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Evaluating The Impact Of Bulding Information Modeling (BIM) On Sustainable Architectural Designs

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Abstract

Some significant global problems, such as global warming, depletion of the ozone layer and natural resources depletion, point out that sustainable solutions are critical in the construction sector, as in many other fields. In this context, the Life Cycle Assessment (LCA) method, which enables the determination of the environmental impacts of buildings, comes to the fore. In addition, due to the negative environmental impacts caused by the building sector, the tools developed to create sustainable designs have started to be used. The Building Information Modelling (BIM) method, which uses these tools and is becoming increasingly important, can produce solutions in different ways in design, construction and use processes from an environmental perspective. The decisions, especially in the early stages of building design, are effective for sustainability goals, and the analysis and simulation functions provided by the BIM help the designers to make sustainable design. In this study, it is aimed to to explore and analyse the potential of using LCA in an early design stage using design tools. It was focused on researching and defining the most important aspects of LCA and BIM through a literature review. Thus, the importance of the decisions taken at the early design stages for sustainable designs and the necessity of innovative methods that the BIM method provides to the designer while making these decisions are revealed. The studies highlight the potential of integrating LCA and BIM to make sustainable design decisions early on also indicate the importance of LCA data, level of development (LoD) of the BIM model, and the knowledge of designers on the topics of LCA and sustainable design.

Keywords: Sustainable Architecture, Building Information Modelling (BIM), Life Cycle Assessment.

Yapı Bilgi Modellemesinin (BIM) Sürdürülebilir Mimari Tasarımlar Üzerine Etkisinin Araştırılması

Özet

Küresel ısınma, ozon tabakasının incelmesi ve doğal kaynakların tükenmesi gibi bazı önemli küresel sorunlar, birçok alanda olduğu gibi inşaat sektöründe de sürdürülebilir çözümlerin kritik önem taşıdığını gösteriyor. Bu bağlamda, binaların çevresel etkilerinin belirlenmesini sağlayan Yaşam Döngüsü Değerlendirmesi (LCA) yöntemi ön plana çıkıyor. Ayrıca yapı sektörünün neden olduğu olumsuz çevresel etkiler nedeniyle sürdürülebilir tasarımlar oluşturmak için geliştirilen araçlar kullanılmaya başlanmıştır. Bu araçları kullanan ve önemi giderek artan Yapı Bilgi Modellemesi (BIM) yöntemi, çevresel açıdan tasarım, yapım ve kullanım süreçlerinde farklı şekillerde çözümler üretebilmektedir. Özellikle bina tasarımının

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erken aşamalarında alınan kararlar sürdürülebilirlik hedefleri için etkili olmakta, BIM'in sağladığı analiz ve simülasyon fonksiyonları tasarımcıların sürdürülebilir tasarım yapmalarına yardımcı olmaktadır. Bu çalışmada, tasarım araçları kullanılarak erken tasarım aşamasında LCA kullanımının potansiyelinin araştırılması ve analiz edilmesi amaçlanmıştır. Literatür taraması yoluyla LCA ve BIM'in en önemli yönlerinin araştırılması ve tanımlanmasına odaklanılmıştır. Böylece sürdürülebilir tasarımlar için erken tasarım aşamalarında alınan kararların önemi ve BIM yönteminin bu kararları alırken tasarımcıya sağladığı yenilikçi yöntemlerin gerekliliği ortaya konmuştur. Sürdürülebilir tasarım kararlarının erkenden alınabilmesi için LCA ve BIM entegrasyonunun potansiyelini vurgulayan çalışmalar, aynı zamanda LCA verilerinin, BIM modelinin gelişmişlik düzeyinin (LoD) ve tasarımcıların LCA ve sürdürülebilir tasarım konularındaki bilgilerinin önemini de ortaya koymaktadır.

Anahtar Kelimeler: Sürdürülebilir Mimari, Yapı Bilgi Modellemesi (BIM), Yaşam Döngü Değerlendirmesi (LCA)

1. INTRODUCTION

Throughout history, as a result of events such as the Industrial Revolution and World Wars, many technological developments have been achieved in the building sector as in many fields. These technological developments have created new requirements as well as opportunities. Due to some of these requirements, an expeditious increase in AEC (the architecture, engineering and construction) industry has started and caused some crucial global issues such as global warming, depletion of ozone layer, depletion of natural resources and so on (Çavuşoğlu & Çağdaş, 2018).

Different global scientific studies indicate that the construction sector has high CO2 emissions from the use of energy and raw materials, puts great pressure on the natural environment. According to environmental reports prepared by the United Nations, the building sector is responsible for approximately 38% of the greenhouse gases emitted globally, as it uses significant amounts of energy in different life cycle stages such as material production, construction, operation, maintenance and demolition (Fig. 1) (Duru, Dinçer & Koç, 2022; UNEP, 2020).

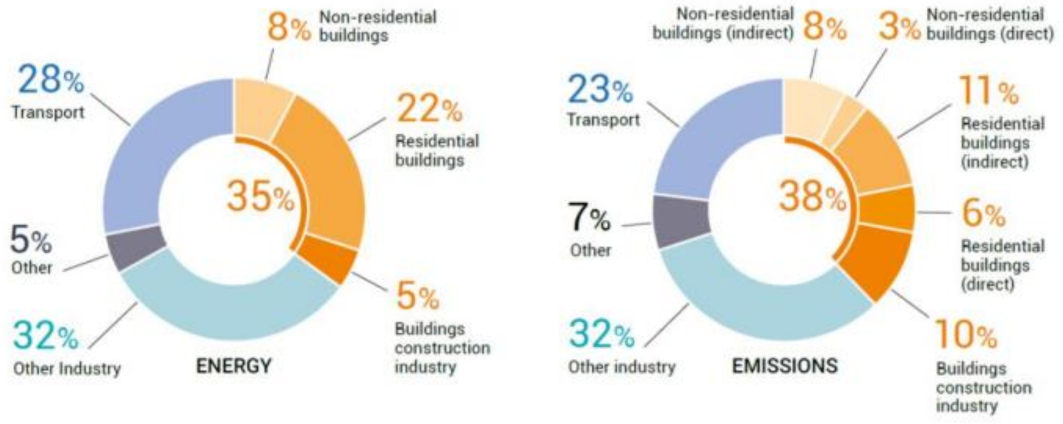

Figure 1. Global share of buildings and construction final energy and emissions, 2019 (UNEP, 2020).

