THE COVID-19 PANDEMIC AND ITS IMPACT ON SMART CITIES CONCEPTS

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Abstract

The Covid-19 pandemic has changed the daily lives of millions of people around the world. Its impact has also been felt in the Smart Cities concept. The aim of this paper is to identify the main challenges created by the Covid-19 pandemic through its impact on the Smart Cities environment. To achieve the objective, a secondary analysis of 80 peer-reviewed relevant articles from Web of Science and Scopus databases between 2020 and 2021 was used. The results of the paper are intended for use by fellow researchers, strategic Smart Cities management and citizens interested in the future direction of their cities. The findings suggest that cities should promote the development of new technologies, not forgetting the social aspect, the needs and participation of citizens through communities, and the protection of the environment in the field of sustainability of resources for future generations.

Key words: Smart Cities, Covid-19, Challenges, development, management

1   INTRODUCTION

The Smart Cities market is influenced by global trends of urbanization, the use of advanced technologies such as the Internet of Things (IoT) or artificial intelligence, ecological aspects of limited resources, and pandemics. Despite the coronavirus, experts forecast the Smart Cities market to grow at a CAGR of 18.22% during the time span of 2021 to 2026 [25].

The first outbreak of Covid-19, the so-called SARS-Cov-2 respiratory syndrome, was recorded in December 2019. According to statistics evaluated on February 1, 2021, more than 2 million people have succumbed to the virus, with more than 100 million infected from 210 different countries around the world [29].

The pandemic has spurred the development of new technologies that replace the social factor in different areas, reducing the risk of transmission between people [29].

Strategic management at the national, regional and local levels must deal with stabilizing social distance, economic growth, adherence to quarantine measures, or promotion of science and research. Covid-19 created the need to look for global collective solutions not only in the health sector based on a more user-oriented management system, i.e. bottom-up [26].

The impact of the pandemic has been particularly evident in major Smart Cities such as Milan, London, New York and Paris. Covid contributed to the disruption of the simultaneous flow of two basic managerial functions, i.e. planning and organising. However, rural urbanisation has embraced the virus more resiliently than cities with high population densities, a preference for individual transport and a lack of green space. Research suggests that future Smart Cities need to improve spatial planning, use digital services and tools, and invest in science and research. These changes can be achieved through a holistic and multidisciplinary approach. Covid has affected the whole world and all cities, but with different intensity. Better prepared cities, with digitalization-based Smart City concepts already in place, generally coped better with the pandemic [10].

Smart Cities and innovation form a win-win strategy, as innovative technologies are the driving force behind the development of Smart Cities that support research activities. City stakeholders have reacted differently to the new pandemic situation. The government has ordered restrictions, regular testing, border control and financial assistance. Businesses and

educational institutions have cancelled business trips and introduced home-office. Citizens in the early stages of the pandemic bought durable goods in bulk, used online tools such as MS Teams and Zoom, and used online data. ICT infrastructure and its future innovative development play a key role in coping with these responses. Kim argues that Smart City concepts will dominate plans for growth in sustainability, livability, productivity, and the strengthening of technological and social connections [11, 15, 16].

2 THEORETICAL BACKGROUND

Smart City is a concept of urban development that seeks to address social problems through the use of information and communication technologies (Manville et al., 2014; Chun et al., 2021). According to Dirks et al. a focus on the effective use of technology, analytics and systems thinking for the needs of sustainability and citizen satisfaction is typical of smart cities [4, 6, 15, 16]. (Dirks et al., 2010; Chun et al., 2021; Koman, Kubina, Holubčík, Soviar, 2018).

According to the authors, a Smart City represents "a city inhabited by a high number of different ethnic groups that can cohabitate and generate synergies based on the perception and management of diversity as a competitive advantage of 21st Century Smart Cities" [28].

Magare, Kondekar, and Dudhgaonkar view the Smart City concept as a key platform and digital ecosystem that can effectively collect, share, analyze, and leverage Big Data in times of pandemic [22].

