect costs, which can be very significant, especially in case of introduction the state-of-the-art technology, which requires serious administration. At last but not the least, they do not consider the opportunity costs, and it can result in serious economic losses. Quite often the introduction of new technology requires the refuse of the previously used one, and this process can be really costly, and these costs must also be considered. Certainly, this situation cannot be considered as a mistake of the researchers, since they do

not set the goal of presenting comprehensive economic or financial substantiation of the offered smart solution.

After analysing other studies, it was found out that many scholars use the terms «cost analysis» and most often «cost efficiency» without really addressing to the cost analysis or analysis of efficiency. It is possible to assume that these types of analyses were done by the authors, but they do not find it as necessary to show them in the articles. They use the words «low cost», which means they have compared the costs of the devices/systems/processes, but this comparison is not included in the researches. The fact of excluding the process of cost analysis from the research does not allow considering these studies within the scope of publications taking into account the cost analysis.

4. Discussion

The main issue that the author would like to discuss is the lack of papers concerning the economic and financial substantiation of the smart solutions. The concept of smart city comes into practice, and as all part of life, the smart city requires not only technical and technological solutions, but also precise and accurate calculations of costs, monetization of benefits, return on investment. When theoretical provisions come into life, the urgent necessity in economic basis for them becomes actual. Therefore, smart city is the field for researches, provided by economists. It is time to join the efforts of specialists in multi-disciplinary studies (which already happens in Smart City solutions) including economists.

Table 1:
Summary of cost analysis presented by the researches

Researches	Field of Research	Cost analysis
Bataev et al. (2020)	Robots and artificial intellect	Demonstrated a very deep cost analysis of a robotic system with artificial intelligence, with estimation of project using financial tools. This article can be highly recommended as an example of cost-benefit analysis of smart solutions.
Turečková & Nevima (2020)	Smart solutions for population living	Detailed cost-benefit analysis; there also presented the review of literature devoted to smart solutions.
Pournaras et al. (2019)	Population living in digital society	Presented the economies of scale in communication cost.
Laha et al. (2020)	Edge Nodes	Presented the analysis of costs of Edge nodes and the profit maximisation under the budget constraint.
Tsegaye et al. (2020)	Utilities / Water distribution system	Presented a detailed analysis of costs, sets the optimization problem for finding the lowest cost, considering such function factors as cost of pipes, energy, pressure.
Ahvenniemi & Häkkinen (2020)	Energy consumption	Cost efficiency is based on comparison of prices of various home appliances with different levels of energy efficiency.
Dongol et al. (2019)	Energy: battery vs grid	Provides economic-benefit analysis basing on the objective function for the price based optimization problem.
Rodrigues Filho et al. (2018)	Energy / Utilities	Analysis of impact of deviation in electricity input on economy for 1 year period.
El Yamami et al. (2018)	Smart devices	Provide guidance for device for full cost management, including calculation of direct/indirect costs, costs limit for decision making, degree of cost estimation precision, cost reporting procedure and formulae for cost performance.
Li et al. (2018)	Energy	Provides deep cost analysis and cost-benefit analysis of the battery storage system.
Bačeković & Østergard (2018)	Energy	Consider cost structure of various scenarios and provide cost analysis.
Dominković et al. (2018)	Energy	Provides analysis of externalities.
Sarma & Ganguly (2018)	Energy / Transport	Present reliable fuel efficiency analysis, with some points of monetisation. The authors claim it as a cost benefit analysis, and partially their study corresponds to this analysis.
Ramli et al. (2018)	Energy	Presents calculation of electricity cost considering economic approach, not only adding costs of components.
Huang et al. (2017)	Energy	Comprehensive costs analysis.
Ferreira et al. (2017)	Utility	Comprehensive cost analysis, including depreciation and idle units costs, NPV, description of procedure for benefit calculation.
Chen et al. (2017)	Smart devices / Location	Traditional well-formulated cost function is developed.
Al-Saadi & Al-Jabri (2017)	Energy	Costs function is presented, considering the discount rate, life cycle, cost of energy with and without subsidies.
Beccali et al. (2017)	Energy	Provides cost analysis regarding fixed and variable costs.
Gavalas et al. (2016)	Population / Sharing Economy	Use cost approach to modelling.
Boeri et al. (2016)	Energy	Calculated costs of technical solutions.
Alamaniotis et al. (2014)	Energy	Presents a good model of pricing.

Source: Compiled by the author using data of Scopus database

5. Conclusion

This study addresses the research question: Do the researchers demonstrate economic or financial substantiation for implementation of smart solutions for different dimensions of smart city? The goal of the research is determining the publications presenting the economic or financial substantiations for smart solutions for smart city. Therefore, it is a systematic review of publications devoted to the smart city solutions and simultaneously considering the economic and financial issues.

Only 22 studies of 927 papers from Scopus database, containing terms «cost efficiency», «cost effectiveness», «cost analysis» and «cost benefit analysis» were selected for detailed analysis. These 22 researches present various types of economic and financial analyses, differ in tools and way of implementation, but they give the economic basis for smart solutions for smart city.

The value added of this research is specifying the fact that very few papers devoted to smart solutions within smart city comprise the comprehensive economic or financial analysis, and it is time for multi-disciplinary researches in the field, including the economists.

The study allows the scholars to use the reviewed publications as providing the economic and financial basis for smart city; it also demonstrated the lack of such publications and discovers the area where specialists in economy can apply their competences.

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