This high negative impact of the building sector causes a reconsideration of project design and business processes in building production in the context of environmental sustainability principles. Effectively combating climate change resulting from the production of the built physical environment requires an approach that considers environmental impacts from the beginning of the architectural design process and adopts holistic sustainable design goals (Duru, Dinçer & Koç, 2022).

Environmentally sustainable buildings are gaining importance to reduce the negative effects of climate change and maintain the balance of the natural system. In order to prevent the increase in greenhouse gases, renewable energy sources should be used more in buildings. Energy conservation, water conservation, material conservation and prioritizing the use of natural materials are among such requirements. It can be said that the demand for sustainable buildings that meet these requirements, reduce energy consumption and increase energy efficiency has increased in recent years. Since sustainable building designs will contribute to a greener world, it is significant to establish interdisciplinary and integrated working groups based on ecological sensitivity. Building Information Modelling (BIM) technology enables the optimization of the building performance as a whole with a multidisciplinary study from the beginning of the design (Koçhan & Akın, 2022).

Therefore, in this study, through a literature review, the ways of using this technology, which has increased in use in recent years and supports integrated work based on interaction between systems, to enable integrated design and analyzes during the project stage have been investigated. In this sense, the integrating the technology with the Life Cycle Assessment (LCA) method is focused, and its effects on sustainable designs are questioned.

1.1. The Purpose and Method

It is aimed to investigate and analyze the potential of integrating BIM and LCA methods and their potential to be used in the early design phase. Through a literature review, the focus was on investigating and identifying the key aspects of LCA and Building Information Modelling (BIM) methods. Furthermore, the interoperability of these two methods was investigated by analyzing relevant publications.

2. THE THEORETICAL FRAMEWORK

In this section, the literature about Life Cycle Assessment (LCA) and Building Information Modelling (BIM) is presented.

2.1. The Life Cycle Assessment (LCA)

Considering the size of the built environment in the world, it can be predicted that the environmental impacts caused by the production of these structures have very negative consequences on the natural environment. Determining the environmental impacts of buildings is the first step towards reducing these negative environmental impacts.

Life Cycle Assessment (LCA) is recognized as one of the most comprehensive objective methodologies for determining the environmental impacts of buildings (Khasreen, Banfill & Menzies, 2009). With LCA, the effects of a building on its environment throughout its entire life cycle can be analysed. With the use of this method, environmental impacts can be calculated and energy controls can be made in buildings. Thanks to designers who are sensitive to this issue, a more sustainable design approach has started to emerge in building production.

According to ISO 14040 (2006), LCA is performed in four steps (Figure 2). These are given below respectively:

1- Goal and Scope Definition: In this phase, some issues should be cleared, such as the reason for applying LCA study, the application areas of the LCA results, the function of the product system, the product system boundaries, and data category.
2- Life Cycle Inventory Analysis (LCI): This phase involves data collection and calculation to quantify inputs and outputs of materials and energy associated with a product system under study.
3- Life Cycle Impact Assessment (LCIA): It consists of optional and mandatory elements such as classification, characterization, normalization, and weighting.
4- Interpretation: The quantitative results are interpreted in order to identify significant issues.

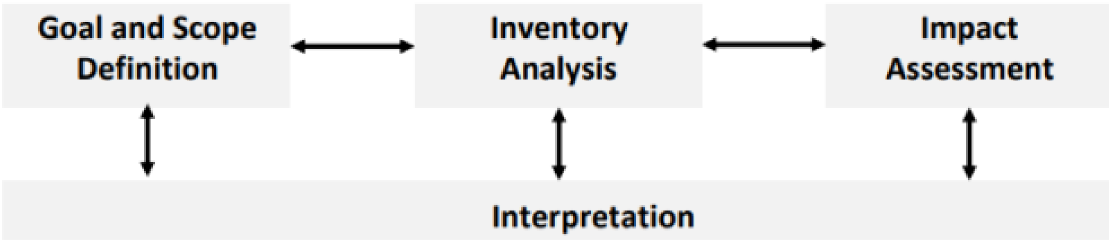

Figure 2. Phases of LCA (Gomaa, Farghaly, & El Sayad, 2021; ISO14040, 2006)

According to ISO 14044, the system boundary determines which processes should be included within the LCA and should be consistent with the goal of the study. Similar to other products, the system boundary of the building LCA consists of either a cradle-to-grave, cradle-to-gate (for building product analysis) or gate-to-gate (for construction process analysis). In most cases, the cradle-to-grave approach, which starts from the pre-use phase to end-of-life (EOL) phase, is normally used (Fig. 3) (ISO 14044, 2006; Abd Rashid & Yusoff, 2015).

