Smart-BIM for Smart Cities: Issues and Challenges

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Abstract. Building Information Modelling (BIM) is implemented in several sectors of the Architecture, Engineering, and Construction (AEC) industry. Faced with the challenges of urban management, smart cities are a response to this situation. Research indicates that BIM is one of the technological approaches with great potential for designing, constructing, and managing smart cities. Despite too few systematic reviews, this paper aims to highlight the potential, opportunities, and challenges of integrating BIM into the smart city environment through a literature review. Based on this review, a classification of issues, trends, and challenges has been made. The paper reveals current research gaps and possible future work in smart city management through information technology, specifically BIM. The focus of this paper contributes to the understanding and promotion of technology for smart cities to address the cumulative challenges of urban environments.

1 Introduction

In the 4th industrial revolution era, the AEC industry is embarking on a path of digitalisation. This commitment aligns with solving global challenges such as rapid urbanisation, pollution, sustainable development, and urban management [1].

Many of the processes that have emerged from Construction 4.0 have given a new lease of life and a new opportunity to meet current and future challenges. For example, smart cities and Building Information Modelling (BIM) are two processes associated with managing urban environments. The smart city is a model designed to create joint and collaborative urban management between stakeholders [2].

First introduced in 1990 and widely defined as the harmonisation of six aspects that make a city smart: smart people, smart economy, smart governance, smart mobility, smart life, and smart environment [3]. This notion considers sustainable and efficient management of resources by deploying intelligent systems based on information and communication technologies (ICT) and cyber-physical systems (CPS) [4].

Although BIM was designed for the building industry, it has emerged in all areas of civil construction [5]. Urban design and planning include the indispensable needs of a smart city, such as infrastructure, electricity needs, drinking water supply, sewage and stormwater treatment, and any other public service [6].

There is a growing body of research on the potential role of BIM in improving the services offered by a smart city. As well as a small body of research literature synthesising the ways, issues, and limitations in which BIM can support the design, planning, and construction of smart cities. This paper aims to explore the potential impacts and critical barriers facing the integration of BIM into the smart city environment.

This preliminary research looks to and provides a review and reinvigorates the discussion on the relationship of BIM with the smart city. To do this, the paper is structured as follows. After an introduction of the topic, section 2 describes the methodology adopted. Section 3 presents the main results. Before concluding the paper, a short discussion is presented in section 4.

2 Research Methodology

This study attempted to conduct systematic research on the applications, benefits, and challenges of BIM deployment to promote the smart city concept. Information is collected via scientific databases, including recently published articles up to 2023. The main databases were Scopus and Web of Science. The research combines two key concepts: BIM, which is used in different forms, and the smart city. The following search terms were adopted to consider the different forms that could result from merging this concept: “Building Information Model*” and “Smart Cit*.”

The literature search based on these keywords considered the following limitations:

(i) Research articles, conference proceedings, and book chapters were included.

(ii) TITLE-ABS-KEY was searched for Scopus and ScienceDirect, Topic for WoS.

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(iii) A limitation to the English language only. However, other languages are accepted if the title, abstract, and keywords are in English.

Once the data was available, the literature review was conducted to clarify the trends, applications, and challenges of BIM deployment for smart cities. According to Figure 1, this analysis was divided into two main steps. Firstly, the constitution of the document base and its implementation in the Mendely bibliographic management software. Secondly, the consolidation of the documents. In this stage, three sub-stages were applied. Initially, duplicate articles were eliminated. Then, a content analysis was done with an initial reading of the abstract and the full text. Finally, the database was improved by adding documents related to the relevant references cited. The search identified 78 articles related to the topic and the study under consideration.

3 Results

3.1 Quantitative analysis and publication trends

Looking first at the evolution of this topic. From the selected database, the relationship between BIM and smart cities appears to be in the last decade. The first publication appeared in 2011. The year 2020 records the peak of publications. Figure 2 illustrates the evolution of the published documents until 2023. The data represent the overall trend in research aspects related to BIM and smart cities. Overall, the number of publications varies and reaches 13 in the previous year, with one publication appearing in 2023. This fact shows that the scientific community is paying particular attention to the extensive research on BIM to its deployment in the cities of tomorrow.

