Chapter 31
Using City Information Modelling to Evaluate Urban Circularity Through Sustainability Indicators

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Abstract While promoting a holistic view of cities, sustainability assessment methods and the circular economy concept have gained attention among urban planners and policymakers. Those methods associated with information technologies can enable intelligent solutions to accelerate sustainability goals. City Information Modelling (CIM) can facilitate the assessment of urban sustainability and circularity. Continuing a previous study, this article examines whether traditional sustainability assessment tools may be adapted to CIM while promoting circular economy practices. Furthermore, the relationship between the most prioritized sustainability indicators and primary urban circularity concerns is examined through theoretical analysis. Therefore, a correlation matrix is proposed and indicators associated with each circularity concern are identified. In total, 24 indicators out of 48 are directly related to urban sustainability. Accordingly, this article discusses how urban circularity concerns can be determined using CIM, based on their correlation with the prioritized indicators. The findings indicate that a CIM-oriented strategy could be used to evaluate urban circularity concerns through sustainability indicators.

Keywords City information modelling · Sustainability assessment methods · Circular economy

31.1 Introduction

Cities can play a significant role in sustainable development by providing opportunities and serving as an important instrument for change and quality of life improvement. In addition, to minimize cities' environmental footprints, the circular economy provides symbiotic ways to design circular urban systems and optimize resource and energy consumption [1]. A circular economy could also help cities achieve urban

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sustainability [2]. A growing focus on urban sustainability has led to the development of indicators, assessment methods, tools, and rating systems [3, 4]. It is possible to use sustainability assessment methods to identify alarming weaknesses in the environment, socio-economic conditions in communities, and inadequacies or problems related to the built environment [5]. To evaluate sustainable aspects, assessment systems use indicators, which serve many purposes, including simplifying, quantifying, and analyzing complex data. They also provide a better way to predict outcomes, monitor progress toward targets, and reinforce them. Nevertheless, one single issue can be assessed using an array of indicators and addressed from multiple perspectives [6].

It is necessary to use more innovative and efficient urban planning and management methods in order to meet the growing demands of cities and the challenges of sustainable development [7]. Therefore, City Information Modeling—CIM—can be viewed as a paradigm for the intelligent modeling of urban spaces by integrating different elements of the urban environment. The use of an intelligent city model enables city planners and urban designers to analyze the demands of cities and make more effective, efficient, and sustainable urban plans [8]. City Information Modelling has received significant attention in the literature over the last decade. CIM is a novel concept that has spawned several approaches in the literature. In general, the concept is based on urban digital models that include rich geospatial information and a complete and up-to-date database [9–12]. CIM has been defined as the "latest advancement from BIM" by Dall'O et al. [13], where data can be viewed in a 3D environment, including various city components. Using city data, all stakeholders can collaborate and make informed decisions. A key feature of CIM, according to Wang and Tian [14], is its close relationship with smart cities, integrating various technologies such as the Internet of Things (IoT), Geographic Information Systems (GIS), and Building Information Modeling (BIM). Despite the fact that CIM is currently under discussion and no widely accepted concept has emerged, many authors propose integrating GIS and BIM to compose a CIM platform [14–18]. As with BIM, CIM could be applied throughout the entire life cycle of a city, from the design and planning stages through the construction and maintenance stages [16]. Furthermore, sustainable and circularity criteria such as energy use, water and waste management, mobility and transport, can be incorporated into CIM's urban database. Using data from BIM and CIM, Dantas et al. [19] evaluated how CIM could be used to obtain data to support the indicators of ISO 37120 to improve public services and quality of life. In their study, Sabri et al. [20] proposed a 3D geospatial platform for assessing the processing, publishing, and visualization of urban environments in 3D. According to the authors, the platform is intended to support urban planning decisions from an intuitive perspective, so that planners can interact with the lives of people directly. In a case study using BIM for urban planning and management, Tao and Qian [21] proposed simulation models to analyze and evaluate solar radiation, ventilation, and energy consumption. Beirão [22] discusses an approach to utilizing a CIM platform, suggesting that it should be open, accessible, and interactive for all users, such as urban planners and citizens. Despite the wide variety of approaches, a

CIM platform typically has elements of interactivity, collaboration, interoperability, information sharing, as well as BIM and GIS integration.