The Covid-19 pandemic has affected the future development of Smart City in the areas [22]:

- development of advanced trend technologies,
- education,
- social planning,
- security,
- sustainability,
- monitoring.

There are mutual feedbacks and relationships between the Covid-19 pandemic and Smart Cities concepts. According to a research study by Yang and Chong, control and prevention affect communities, strategic city management, information, and health care levels. Results from Chinese projects argue that if the government invests 1 million yuan in smart pandemic solutions, the number of positive cases will decrease by 0.342 per 10,000 inhabitants [30].

Costa and Peixoto view the Smart City as a living organism that should grapple with the pitfalls of civilizational epidemics through detection, alerting, and mitigation processes [5].

Smart City concepts, by building new technologies and responding quickly to pandemic challenges, can detect outbreaks in real time through sensors, IoT, and the network, and effectively improve management functions of planning, control, and monitoring processes [8, 30].

3 METHODS

The aim of this paper is to identify the main challenges created by the Covid-19 pandemic through its impact on the Smart Cities environment. Secondary analysis of relevant publication sources from Web of Science and Scopus databases was used to fulfill the stated objective. In both databases the keywords "smart cities and covid-19" were searched, in Scopus the search criteria were filtered as follows:

(TITLE-ABS-KEY (smart AND cities AND covid-19)) AND (challenges) AND (LIMIT-TO (OA , "all")) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019))

To ensure temporal relevance, articles were selected from the current period 2021 compared to the previous period 2020, with a preference for open access publications. The first filtering

generated 55 articles of interest in 2020 and 28 in 2021 in Web of Science, while in Scopus it was 134 articles for 2020 and 67 in the current year 2021.

The second filter included all previous criteria with the addition of the new keyword "challenges". In Web of Science, 13 articles from 2020 and 9 from 2021 were identified in this way. In Scopus, 35 articles from 2020 and 23 from 2021 (until April) were identified that matched the keywords "smart cities", "covid-19", "challenges" (Table 1).

Table 1. Number of relevant publications in WoS and Scopus databases in 2020-2021

Year	Number of relevant publications with keywords "smart cities", "covid-19", "challenges"	
	Web of Science	**Scopus**
2020	13	35
2021	9	23

Source: own processing according to selection results in WoS and Scopus databases

For the selected articles, the abstracts were read. Their analysis revealed a similar focus, based on which they could be assigned to the three categories created (technology, sustainability and communities in Table 2).

Table 2. Number of relevant publications classified into the three categories

Database	Category		
	Technological development rozvoj	**Sustainability**	**Community formation**
Web of Science	12	8	2
Scopus	34	18	6

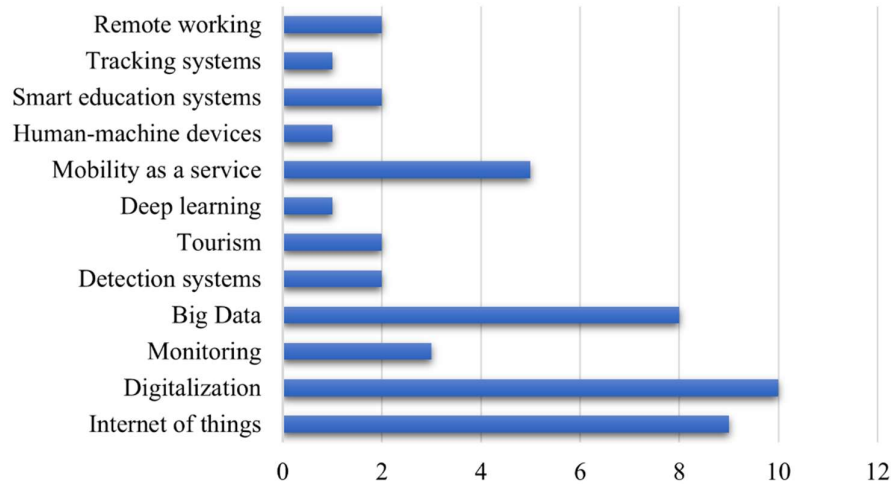*Source: own processing according to selection results in WoS and Scopus databases*