This search found 78 documents, divided into 26 journal articles, 47 conference papers, three literature reviews, and 2 BOOK chapters. Over 60% of the papers are established at conferences (see Figure 3).

Looking qualitatively at the participating journals in this discussion. The three journals with the highest number of publications were selected and represented in Table 1.

In the information obtained, the journal Automation in Construction is first an international research journal related to automation and technology in the AEC industry, followed by the journal Sustainability Switzerland which publishes studies on environmental improvement and socio-economic frameworks of human beings. Therefore, it can be expected that most of the articles selected in this journal cover similar topics required for analysis.

It is clear from the table that several journals cover the topic, and there is not one influential journal. However, the intersection between the top 3 scopes reflects the article's focus on deploying BIM as a technology for human benefit in the context of a smart city.

This result also shows that the topic is new, and few newspapers have tackled it. The presence of a large percentage of conference proceedings is a clue to the novelty of this discussion, which remains sketchy and requires capitalisation on the existing too deeply attack future research.

Table 1. Top journals on the subject

Journal	No. Articles
Automation In Construction	3
Sustainability (MDPI)	2
Sustainable Cities And Society	2

As part of this section, an additional analysis was conducted. This is the examination of the countries driving this discussion. Table 2 shows the top 5 based on the authors' university affiliations.

Country	No. Publication	Top University
China	32	The University of Hong Kong
United States	8	Georgia Institute of Technology
United Kingdom	7	Loughborough University
Italy	5	Università degli Studi di Brescia
Australia	4	Curtin University
Germany	4	Ruhr-Universitat Bochum
India	3	National Institute of Technology
Russia	3	Moscow State University of Civil Engineering
South Africa	3	University of the Witwatersrand, Johannesburg
Egypt	2	Cairo University

China leads the countries interested in the development of BIM-based smart cities. According to this ranking, all continents are represented. South Africa and Egypt lead the African continent.

3.2 Using BIM for smart cities

3.2.1 Smart Infrastructures

BIM is known for its potential to create frameworks and integrate with a variety of approaches, both technological and managerial [7]. One of the most renowned frameworks for smart cities is the one developed with Geographic Information Systems (GIS) [8]. This inclusive framework of BIM and GIS allows the planning and forecasting of infrastructure and public service needs. This planning respects the concepts of intelligence and sustainability essential for the performance of a city throughout its expansion and development [9]. All urban systems are intelligently simulated using 3D models to create transport systems, drainage, sanitation, traffic management, and travel conflicts [10].