In a previous study, Salles et al. [23] analyzed internationally recognized systems and identified the prioritized issues and aspects of urban sustainable assessment techniques, demonstrating existing sustainability concerns. Considering the Portuguese methodology SBTool^{PT} Urban as a baseline, the study compared it with the similar indicators of the following methods: Sustainable Neighborhood Tool (SNTool) from iiSBE, BREEAM Communities (BREEAM-C), and LEED for Neighborhood Development (LEED-ND). Also, the alignment of the indicators with the Sustainable Development Goals (SDGs), ISO 37120 standards, and Level(s) was considered.

Accordingly, this study aims to discuss how CIM can be used to implement circular economy strategies in the built environment. After that, it is evaluated how the method proposed in the previous study might help achieve urban circularity.

31.2 Materials and Methods

As stated previously, Salles et al. [23] proposed a method to assess urban sustainability using CIM. By evaluating the method, this paper aims to discuss the feasibility of using it for urban circularity. The results obtained by Salles et al. [23] showed that the averaged indicators of most evaluation methods promote similar sustainability concerns. As a result, 48 indicators have been identified as being essential to be assessed in every urban context, with 41 indicators being covered by the Portuguese methodology SBTool^{PT} Urban, while the remaining seven are uncovered or partially covered. Then the article analyzes the feasibility of each indicator being calculated using CIM. A total of 52 parameters are used in the calculation of the 41 indicators presented in the SBTool^{PT} Urban methodology. As part of the assessment process, each indicator was validated based on the calculation criteria and methodology and their ability to be integrated into a digital information model. In this regard, the indicators are categorized as 'YES', 'NO', or 'PARTIALLY' meaning, respectively, that indicators can or cannot be assessed using CIM, while others can only be partially assessed using CIM. Data type, the feasibility of modeling, and availability of relevant information and similar cases in the literature determine whether a parameter is considered 'YES'. If a parameter cannot be modeled, is not found in any related case study, or is not likely to benefit greatly from CIM, then it is classified as 'NO'. 'PARTIALLY' refers to the fact that most of the criteria can be assessed using the model, however, one or two criteria cannot be assessed. In the absence of a calculation methodology for the new indicators, they were considered 'NON-APPLICABLE'. Therefore, the CIM model can be used to calculate at least 28 parameters, and seven more can be partially calculated by CIM.

The method proposed by Salles et al. [23] uses CIM to assess urban sustainability. Considering that CIM is the integration of BIM and GIS, the study proposed the use of Autodesk Revit, as a BIM tool along with CADMAPPER, for the incorporation of GIS information into the model, and Dynamo, for the calculation of the results.

As a Revit plug-in, Dynamo allows users to create routines to execute activities and calculations, it is also a versatile and adaptable tool to calculate indicators. Once the platform is created, the modeling phase is the following step, adding to the model all the necessary data. CADMAPPER allows the urban area to be inserted into the model, then the area has to be characterized by the material parameters in the model, the topography, and the shared parameters. Afterward, calculation routines can be created using Dynamo to quantify the indicators. Each indicator has a different calculation routine, according to its parameters.

The literature review pointed out a relationship between circular economy and urban sustainability [1, 2, 24, 25]. Dong et al. [1] explored the synergies between urban sustainability and circular economy. According to the authors, applying the circular economy to urban areas enables a systematic approach to exploring symbiotic relationships. This includes, for example, urban industrial symbiosis and community waste separation and recycling, which can be used to create circular urban systems, optimizing the metabolism of cities while maximizing resource efficiency and reducing environmental impact. In this regard, the concept of urban sustainability can be described as an increase in the efficiency of urban resources. By integrating circular economy principles, the urban space, industrial facilities, and infrastructure can be designed in a closed-loop environment.