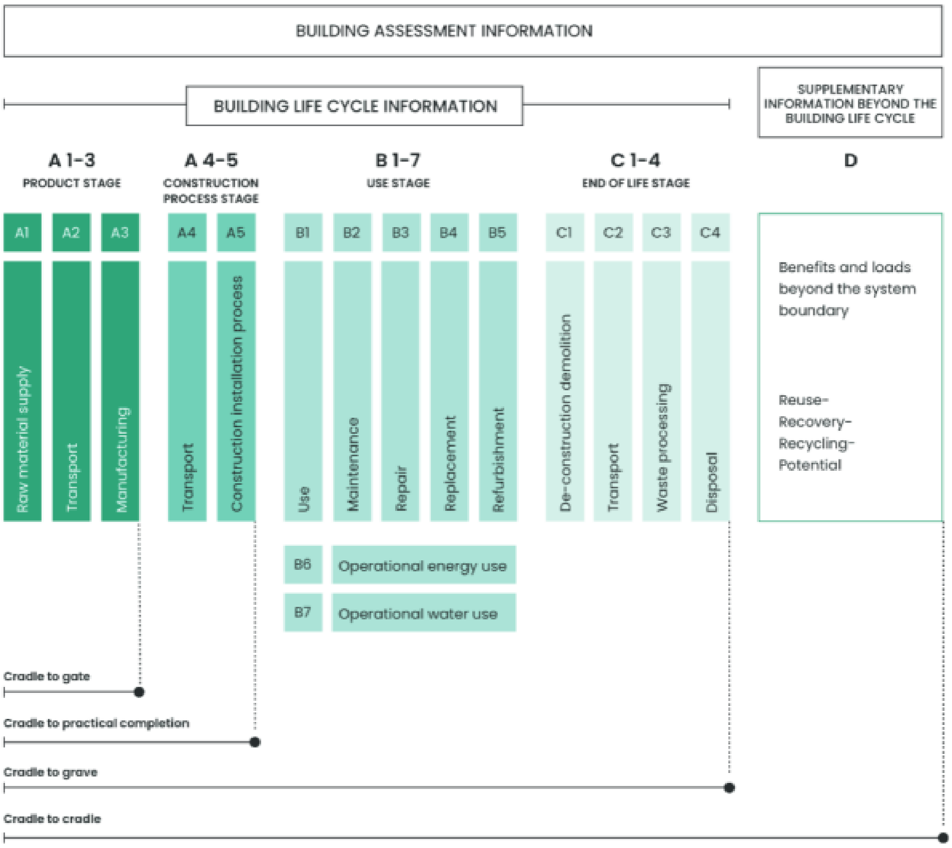

Figure 3. Life-cycle scope specified according to the standardized module designations (Bruce-Hyrkäs, 2021).

The LCA method, which is one of the important tools that contributes to realize sustainable building production, covers all stages starting from the extraction of raw materials to the reuse / recycling of materials obtained from the demolition of the building. Therefore, accurately calculating the environmental impacts of buildings throughout their lifetime requires analyzing a large amount of information. Data requirement makes it difficult to carry out environmental impact assessment, which should be considered especially in the early stages of design (Duru, Dinçer & Koç, 2022).

Decisions made in the early stages of the design process have a major impact on the process as they set the general conditions for the later stages of building production. Due to the impact of the early design phase on incurred costs, operational energy demand and environmental impacts; this phase has a great potential for the optimisation and reduction of GHG emissions. Therefore, LCA should be applied in the early design stages to ensure holistic environmental optimisation of buildings (Fig. 4) (Basic, Hollberg, Galimshina, & Habert, 2019).

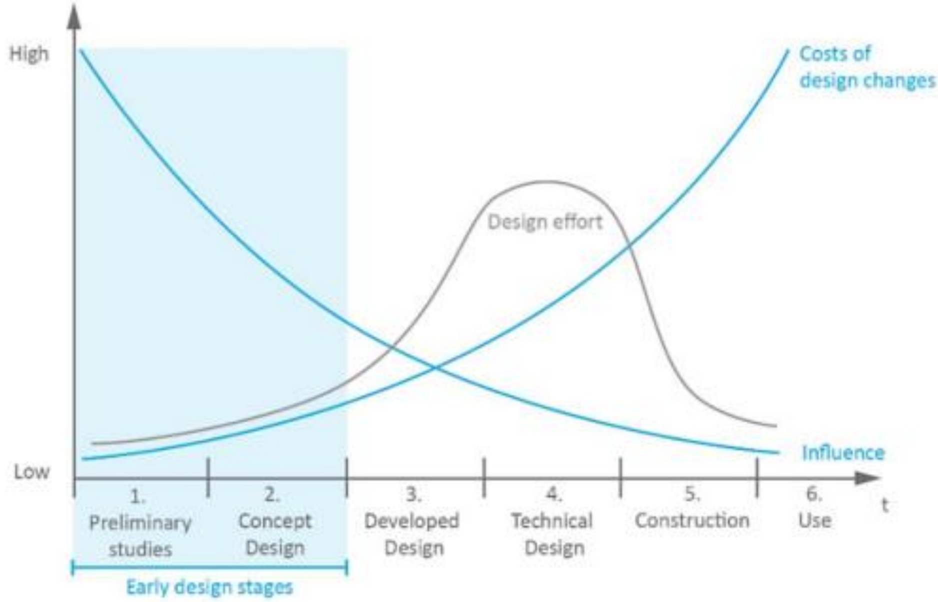

Figure 4. Influence of the early design stages (Basic, Hollberg, Galimshina, & Habert, 2019)

In LCA analyses performed through visual programming languages (VPL), the specified life cycle inventory data is used extensively. In creating this information, it is a prerequisite to determine the system boundaries with the help of the aim and scope definition in the first stage of the LCA method. Creating the inventory without meeting this condition causes the great uncertainties in the calculations. Therefore, the inventory data to be selected directly changes the impact assessment results, which is the next stage due to the modules LCI contains (Duru, Dinçer & Koç, 2022; Lasvaux et al., 2014).