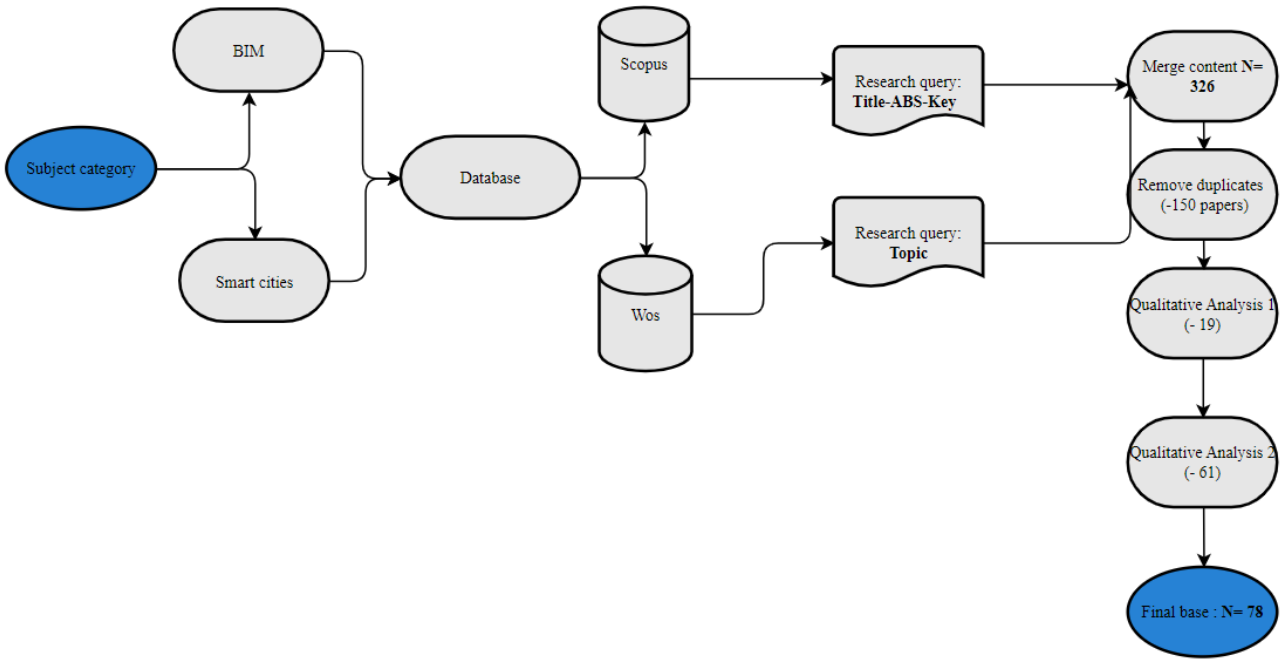

Fig. 1. Research methodology

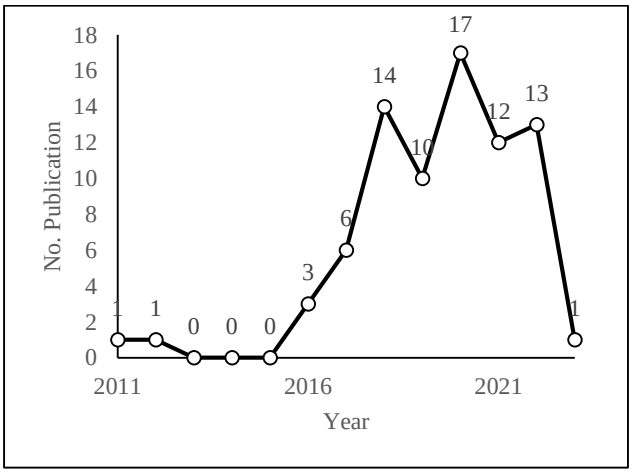

Fig. 2. Publication trends

3.2.2 Monitoring Management

This system is based on wireless sensor networks (WSN) from the Internet of Things (IoT) technology and advanced BIM [11].
Radio-frequency identification (RFID), a wireless collection and reading system, is compatible with 3D BIM, which refers to modelling a city as an object [12]. Thanks to RFID, this combination works in real-time for managing construction sites. This is thanks to obtaining accurate, complete BIM models that integrate real data, such as the location and tracking of resources [13].
Sustainable transport is at the heart of smart city monitoring management [14]. Geo-BIM is the syllable commonly used to describe the combination of GIS and BIM, offering improved traffic monitoring and coordination from the design and pre-construction phases of smart cities [15].

3.2.3 Smart safety cites

The cities of tomorrow must guarantee high security for their inhabitants [16]. This is driving governments to overcome cyber challenges [17]. Undertaking building information and systems is the key to identifying safety, security, and resilience issues in cities [18]. A synergy between BIM and complex cyber-physical systems allows for improved asset management, managing intellectual property well, and ensuring operational safety. This model is only about access control in smart cities but facilitates the design, implementation, and operation of urban systems and processes with the satisfaction of cyber security risks [19].

3.2.4 Urban Energy performance

Reducing energy consumption in construction is one of the reasons to promote the deployment of BIM rapidly. Building Energy Modeling (BEM) is a dedicated extension to simulate the energy consumption of the structure, heating, ventilation, air conditioning systems, and weather conditions [20,21]. BIM or BEM fits perfectly with the energy dimension of the smart city, participating in the analysis and evaluating the energy character to support the planning of this type of city [22,23]. Dursun, İ (2022) developed and applied a technical solution to readjust urban infrastructure and urban energy planning based on GIS-BIM [24]. In Europe, the Smart Readiness Indicator (SRI) concept has been adopted, whose measurement promotes the energy efficiency guidelines of intelligent systems integrated into buildings and smart cities [25]. Mathematical models could improve BIM-based energy assessment methods to increase the accuracy and decrease the error rate in smart buildings and city

construction [26] by deploying a framework with GIS for urban energy performance assessment [27].