Technology-oriented articles make up a significant majority, accounting for 55% of relevant articles in Web of Science and 59% of relevant articles in Scopus. Sustainability-focused articles come second (WoS 36%, Scopus 31%). The third category is represented by articles on communities, with a 9% share in WoS and a 10% share in Scopus. The primary task of the Results section was to identify and summarize the specific challenges posed by the Covid-19 pandemic in the categories of technological development, sustainability, and community formation.

4 RESULTS
4.1 Technological development challenges
Of the 46 articles in the technology category (Table 2), 10 of them, i.e. 22%, were focused on digitalisation and 9 publications (20%) on the Internet of Things. These two elements represent the main challenges of the Covid-19 pandemic in the technological aspect of the Smart City concept (Figure 1).

Figure 1. Thematic focus of the articles in the technological development

Source: own processing according to selection results in WoS and Scopus databases

The following topics were also covered:
- Big Data (8 articles, i.e. 17%),
- Mobility as a service (5 publications, 11%),
- process monitoring (3 articles, 8%),
- 2 articles (4%) were published in each of the areas of detection systems, tourism, educational systems and remote working,
- deep learning and tracking systems had 1 article each (2%).

Globally, the pandemic has highlighted the importance of quality information and communication technologies, public administration applications and the availability of digital infrastructure for all [7, 20].

According to Marston, Shore, and White, digital technologies can solve future societal challenges in Smart Cities concepts, which include Covid-19 [23]. Strategic management of cities has applied different approaches for managing the virus depending on their geographical location. While Asian cities address Covid-19 by incorporating modern technology, Western cities focus more on the human aspect of the virus and adherence to quarantine measures. Although the technological approach is more productive, it places little emphasis on the needs, attitudes and demands of citizens [17].

Reduced travel and the negative impact on tourism to once popular holiday destinations is also an important challenge for today's cities. Governments are therefore promoting new forms of virtual tourism including unmanned aerial vehicles, such as convergence-smart tourism cities [19]. As of March 2020, the pandemic has also had a rapid impact on the teaching process of educational institutions. Distance education appeals to the need for the development of the Internet of Things, which will contribute to achieving the smart universities of the future [24].

In addition to digital tools and advanced IoT technology, new diagnostic monitoring systems have begun to be developed through the use of smartphones and online platforms of each patient's medical record. For example, the system has been implemented in the Korean city of Daegu. Its benefits consist of real-time data and higher efficiency of monitoring processes [12, 13]. Scanning techniques using deep learning principles are also currently being used to prevent Covid-19 for the need of analysis of medical imaging tools and methodologies [1].

4.2 Smart Cities Sustainability Challenges

Pandemic Smart Cities challenges, for the sustainability category, have been published in 26 relevant peer-reviewed articles. A significant proportion of the publications were oriented towards the area of preference for technological approaches and appealing to the importance of social approaches to Smart City management (10 articles, i.e. 37%).

Figure 2. Thematic focus of Smart Cities sustainability articles
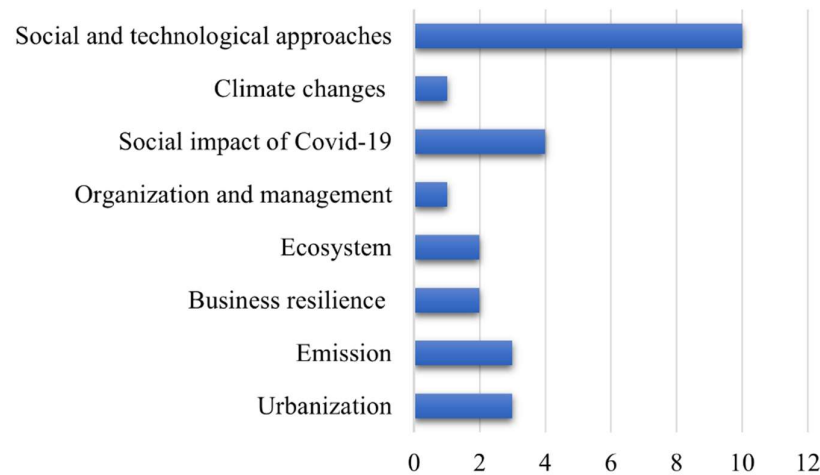
Source: own processing according to selection results in WoS and Scopus databases