Furthermore, Schaubroeck et al. [26] proposed the use of a 3D city model to store building joints. According to the authors, building joint data can be used to apply circular strategies at an urban scale. In this regard, city models can store data and serve as databases. Moreover, the digitalization of the building stock can contribute to reaching various sustainability targets.

Accordingly, based on a literature review, this study evaluates the synergies between sustainability indicators and the circular economy in the built environment. In addition, it is discussed the feasibility of using CIM for urban circularity.

31.3 Results and Discussion

Analyzing the prioritized sustainability indicators identified in the previous study by Salles et al. [23], and comparing them with the main concerns of urban circularity, this study finds out that 24 out of 48 indicators are directly connected to urban circularity strategies. The results are presented in the correlation matrix shown in Fig. 31.1. The main concerns about urban circularity identified in this paper are screened and selected based on a literature review. A general finding is that applying circular economy concepts in the urban environment can contribute to urban sustainability. At least, half of the sustainability indicators are directly related to urban circularity concerns. And most of the circularity concerns are related to more than 6 indicators. This indicates that the implementation of circular economy concepts in an urban environment could have a positive impact on multiple aspects of sustainability, including the economy, environment, and society. The matrix also reveals that it is possible to focus on circularity concerns to address a significant number of sustainability indicators, which could lead to improved outcomes for the city.

Circularity is the concern that has devoted the highest number of indicators. This concern represents the extent to which circular economy principles have been applied. Increased circularity leads to increased recycling ratios, greater reuse, and reduced resource consumption. Reduce, Circular business model, and Industrial symbiosis are subsequently second, third, and fourth, addressing 15, 13, and 12 indicators, respectively. Reuse and Recycle are related to 11 indicators. In the sequence, Extend lifetime