3.2.5 Smart city Management

Smart city transformation programs are closely related to BIM [28,29]. Chen et al. (2018) developed a method named Multi-Source Rectification of Geometric Primitives (mSTEP), based on Level of Detail 1 (LoD1), to reconstruct automated BIM models in high-density urban areas [30]. IoT with BIM has been proposed to overcome smart city management challenges by integrating IoT data and sensors to improve communication, integration, and data sharing in a smart city environment [31]. A similar framework (IoT-BIM) is proven in the case of a campus in a smart city vision based on the use of IoT devices and networks to establish a smart building [32]. One of the remarkable contributions of BIM is project management in collaborative platforms [33]. In the context of smart city development, a platform based on BIM, GIS, and next-generation IoT is designed to manage a smart city in terms of operation and maintenance [29], and a management portal could apply [34]. These three approaches are merged to generate an extraction and decision engine to help citizens and smart city managers [29].

3.2.6 Life cycle management

Life cycle management is essential in developing smart cities [35]. BIM-based smart city development and design provides a rich database of information on urban systems, infrastructure, and requirements for maintainability, operation, and maintenance [36]. BIM is, therefore, a catalyst to support the development, storage, and transformation of data throughout the lifecycle of a smart city environment. Through BIM, consistency in deliverables is ensured, and intelligent control and global and centralised management of systems, infrastructure, and cities are implemented [37]. BIM allows urban planners to simulate, visualise and formulate good decisions on urban development scenarios. BIM, with its extension City Information Modelling (CIM), is a breeding ground for sustainable conversion and management of a city during its transfer to intelligent mode [38,39]. Complete life cycle management through CIM helps designers, planners, and decision-makers better predict a smart city's needs according to the scope criteria [40].

3.3 Challenges

BIM is accepted as a pioneering tool for smart city management that initially faces the challenge of being a fatal conversion that can be integrated into countries' industrial development strategies [41]. Nevertheless, the use of BIM faces several barriers. The literature places and discusses the regulatory challenge first. The development of unified and standardised internal processes, exchange, and sharing between the different stakeholders for using BIM is necessary to successfully transfer the city to smart mode [42]. On another legislative register, smart city initiatives are closely related to the different disciplines of architecture and engineering, which are governed by building codes. At the same time, there is a need for strong codes specific to smart city development [43].

Practically the deployment of BIM for the smart city is restricted by the maturity of BIM capabilities and the existence of factors that hinder its promotion [44]. In an experiment in urban space management, Ho and Rajabifard (2016) note two major challenges. A cultural challenge related to the low demand for BIM due to the favouring of 2D practices. Then a training and competence challenge lies in the lack of qualified human resources to lead this process. BIM alone cannot meet the desired expectations of the digital and sustainable transformation of the city [45]. Other tools and approaches, such as GIS, have consolidated it. In this collaborative deployment of BIM and GIS, major challenges arise in connectivity, collaboration, and interoperability because of the difference in the structure and way of cutting projects [46]. The limitations of BIM capabilities are overcome by the introduction of IoT during the sustainable management of smart city projects [47]. This requires a level of unfragmented and integrated professional connection [34]. This technological approach reveals the primary obstacles and challenges of the integration process, particularly the lack of technological solutions and methods [48,49].

4 Discussion

BIM has given a new lease of life to various aspects of infrastructure management and smart cities. The results of this study illustrate the existence of a growing trend among the scientific community toward implementing BIM in the context of smart cities. BIM is one of the technologies serving the development and planning of tomorrow's cities and other technologies and tools. The thematic analysis identified five distinct areas: Smart Infrastructures, Monitoring Management safety, Urban Energy performance, Smart City Management, and Life cycle management.

Several problems and limitations were identified despite the promising results proven by the mentioned studies on the BIM-based smart city to mitigate the litigation of its development. Section 3.3 describes the identified challenges in three categories: training, regulation, and trust.

This review, based mainly on identifying previous research themes, has considered all publications up to April 2023. While previous literature review studies omitted new publications. According to the database, this review joins and consolidates the small number of existing reviews that have chosen other methods that are more qualitative in their analysis. All these methods overcome the capabilities of BIM in sustainable smart city development, management, and planning. Previous researchers have reserved their literature review for discussing the issues of BIM in collaboration with other technologies such as IoT, Cyber Physical Systems,

Blockchain, and GIS on smart cities [34,39,49,50]. Only one review focused on BIM and the smart city was developed by Goyal L. et al. (2020). In this review, the authors focused on identifying smart city components using BIM [51].