The secondary most covered issue was the impact and challenges of the pandemic on the social life of urban dwellers (4 articles, 15%). Articles analysing:

- Urbanization trends (3 articles, 12%),
- reduced emissions (3 articles, 12%) during the home-office,
- business resilience (2 articles, 8%),
- ecosystem (2 articles, 8%),
- climate change (1 article, 4%),
- organisation and management (1 article, 4 %).

To meet the long-term sustainability goals of Smart Cities by 2030, digital architectures and services need to be built primarily at the household level with a secondary extension to the city to national level. In times of pandemic, the need for digital tools during home-office work has increased [14]. Social distance and regulatory measures caused a reduction in mobility, thus decreasing emissions in direct proportion. A study from Cyprus argues that through pandemics, distance learning and home-office, the region saved 4 litres of fuel and produced 7.4 kg less CO_2 per hour, contributing to a lower ecological footprint for humanity [18]. Survey results from Sui et al. in 2020 provide a counter-argument that 56.3% of post-pandemic travellers want to reduce their travel by public transport and make more use of private car transport. However, doing so will increase the number of emissions produced in the future [27].

Surprisingly, rural areas have coped better with the pandemic, as confirmed by research in Romania arguing the importance of Smart City issues, sustainability and entrepreneurial initiatives [9]. A major sustainability challenge is the increased demand for protective medical equipment (gowns, respirators) that needs to be recycled after use. The challenge for cities is to provide a smart waste disposal system in collaboration with Industry 4.0 in the circular economy [3].

4.3 Challenges in building communities

Only 8 articles were identified in the category of community building challenges. Within the topics, the authors mainly preferred the area of planning (2 articles, i.e. 25%) and civilization transition (25%).

Figure 3. Thematic focus of articles in the area of community building
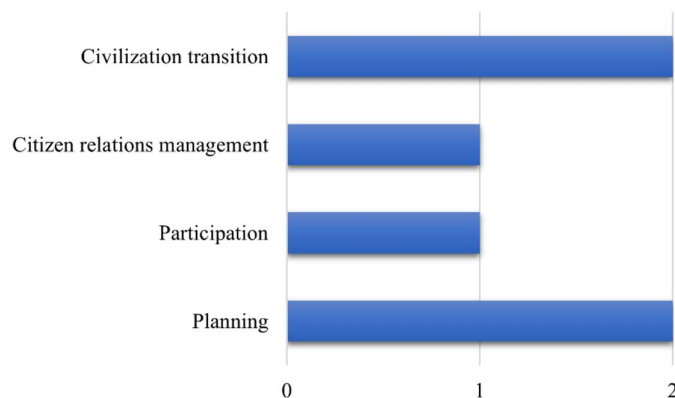
Source: own processing according to selection results in WoS and Scopus databases

Issues also included professional publications on partcipation (1 article, i.e. 12.5%) and citizen relations management (12.5%, Figure 3).

In the current pandemic situation, it is not enough to build classical communities, but it is essential to generate intelligent clusters of people. The new standard for building Smart City communities in 2021 should be based on the collective values, expectations, needs and demands of all city stakeholders. Smart citizens no longer just occupy the role of technology users, but also participate in the city's planning and innovation processes. An important challenge of the future is to provide immediate feedback and generate urban social innovations [2].