If LCA analyses can be used effectively in the early design phase where decisions such as material preferences and layout options are determined, these analyses will constitute an important design criterion for the designer. With three-dimensional software that can perform these analyzes, more environmentally friendly and sustainable designs can be produced. Thus, with the calculations made, the most sustainable and economical option among different design variations can be implemented in a way that minimizes the loss of time and cost.

2.2. The Building Information Modelling (BIM)

The National Institute of Building Sciences (NIBS) has defined BIM as a model and a process: " A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward. A basic premise of BIM is collaboration by different stakeholders at different phases of the lifecycle of a facility to insert, extract, update, or modify information in the BIM to support and reflect the roles of that stakeholder" (NIBS, 2007).

BIM is a new way of thinking that differs from traditional workflow. All stakeholders (architects, engineers, contractors, etc.) work on a common database. In the conventional method, stakeholders work on separate information tools and different (often incompatible) software packages (Özorhon, 2018).

BIM is a method in which a building and the entire system for the building is first built in a virtual environment. Much information, such as material data, is processed into the model created with predefined three-dimensional objects. Thus, a model is obtained in which many analyzes can be made before the construction of the system, and errors can be detected in advance. Since this model contains all the information about the building, it also constitutes a source of information that can be used in the use and management phase of the building. BIM Application Levels (nD), BIM Development Levels and BIM Based Visual Programming Tools are stated below.

2.2.1. BIM Dimensions (nD)

The BIM working system has application levels of different dimensions (D) (Table 1) (Özorhon, 2018). These dimensions, which are determined according to the project requirements and the life cycle phase in which BIM will be used, are among the basic concepts of BIM.

Table 1. BIM Dimensions (Özorhon, 2018).

3D	Modelling	3D is the level where a digital representation of the physical structure of the building is created.
4D	Scheduling	4D is the level at which time data is entered into the model in planning, enabling more efficient execution of work.
5D	Estimating	5D is the level that enables analysis such as detailed budget analysis by assigning costs to the elements in the model.
6D	Sustainability	6D is the level that is relevant to sustainability goals, such as calculating size/energy use.
7D	Facility Management	7D is the level that ensures that the implemented BIM model enables accurate facility management and asset management.

2.2.2. BIM Level of Development (LOD)

Another concept frequently encountered in BIM technologies is BIM Levels of Development (LOD). Every year since 2013, the American Institute of Architects (AIA) (2013) and BIMForum (2015) publish LOD (level of development) specifications and provide information on classifications (Bahadır, 2018). The LOD framework sets the floor for Model content and the ceiling for Model use (AIA, 2013). These levels, which vary between 100 and 500, are explained in Table 2.

Table 2. BIM-Levels of Development (Özorhon, 2018).

LOD 100	Conceptual	It is the level of conceptual design. Data is represented in symbols and approximations.
LOD 200	Approximate Geometry	Conceptual design is improved by adding non-graphical information to the model element.
LOD 300	Precise Geometry	This is the level of application design where information such as size, position, quantity and direction of model elements can be retrieved from the model.
LOD 400	Fabrication	This is the construction level where information such as element details, manufacturing, assembly and installation are added to the model.
LOD 500	As-Built	The model elements represent the application conditions and can be used in facility management.

2.2.3.BIM-Based Visual Programming Tools and Dynamo

Thanks to the new technologies developed in the BIM method, visual programming tools that contain algorithms according to their specialised purposes without knowing how to write code are now frequently used by designers (Kensek, 2015). Thanks to the development of the software used in the BIM method, which enables modelling with predefined objects, new approaches have emerged in which visual programming languages can be used in architectural design stages. Thus, it is ensured that fast and automatic repetitive analyses can be performed on the model prepared with BIM software using these visual programming tools. Analyses and data flow in design processes can be carried out quickly in this way (Autodesk, 2016; Seghier, Lim, Ahmad, & Williams, 2017).

The Dynamo, which was developed to improve design processes in both parametric design and BIM-based designs, can be mentioned. Autodesk Revit, which has a very wide user base among BIM programs and allows modelling using information-coded three-dimensional objects, uses the Dynamo visual programming tool for design analysis. Thus, various environmental impact results related to the building can be obtained by using this programming tool on the created BIM model. In this context, Dynamo contributes to sustainable designs.

3. THE RELATIONSHIP BETWEEN BIM AND LCA FOR BUILDING SUSTAINABILITY ASSESSMENT

BIM is a three-dimensional platform that allows the design and construction process of the project to be monitored step by step and intervene when necessary. With this feature, the BIM system can offer ease of revision even during the construction phase (Özcan & Erol, 2018). Thanks to this benefit of the BIM method in the building production process, the data obtained with the LCA method can be used together, especially in the design phase, creating a potential for creating sustainable designs.

3.1. LCA and BIM in Building Life Cycle

The LCA modules in the building life cycle and the emission rates at each stage are given in Fig. 5.