This study has attempted to bring together the main challenges facing the effective deployment of BIM in the smart city environment. No journal has collected and ranked these challenges. Readers of its results would be able to draw up future research to provide solutions. In addition, the analysis conducted in this study cites and examines the frameworks developed by BIM with other technological approaches to promote smart city planning. These frameworks are research gaps highlighted by this paper and could be future research directions.

5 Conclusion

Using a literature review, this study examined the issues and challenges of using BIM to develop smart cities. After following a process of research question delineation, bibliographic search, and document consolidation, a total of 78 articles were sectioned for review. The publication trend proved to be increasing and reveals the areas of use of BIM in the context of a smart city. Despite the growth recorded and the remarkable impact of BIM alone or with other technology on improving BIM thinking and decision-making, there are still challenges to be overcome. The paper reveals three natures of challenge: legislative and regulatory, cultural, and finally, the challenge of competence and training.

Looking at the research method, the paper has three limitations. Firstly, the documents analysed are from Scopus and Wos, so data not available in these two databases were not considered. The second limitation of the quantitative analysis to the evolution of the research question. Thirdly, the results concerning the challenges should be confronted by the opinion of professionals.

Future studies can exploit the latest information mentioned above to obtain more profound and recent results. The presented work enriches previous studies and contributes a good and exploitable information base for the practice and professional community.

References

1. K. Idrissi Gartoumi, M. Aboussaleh, and S. Zaki, Proceedings of the Institution of Civil Engineers - Engineering Sustainability **176**, 82 (2023)
2. C. Yin, Z. Xiong, H. Chen, J. Wang, D. Cooper, and B. David, Science China Information Sciences **58**, (2015)
3. T. Monfaredzadeh and U. Berardi, International Journal of Sustainable Building Technology and Urban Development **6**, 140 (2015)
4. Y. Lei, Y. Rao, J. Wu, and C.-H. Lin, Journal of Industrial Information Integration **20**, 100171 (2020)
5. I. G. Khalil, A. Mohamed, and Z. Smail, in (IEEE, 2021), pp. 1–7
6. M. Marzouk and A. Othman, Journal of Cleaner Production **141**, 1400 (2017)
7. K. Idrissi Gartoumi, M. Aboussaleh, and S. Zaki, in *2022 International Conference on Smart Information Systems and Technologies (SIST)* (2022), pp. 1–6
8. M. Marzouk and A. Othman, Sustainable Cities and Society **57**, 102120 (2020)
9. P. P. A. Zanen, T. Hartmann, S. H. S. Al-Jibouri, and H. W. N. Heijmans, Automation in Construction **32**, 136 (2013)
10. D. Gotlib, T. Kulisiewicz, M. Muraszkiewicz, and R. Olszewski, ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences **IV-4-W9**, 49 (2019)
11. Y.-C. Lin and W.-F. Cheung, Journal of Management in Engineering **36**, 04020012 (2020)
12. G. B. Mandava, Vidyullatha, P. Rao, and V. Sucharita, INTERNATIONAL JOURNAL OF ENGINEERING & TECHNOLOGY (UAE) **7**, 652 (2018)
13. E. Valero and A. Adán, Measurement **94**, 614 (2016)
14. A. Homainejad, ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences **XL-7/W3**, 1381 (2015)
15. E. Karan and J. Irizarry, Automation in Construction **53**, (2015)
16. C. Potsiou, R. Khouri, R. McLAREN, and H. Mueller, (2010)
17. X. Caron, R. Bosua, S. Maynard, and A. Ahmad, Computer Law & Security Review **32**, (2015)
18. K. Alshammari, T. Beach, and Y. Rezgui, ITcon **26**, 159 (2021)
19. H. A. Boyes, R. Isbell, P. Norris, and T. Watson, in *IET Conference on Future Intelligent Cities* (2014), pp. 1–6
20. T. Reeves, S. Olbina, and R. R. A. Issa, Buildings **5**, 1361 (2015)
21. C. Zanchetta, R. Paparella, P. Borin, C. Cecchini, and D. Volpin, *The Role Of Building Energy Modeling To Ensure Building Sustainability And Quality In A Whole System Design* (2014), p. 93
22. Z. Pezeshki, A. Soleimani, and A. Darabi, Journal of Building Engineering **23**, 1 (2019)
23. F. Causone, A. Sangalli, L. Pagliano, and S. Carlucci, Building Services Engineering Research and Technology **39**, 99 (2018)
24. İ. Dursun, *INTEGRATION AND WEB-BASED PRESENTATION OF 3D CITY MODELS AND BIM DATA: THE CASE OF THE KÖYCEĞİZ CAMPUS* (2022)
25. P. A. Fokaides, C. Panteli, and A. Panayidou, Sustainability **12**, 9496 (2020)
26. J. Wang, Strategic Planning for Energy and the Environment **41**, (2022)
27. S. Yamamura, L. Fan, and Y. Suzuki, Procedia Engineering **180**, 1462 (2017)
28. F. Bian, in *International Conference on Intelligent Traffic Systems and Smart City (ITSSC 2021)* (SPIE, 2022), pp. 448–455
29. B. Wang and Y. Tian, IOP Conf. Ser.: Earth Environ. Sci. **693**, 012129 (2021)