For Smart Cities to be successful they need to know the psychological needs of citizens above all in critical times of pandemics, for example through the new integrated platform NeedFull, or the modern framework of so-called Virtual Communities in Practice [2, 21].

Virtual Communities of Practice (VCoPs) function as social learning systems that co-create the universal design of a city. Smart Cities should prefer to focus on problem solving and prevention, which is more effective than just collecting raw data with unmanned aerial vehicles from the field. According to Bricout et al. the community building pandemic has created a challenge in the form of the need for communities of citizens to respond quickly to technical, social and ecological changes [2].

5   DISCUSSION

The topic of Smart City in connection with the challenges posed by the Covid-19 pandemic is very present. The new challenges in the field of technology, which should be more centric to the needs of the inhabitants, safe and supportive of sustainable intentions, should be addressed by the strategic leadership of the city with its initiatives, development plans and organizational structures.

The limitations of the article are the logical reduction of articles from two databases (Web of Science, Scopus) according to the identified keywords in the time period of 2020 and 2021.

The evolution of technology is subject to constant change, and it was therefore necessary to identify the main challenges summarised in Table 3 that affect cities today and will also drive their future direction, as the post-pandemic world will never be the same again.

In terms of the technology category, cities need to ensure that, once the pandemic has been contained, they will first and foremost provide monitoring, scanning and digitisation processes, collaborate in the development of new forms of tourism and not forget the social aspect of technological development.

Table 3. Summary of the main challenges of Smart Cities in the context of Covid-19

Categories	Challenges identified
technology	real-time data monitoring with sensor and UAV (unmanned aerial vehicles)
	scanning techniques based on deep learning
	development of internet of things and the digitalisation process
	focuding not only on technologies, but also on the social aspect
	need for new forms of tourism (for example using drones)
sustainibility	massive increase in medical waste
	increase in the need for digital tool
	an increase in emission after the pandemic due to the preference for individual transport for safety reasons
	need to build greater resilience of cities to change
communities	community building should be based on collective and psychological needs
	participating communities need immediate feedback in an online environment

Source: own elaboration according to the results found in the Results section

In the context of sustainability, the strategic management of cities should focus on the efficient management of medical waste, digitalisation and the increase in emissions from road transport. Smart Cities for the future need to build participatory smart communities, know the needs of their citizens and build greater resilience to unpredictable changes.

6   CONCLUSION

The importance of building Smart City concepts deepens especially in difficult times of pandemics. The aim of this paper was to identify the main challenges of the impact of Covid-19 on aspects of Smart Cities. Analyzing relevant publications that are published in Web of Science and Scopus databases in 2020 and 2021 (until April) identified three areas of challenges, i.e. technological, sustainable and social.

In the technological area, the pandemic is accelerating digitalisation, the development of advanced technologies, the implementation of monitoring through drones or the preference for socially oriented technologies. Currently, it is important that citizens not only act as users of technology, but also as co-creators. According to the approvers, this goal can be achieved by creating smart communities. Smart cities of the future should be adaptive to change, ready to protect scarce resources and able to dispose of the large amounts of new waste generated in the form of gowns and respirators in an environmentally friendly way.

In future research activities, it is planned to map the situation after the end of 2021, since in the current situation the pandemic is still ongoing and the dynamic development of technology, scientific and research activities in the field of Smart City and the pandemic Covid-19 may bring new interesting results from the studies of foreign experts.