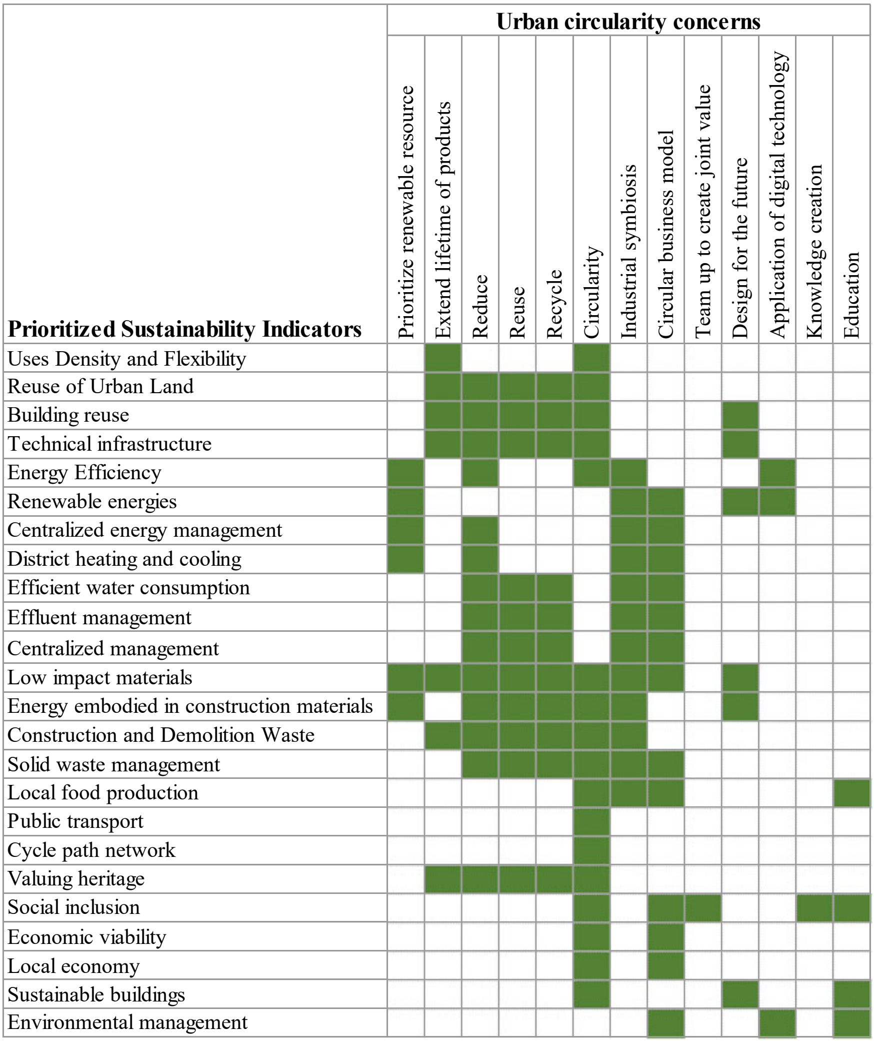

Fig. 31.1 Relationship between sustainability indicators and urban circularity concerns. *Source* Authors

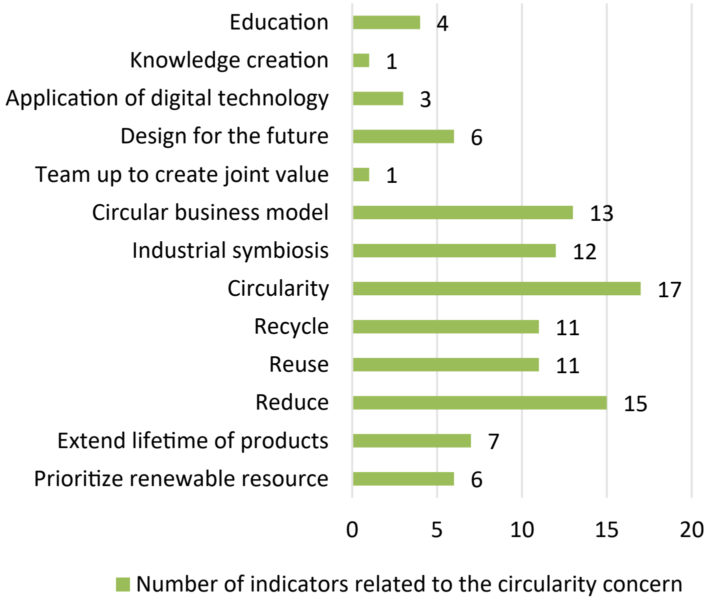

Fig. 31.2 Number of indicators related to the circularity concern. *Source* Authors

of products is related to 7 indicators, followed by Prioritize renewable resources and Design for the future, with 6 indicators each. Education, Application of digital technology, Team up to create high value and Knowledge creation are the latest ones, with 4, 3, and 1 indicators, respectively. The results are shown in Fig. 31.2.

Evaluating the method proposed by Salles et al. [23] the results indicate that CIM can be used to access urban sustainability. The SBTool^{PT} Urban methodology promotes 41 of the 48 prioritized indicators. To calculate these indicators, SBTool^{PT} Urban Guide developed a set of calculation parameters. Among the 41 indicators, there are 52 calculation parameters, and at least 28 parameters can be calculated using the CIM model, and another 7 can be determined in part. The classification criteria (YES, NO, or PARTIALLY) are related to the calculation parameters and the information needed to quantify them. Therefore, 24 indicators have a direct relation to urban circularity concerns from the 48 prioritized indicators. This helps to identify which indicators contribute the most to overall circularity performance, as well as which have the greatest potential for improvement.

Considering the relationship between sustainability indicators and the circularity concerns, presented in Figs. 31.1 and 31.2, this study has identified the number of indicators classified as YES, NO, PARTIALLY, or NON-APPLICABLE, for each circularity concern. Figure 31.3 presents the results. According to the findings of the study, CIM cannot be used to calculate the indicators of only three circularity concerns. The majority of concerns have indicators that can be assessed by CIM. In five circularity concerns, more indicators were able to be determined through CIM