30. K. Chen, W. Lu, F. Xue, P. Tang, and L. H. Li, Automation in Construction **93**, 22 (2018)
31. B. Dave, A. Buda, A. Nurminen, and K. Främling, Automation in Construction **95**, 35 (2018)
32. X. Gao, P. Pishdad-Bozorgi, D. R. Shelden, and S. Tang, Journal of Construction Engineering and Management **147**, 04020169 (2021)
33. K. Idrissi Gartoumi, M. Aboussaleh, and S. Zaki, Materials Today: Proceedings **58**, 1174 (2022)
34. S. Tang, D. R. Shelden, C. M. Eastman, P. Pishdad-Bozorgi, and X. Gao, Automation in Construction **101**, 127 (2019)
35. A. Passer, J. Wall, H. Kreiner, P. Maydl, and K. Höfler, Int J Life Cycle Assess **20**, 1 (2015)
36. V. Gutiérrez, D. Amaxilatis, G. Mylonas, and L. Muñoz, IEEE Internet of Things Journal **5**, 668 (2018)
37. J. Heaton and A. K. Parlikad, Cities **90**, 32 (2019)
38. Y.-W. Li and K. Cao, Computer Communications **153**, 382 (2020)
39. H. Zhang, J. Wei, J. Jiao, and Y. Gao, in *Big Data Analytics for Cyber-Physical System in Smart City*, edited by M. Atiquzzaman, N. Yen, and Z. Xu (Springer, Singapore, 2020), pp. 1027–1033
40. Z. Liu, Z. Chi, M. Osmani, and P. Demian, Sustainability **13**, 2090 (2021)
41. P. Saputra and A. Ramadhan, International Journal of Reconfigurable and Embedded Systems (IJRES) **12**, 29 (2023)
42. C. Mgbere, V. A. Knyshenko, and A. Bakirova, *Building Information Modeling. A Management Tool for Smart City* (2018), p. 182
43. S. Ghosh, *Smart Homes: Architectural and Engineering Design Imperatives for Smart City Building Codes* (2018), p. 4
44. T. Wang and J. Feng, Journal of Urban Planning and Development **148**, 04022025 (2022)
45. S. Ho and A. Rajabifard, Land Use Policy **57**, 1 (2016)
46. H. Xia, Z. Liu, M. Efremochkina, X. Liu, and C. Lin, Sustainable Cities and Society **84**, 104009 (2022)
47. L. Souza and C. Bueno, Building and Environment **207**, 108403 (2022)
48. M. Corekci, O. Pinarer, and S. Servigne, *Designing a Novel Smart Home Monitoring Systems with the Integration of BIM and WSN* (2019)
49. D. Shkundalov and T. Vilutienė, Automation in Construction **128**, 103757 (2021)
50. A. Banerjee and R. R. Nayaka, Construction Innovation **22**, 727 (2021)
51. L. Goyal, R. Chauhan, R. Kumar, and H. Rai, IOP Conference Series: Materials Science and Engineering **955**, 012010 (2020)