REFERENCES

1. Bhattacharya, S., Maddikunta, P.K.R., Pham, Q.V., Gadekallu, T.R., Krishnan, S.S.R., Chowdhary, C.L., Alazab, M., Piran, M.J. (2021). Deep learning and medical image processing for coronavirus (COVID-19) pandemic: A survey. Sustainable Cities And Society, 65. doi: https://doi.org/10.1016/j.scs.2020.102589

2. Bricout, J., Baker, P., Moon, N., Sharma, B. (2021). Exploring the Smart Future of Participation: Community, Inclusivity, and People With Disabilities. International journal of e-planning research, 10(2), 94-108. doi: 10.4018/IJEPR.20210401.oa8

3. Chauhan, A., Jakhar, S. J., Chauhan, C. (2021). The interplay of circular economy with industry 4.0 enabled smart city drivers of healthcare waste disposal. Journal of Cleaner Production, 279. doi: 10.1016/j.jclepro.2020.123854

4. Chun, S. A., Kim, D., Cho, J.-S., Chuang, M., Shin, S., Jun, D. (2021). Framework for Smart City Model Composition: Choice of Component Design Models and Risks. International Journal of E-Planning Research (IJEPR), 10(3), 50-69. http://doi.org/10.4018/IJEPR.20210701.oa4

5. Costa, D.G. and Peixoto, J.P.J. (2020), COVID-19 pandemic: a review of smart cities initiatives to face new outbreaks. IET Smart Cities, 2: 64-73. https://doi.org/10.1049/iet-smc.2020.0044

6. Dirks, S., Gurdgiev, C., & Keeling, M. (2010). Smarter cities for smarter growth-- How cities can optimize their systems for the talent-based economy. IBM Global Services. Available on: https://www.zurich.ibm.com/pdf/isl/infoportal/IBV_SC3_report_GBE03348USEN.pdf

7. Ho, C.W.L., Caals, K., Zhang, H. H. (2020). Heralding the Digitalization of Life in Post-Pandemic East Asian Societies. Journal of Bioethical Inquiry, 17(4), 657-661.doi: 10.1007/s11673-020-10050-7

8. Holubčík, M., Koman, G., Varmus, M., Kubina, M. (2019). A Model Approach for the Formation of Synergy Effects in the Automotive Industry with Big Data Solutions: Application for Distribution and Transport Service Strategy. EAI/Springer Innovations in Communication and Computing, 2019, pp. 467–488. doi: 10.1007/978-3-319-76998-1_34

9. Ignat, R., Constantin, M. (2020). Multidimensional Facets of Entrepreneurial Resilience during the COVID-19 Crisis through the Lens of the Wealthiest Romanian Counties. Sustainability, 12(23). doi: 10.3390/su122310220

10. Kakderi, Ch., Komninos, N., Panori, A., Oikonomaki, E. (2021). Next City: Learning from Cities during COVID-19 to Tackle Climate Change. Sustainability, 13(6). doi: https://doi.org/10.3390/su13063158

11. Kim, H. M. (2021). Smart cities beyond COVID-19. Smart Cities for Technological and Social Innovation, 299-308. doi: https://dx.doi.org/10.1016%2FB978-0-12-818886-6.00016-2

12. Kim, J. H., Choi, W. S., Song, J. Y., Yoon, Y. K., Kim, M. J. (2021). The role of smart monitoring digital health care system based on smartphone application and personal health record platform for patients diagnosed with coronavirus disease 2019. Bmc infectious diseases, 21(1). doi: 10.1186/s12879-021-05898-y

13. Kirimtat, A., Krajcar, O., Kertesz, A., Tasgetiren, M. F. (2020). Future Trends and Current State of Smart City Concepts: A Survey. IEEE Access, 8, 86448-86467. doi: http://dx.doi.org/10.1109/ACCESS.2020.2992441

14. Kolesnichenko, O., Mazelis, L., Sotnik, A., Yakovleva, D., Amelkin, S., Grigorevsky, I., Kolesnichenko, Y. (2021). Sociological modeling of smart city with the implementation of UN sustainable development goals. Sustainability Science, 16(2), 581-599. doi: 10.1007/s11625-020-00889-5

15. Koman, G., Kubina, M., Holubčík, M., Soviar, J. (2018). Possibilities of application a big data in the company innovation process. Communications in Computer and Information Science, 2018, 877, pp. 646–657. doi: 10.1007/978-3-319-95204-8_54

16. Kubina, M., Koman, G. (2016). Big data technology and its importance for decision-making in enterprises. Communications - Scientific Letters of the University of Zilina, 2016, 18(4), pp. 129–133.