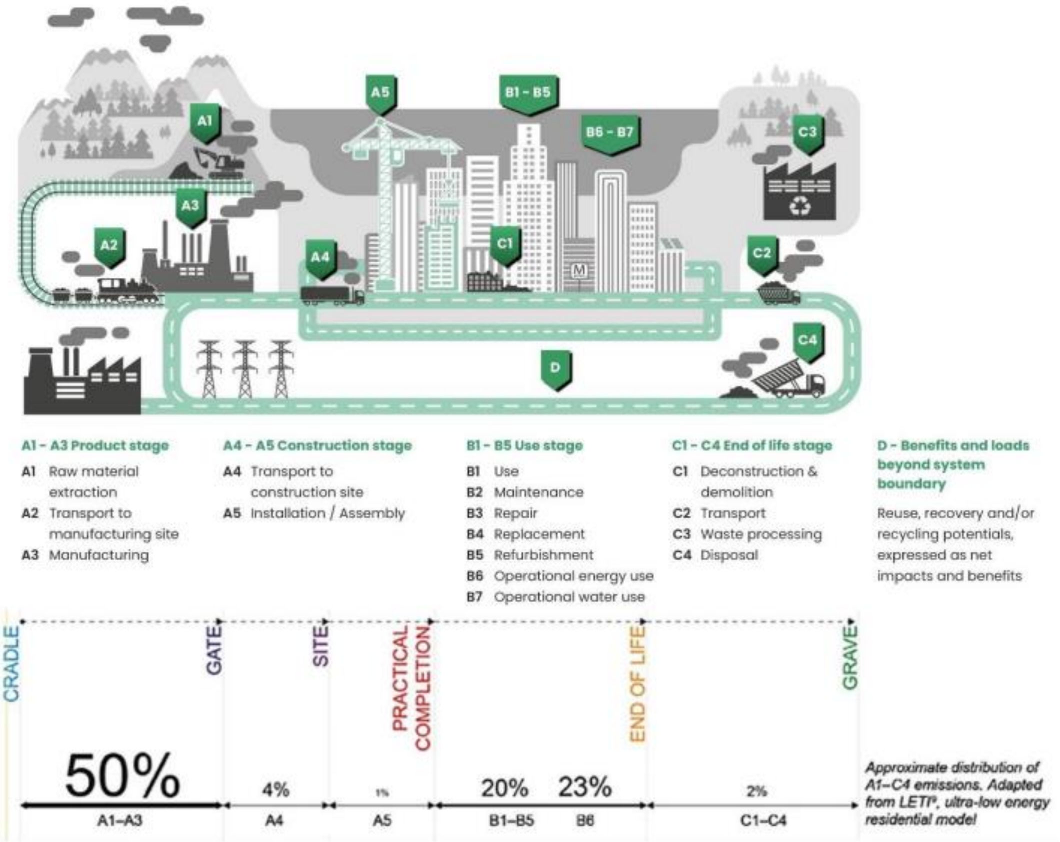

Figure 5. Life-cycle stages of a building (Adapted from: URL1; Gibbons & Orr, 2020)

The material-related processes are divided into certain modules and the effects of these modules on LCA are also in different dimensions in the Life Cycle Inventory (LCI) phase (A1-C4) (Fig. 6). At this point, the place of the BIM method in the building life cycle and its association with the LCA stages should be examined.

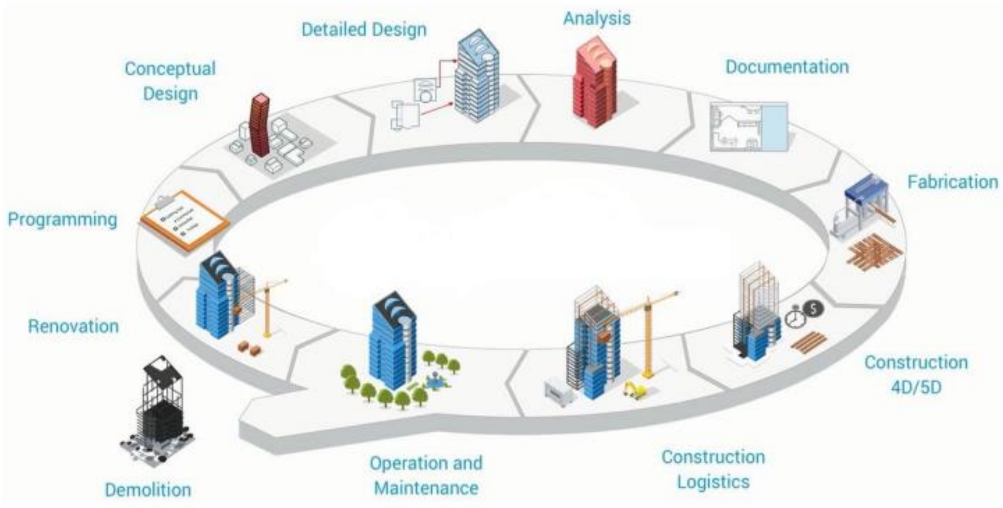

Figure 6. BIM at different stages of the project life cycle (URL2)

BIM enables the process to operate in a planned manner starting from the initial stage of the structures. Numerical and graphic outputs are obtained by analyzing the effects of the physical environment and materials. Since it works with an integrated system, on-site interventions are implemented in a short time and efficiently. Since BIM records and stores information about the building, it ensures the efficiency of the building throughout its life cycle and follows a different path than other software (Koçhan & Akın, 2022).

In the stages of visualization, design and modelling, the BIM model is developed with many data, such as material information, structural system details from the conceptual design and a detailed model. In the detailed design phase, the data obtained from modules A1-5 in the LCI can be processed with the model. In addition, a well-detailed model is significant for the quantification of the materials to be used.

In the stages where analyses are performed on the model obtained, energy analysis, conflict detection and cost estimations are performed to prevent errors that may arise in construction and subsequent use, reduce costs and shorten the construction period. Thus, energy analysis is performed by associating the object-based model created in the previous stage with an energy analysis tool. Visual programming tools developed to perform analyses in the BIM system and capable of calculating environmental impact using LCI data can be mentioned.

With BIM technologies, it is possible to perform some of the following analyses to provide optimum conditions in all building life cycle phases (Fig. 7 and 8) (Özcan & Erol, 2018).