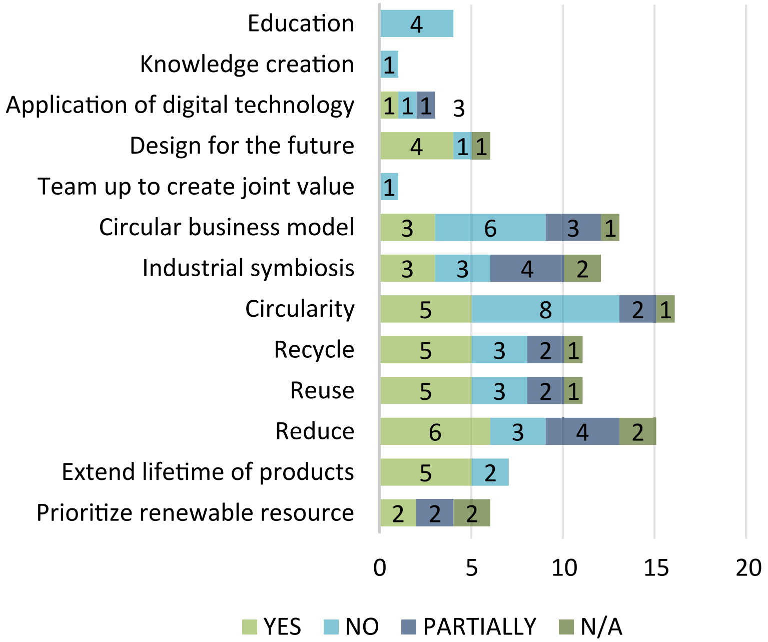

Fig. 31.3 Number of indicators classified according to the calculation using CIM for each urban circularity concern. *Source* Authors

than in those that could not. There are only two concerns in which the number of indicators that cannot be assessed by CIM exceeds the number that can be assessed. These results suggest that CIM is a viable tool for measuring sustainability indicators for most circularity concerns.

Nevertheless, the use of CIM to evaluate urban circularity concerns is highly dependent on quantification. As such, the accuracy of CIM evaluations is limited by the quality of available data. Furthermore, the use of CIM for urban circularity analysis involves the consideration of multiple variables. In this study, circularity concerns were related to sustainability indicators, previously evaluated regarding the feasibility of calculation using CIM. Since SBTool^{PT} Urban sustainability indicators are typically evaluated through quantitative assessments, CIM can provide a quantitative basis for assessing urban circularity concerns. It also can be used to identify and quantify urban circularity concerns, and to evaluate the effectiveness of proposed strategies for urban sustainability.

31.4 Conclusion

The pursuit of urban sustainability has led to advances in research as well as the development of indicators. Information and communication technologies have also contributed to sustainable urban development by providing tools and systems that enhance urban management and operations efficiency. In addition, they help cities transition to digitalization, thus making them more 'intelligent' and sustainable. Accordingly, City Information Modelling can aid in the implementation of sustainability strategies in urban spaces. Moreover, the CIM model can provide a multidisciplinary perspective, facilitate communication, and promote sustainable concept integration.

The circular economy has been seen as a valuable approach to reaching sustainability. When applied to the urban environment, a circular economy promotes the optimization of cities' metabolism, enhancing resource efficiency, while reducing environmental footprints. This could help in reducing resource consumption, allowing for the reuse of materials and components. It also helps to create local jobs and stimulate innovation, while promoting a more equitable and resilient society.

The purpose of this study is to discuss how City Information Modeling can be used to evaluate circular economy strategies in the urban environment. The findings have shown that the use of CIM to assess urban circularity is feasible. However, at first, it is necessary to relate the circularity concerns to indicators, in order to quantify them. The sustainability indicators used were based on a previous study. Using the Portuguese methodology SBTool^{PT} Urban as a baseline, the previous study determined which indicators could be integrated into the CIM concept for assessing urban sustainability. These prioritized indicators were related to urban circularity concerns and a correlation matrix was proposed. Then, for each circularity concern, it was evaluated whether the related indicators could be calculated through CIM. Overall, most of the concerns are related to indicators that can be calculated using CIM. Only 3 concerns presented negative results, concluding that the corresponding indicators cannot be determined. The research concluded that CIM can be used to assess circularity in the urban environment. However, further research is necessary to determine whether the proposal is applicable. The findings provide a foundation for further research into the application of CIM to assess circularity.

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