17. Kummitha, R. K. R. (2020). Smart technologies for fighting pandemics: The techno- and human-driven approaches in controlling the virus transmission. Government Information Quarterly, 37(3). doi: 10.1016/j.giq.2020.101481

18. Kylili, A., Afxentiou, N., Georgiou, L., Panteli, C., Morsink-Georgalli, P.Z., Panayidou, A., Papouis, C., Fokaides, P.A. (2020). The role of Remote Working in smart cities: lessons learnt from COVID-19 pandemic. Energy Sources Part A-Recovery Utilization And Environmental Effects. doi: 10.1080/15567036.2020.1831108

19. Lee, P., Hunter, W. C., Chung, N. (2020). Smart Tourism City: Developments and Transformations. Sustainability, 12(10). doi: 10.3390/su12103958

20. Leelavathy, S., Nithya, M. (2020). Public opinion mining using natural language processing technique for improvisation towards smart city. International Journal of Speech Technology. doi: 10.1007/s10772-020-09766-z

21. Long, Z. J., Alharthi, R., El Saddik, A. (2020). IEEE ACCESS, 8, 136046-136055. doi: 10.1109/ACCESS.2020.3011123

22. Magare, S. S., Kondekar, S. R., Dudhgaonkar, A. A. (2021). "Smart City during COVID-19 Lockdown and its Future Impact," 2020 International Conference on Smart Innovations in Design, Environment, Management, Planning and Computing (ICSIDEMPC), 2020, pp. 209-215, doi: 10.1109/ICSIDEMPC49020.2020.9299589.

23. Marston, H. R., Shore, L., White, P. J. (2020). How does a (Smart) Age-Friendly Ecosystem Look in a Post-Pandemic Society? International Journal of Environmental Research and Public Health, 17(21). doi: 10.3390/ijerph17218276

24. Mircea, M., Stoica, M., Ghilic-Micu, B. (2021). Investigating the Impact of the Internet of Things in Higher Education Environment. IEEE ACCESS, 9, 33396-33409. doi: 10.1109/ACCESS.2021.3060964

25. Mordor Intelligence (2021). Smart Cities Market - Growth, Trends, Covid-19 Impact, And Forecasts (2021 - 2026). Available online: https://www.mordorintelligence.com/industry-reports/smart-cities-market (accessed on 28 April 2021)

26. Ramadi, K. B., Nguyen, F. (2021). Rapid crowdsourced innovation for COVID-19 response and economic growth. npj Digital Medicine, 4. doi: https://doi.org/10.1038/s41746-021-00397-5

27. Sui, Y., Zhang, H.R., Shang, W.L., Sun, R.C., Wang, C.Y., Ji, J., Song, X., Shao, F.J. (2020). Mining urban sustainable performance: Spatio-temporal emission potential changes of urban transit buses in post-COVID-19 future. Applied Energy, 280. doi: 10.1016/j.apenergy.2020.115966

28. Šulyová, D., Vodák, J. (2020). The Impact of Cultural Aspects on Building the Smart City Approach: Managing Diversity in Europe (London), North America (New York) and Asia (Singapore). Sustainability, 12(22), 9463. doi:10.3390/su12229463

29. Wang, Ch., Wang, Z., Wang, G., Lau, J. Y.-N., Zhang, K., Li, W. (2021). COVID-19 in early 2021: current status and looking forward. Signal Transduction and Targeted Therapy, 6. doi: https://doi.org/10.1038/s41392-021-00527-1

30. Yang, S., Chong, Z. (2021). Smart city projects against COVID-19: Quantitative evidence from China. Sustainable cities and society, 70, 102897. https://doi.org/10.1016/j.scs.2021.102897

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