- Climatic Analysis
- Energy Load Analysis
- Sun and Shadow Analysis
- Solar Radiation Analysis
- Natural Lighting Analysis
- Wind Analysis
- Whole-Building Energy Analysis

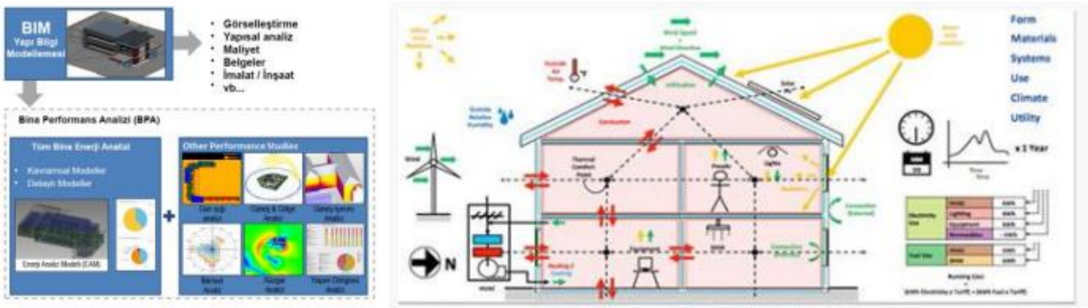

Figure 7. Some energy analysis in Autodesk Revit environment (URL3) and Autodesk Green Building Studio whole-building energy simulation (URL4).

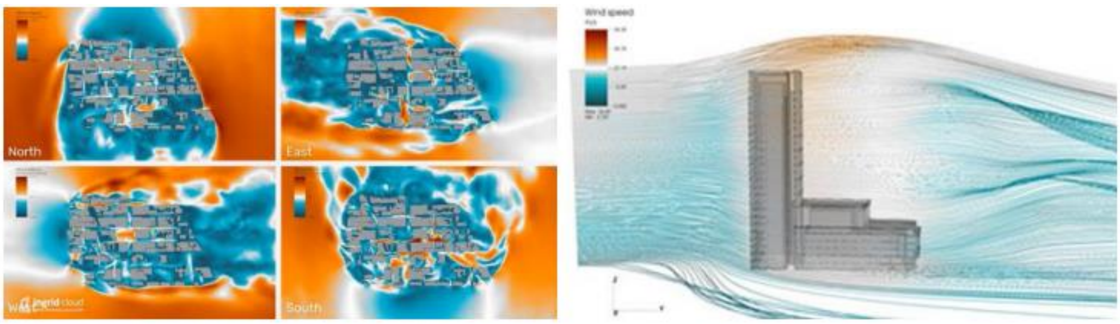

Figure 8. Wind simulations and wind load simulations around the building with Ingrid Cloud (URL5).

When a change is made in the model as a result of these analyses, the cost estimates made by updating the data are also updated. At the same time, the work program prepared with the model is associated with the construction planning. Thus, field coordination is ensured, and the follow-up of the construction process is facilitated. The construction simulation of the building and the virtual state of the site are obtained. With this model, the environmental effects of the building and the effects of the environment on the building can be obtained thanks to analysis tools that can simulate not only the production of the building but also the process until its use and demolition.

With the field drawings that can be easily obtained from the completed model, it is easy to update the designs, such as mechanical, electrical, and plumbing designs, and renew the drawings according to the changes to be made during the fabrication and construction stages. When it is necessary to examine the compliance of the project with the regulations, this process becomes easier, as the BIM model contains detailed specifications. In the facility management phase, it can be used in operations such as renovation and repair since the model contains all the information from planning to production.

The traditional Computer Based Document (CAD) design process requires more effort and cost while the project is in the documentation process. The BIM process requires more effort at the beginning of the project process and starts to decline during the design development phase. Changes made during the design process have a lower value in CAD programs and a higher value in BIM (URL6). As a result, with the advantages provided by the BIM method, making changes in the design throughout the process requires less effort, time, and cost.

Easier and more effective analyzes can be made in terms of sustainability. Thus, as a result of the analysis, the best design in terms of efficiency and sustainability can be decided to be implemented among the design options.

3.2. BIM-LCA Integration and Its Utilization in Early Design Phase

BIM, which provides solutions to the problems that will occur during and after the construction phase, and LCA methods, which calculate the emissions and environmental impacts that a building will cause during its lifetime, have started to be researched and used more and more with the increasing awareness of these issues. This shows that the combination of BIM and LCA has a great potential. Although BIM and LCA have started to be used more and more in building production processes by using the developments in design technologies, ensuring efficiency and increasing importance of environmentalist approaches; the fact that the use of the integration of these two methods is not provided (or provided less) in the process is due to the fact that the BIM model unfortunately cannot provide the detailed and information required by the LCA study, especially in the early stages (Roberts et al., 2020). Although many scientific studies have been conducted for this integration, there are still no LCA calculation modules directly accessible to the end user within BIM programs (Duru, Dinçer & Koç, 2022).

Another obstacle encountered in the integration of BIM and LCA is that the information required for the realisation of LCA is usually too much. The reason for using visual programming tools at this point is that the results of LCA are easier to understand by the designer. Otherwise, too much information -and especially quantitative data- that will be generated as a result of LCA will make the designer's work difficult and prevent the processing of the results (Roberts et al., 2020). Presenting this data to the designer as visualized results can facilitate the designer when comparing different design options. Some visual programming tools that can generate visualized results and can be used without the need to write code can help designers.

Autodesk Revit BIM model and life cycle inventory information (LCI) used in LCA calculations can be brought together through Dynamo, a visual programming tool, to determine the environmental impact results of the building in early design stages (Fig. 9) (Duru, Dinçer & Koç, 2022; Kiamili, Hollberg, & Habert, 2020). The most important feature of the Dynamo visual programming language is that it can establish a relationship with predefined objects in the BIM design environment and move data to the BIM environment through external data sources (Autodesk, 2021).

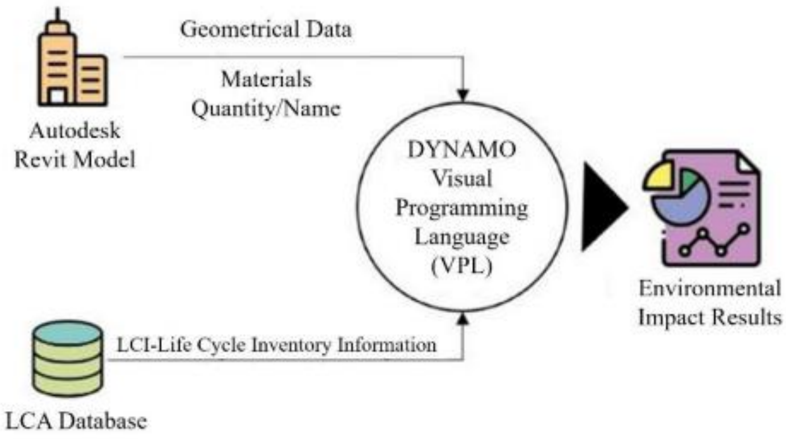

Figure 9. Environmental impact calculation scheme with Dynamo in Revit (Duru, Dinçer & Koç, 2022; Kiamili, Hollberg, & Habert, 2020).

Since the building is primarily constructed virtually in the BIM method, conducting the analyzes in the early stages of the building production process, before the construction of the building starts, provides more efficiency in many aspects such as time, cost and sustainability compared to the old methods. However, the earlier in the process these sustainability goals are considered, the higher the efficiency will be. For this reason, it is important to integrate BIM and LCA methods, especially in the early design stages when the design and model are being created.

Decisions at the beginning of the design process to use resources efficiently yield important results. Especially in the conceptual design phase, the ability to perform some analyzes without difficulty offers significant advantages (Savaşkan, 2015). The ability to generate data on building performance during the conceptual design phase, when basic decisions about the structure and its form are made, allows the design to be redeveloped in order to improve building performance. In this application that measures building performance in advance, difficulties, delays, and additional costs that may arise during building construction and operation can be eliminated (Ofluoğlu, 2021). The process of designing sustainable high-performance buildings has a spiral cycle (Koçhan & Akın, 2022). Fig. 10 shows the conceptual design and design development phases where BIM software and analysis are used.

Figure 10. The use of BIM in the processes of high-performance sustainable building design, adapted from Ofluoğlu, 2018 (URL7) (Koçhan & Akın, 2022).

The early stages of design, such as conceptual design and development, are of great importance for an efficient building production process, as they form the basis for later stages. However, LCA cannot yet be used effectively at these early design stages. Because most of the things related to the design are at a more conceptual level and show a lot of variability.

The high level of uncertainties and lack of detailed information in the early design phase, where the outline of the design is established, limit the realisation of LCA at these stages. As a result, LCA has to be carried out only after the design is finalised so that detailed information can be obtained. This means that LCA is reactive rather than proactive (Röck et al., 2018; Roberts et al., 2020). In fact, LCA is most efficient at the LOD 100 stage, where important decisions are made, rather than at the model stage, which is brought up to the LOD 300 level. At this point, it becomes very difficult to talk about a BIM and LCA integration since it is very limited to get the data required for LCA from the model in the early design phase. In addition, since LCA data is not suitable for the simplicity level of the conceptual model at LOD 100 level, LCA cannot be used at this level where design comparisons are made. Therefore, if LCA data can be adjusted according to early stage model levels such as LOD 100, it can be ensured that result comparisons can be made for different design variations according to their environmental impacts (Rezaei et al., 2019; Roberts et al., 2020). In sum, LCA can be used at the LOD 300 level, where a three-dimensional and detailed BIM model is created, but this poses a problem for the efficiency of the design and modelling process. Because the model is now highly detailed, meaning that the design is now mostly decided at LOD 300. However, it is envisaged that the use of LCA data before the design is fully established at an earlier stage when a choice among design variations is to be made can prevent the creation of detailed models repeatedly and waste of time.

4. CONCLUSIONS AND FURTHER RESEARCH

Thanks to the analysis and simulation tools used in BIM technologies, many problems can be solved in advance in the three-dimensional virtual model before the construction of the building starts, and the building can be made more sustainable. The use of detailed BIM model and LCA data together also enables the effects of the building on its environment throughout its life cycle to be analysed in advance. Thus, many losses, especially time, cost and effort, are prevented, the optimum design for the sustainability of the building is achieved, and the environmental impacts of the building are taken into account before the construction of the building begins. At this point, it is quite clear that BIM is a very significant method for more sustainable solutions throughout the building life cycle.

The combined use of BIM and LCA can be seen as a method that can guide designers in reducing building-related emissions. This indicates the potential of LCA and BIM integration to reduce cost and time losses throughout the building life cycle and to make sustainable design decisions early on.

The positive impact of solutions in the early stages of the building production process, before the construction has even started, on the building production process has been revealed. At this point, efficient design comparisons can be made with environmental impact, performance and efficiency analyses that can be embodied almost instantly with the BIM method after the stage where the detailed model is produced. This enables more efficient and sustainable building design and production. However, in this context, it is necessary to address the design process in order to further increase efficiency. Because it is seen that the decisions taken in the early design stages have the highest impact on the whole process, as they form the basis for the later stages. For this reason, sustainability criteria should be evaluated in the early design stages within the scope of the project.

A completed and well-detailed BIM model contains data on all elements used for the structure. The detailing and LCA data at LOD 300, and more advanced stages of the model can be used together, and environmental impact assessments can be performed. However, since the model is not fully detailed in the early design stages, LCA and BIM cannot be integrated before the model reaches the LOD300 level. As a result, it is seen that in order to ensure efficiency for the designer as much as possible in the building design process and to be able to talk about a complete integration of BIM and LCA, it is necessary to create LCA data suitable for the model for the LOD100 level of the model. With the studies to be carried out on this subject, more sustainable and environmentally friendly designs that can reduce the negative environmental impacts resulting from building production can be achieved.

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REFERENCES

Abd Rashid, A.F., Yusoff, S. (1015). Renewable and Sustainable Energy Reviews 45. A Review of Life Cycle Assessment Method for Building Industry

AIA. (2013). Guide, Instructions and Commentary to the 2013 AIA Digital Practice Documents.

Autodesk. (2021). What's New in Dynamo for Revit 2.12 (Autodesk support and learning). https://autode.sk/3CMCayv.

Autodesk (2016). Discover Dynamo. Available at: http://dynamobim.org/explore/.

Bahadır Ü. (2018). Yenileme Projelerinin Yönetim Süreçlerinde Yapı Bilgi Modellemesinin Kullanımı: Vaka Çalışması, Yüksek Lisans Tezi, KATÜ, Fen Bilimleri Enstitüsü, Trabzon, Turkey.

Basic, S., Hollberg, A., Galimshina, A., & Habert, G. (2019). A Design Integrated Parametric Tool for Real-Time Life Cycle Assessment. Bombyx Project. IOP Conference Series: Earth and Environmental Science, 323. https://doi.org/10.1088/1755-1315/323/1/012112.

Bruce-Hyrkäs, T. (2021). Building Life Cycle Assessment White Paper. Discover Why You Need LCA to Build Sustainably. Retrieved from https://www.oneclicklca.com/building-lifecycle-assessment-white-paper/.

Çavuşoğlu, Ö. H., Çağdaş, G. (2018). Enhancing Decision Making Processes in Early Design Stages: Opportunities of BIM to Achieve Energy Efficient Design Solutions. ITU A|Z, Vol 15 No 1, March 2018, 53-64.

Duru, M.O., Dinçer, S.G, Koç, İ. (2022). Mimari Tasarım Sürecinde Çevresel Etki Hesaplanmasında Görsel Programlama Dillerinin (VPL) Kullanılabilirliğinin İrdelenmesi. Kent Akademisi Dergisi, 15.(Dicle Üniversitesi 2. Uluslararası Mimarlık Sempozyumu Özel Sayısı):072-090. https://doi.org/10.35674/kent.1013859.

Gibbons, O. P., & Orr, J. J. (2020). How to Calculate Embodied Carbon. The Institution of Structural Engineers.

Gomaa, M., Farghaly, T., & El Sayad, Z. (2021). Optimizing A Life Cycle Assessment-Based Design Decision Support System Towards Eco-Conscious Architecture Computational Methods and Experimental Measurements XX. http://dx.doi.org/10.2495/cmem210041.

ISO (2006). "ISO 14040:2006 Environmental Management – Life Cycle Assessment – Principles and Framework," Vol. 2006. International Organization for Standardization, Geneva, Switzerland.

ISO (2006). ISO 14044 Environmental Management — Life Cycle Assessment — Requirements and Guidelines, Vol. 2006. International Organization for Standardization, Geneva, Switzerland.

Kensek, K. (2015). Visual Programming for Building İnformation Modeling: Energy and Shading Analysis Case Studies. Journal of Green Building, 10, 28-43. https://doi.org/10.3992/jgb.10.4.28.

Khasreen, M. M., Banfıll, P. F. G., & Menzıes, G. F. (2009). Life-Cycle Assessment and the Environmental Impact of Buildings: A Review. Sustainability, 1(3). https://doi.org/10.3390/su1030674.

Kiamili, C., Hollberg, A., & Habert, G. (2020). Detailed Assessment of Embodied Carbon of HVAC Systems for a New Office Building Based on BIM. Sustainability, 12, 3372. https://doi.org/10.3390/su12083372.

Koçhan, K., & Akın, C. T. (2022). İklim Değişikliği Karşısında Sürdürülebilir Binaların ve Bütünleşik Tasarımın Önemi (BIM Tabanlı Sürdürülebilirlik Analizleri), Kent Akademisi Dergisi, 15 (Dicle Üniversitesi 2. Uluslararası Mimarlık Sempozyumu) :53-71. https://doi.org/10.35674/kent.1014067.

Lasvaux, S., Gantner, J., Wittstock, B., Bazzana, M., Schiopu, N., Saunders, T., & Gazulla, C. (2014). Achieving Consistency in Life Cycle Assessment Practice Within the European Construction Sector: The Role of the EeBGuide InfoHub. The International Journal of Life Cycle Assessment, 19(11), 1783-1793.

NIBS (2007). The National Building Information Modeling Standarts.

Ofluoğlu, S. (2021). BIM Destekli Tasarımlar Daha Sürdürülebilir Yapılar Yaratıyor. https://www.researchgate.net/publication/352491620.

Özcan, U., Erol, İ. (2018). Sürdürülebilir Tasarımda Yapı Bilgi Modellemesi (BIM). International Congress on Engineering and Architecture, Alanya, Turkey.

Özorhon B. (1018) Building Information Modelling, İstanbul, Turkey.

Rezaei, F., Bulle, C., & Lesage, P. (2019). Integrating Building İnformation Modeling and Life Cycle Assessment in the Early And Detailed Building Design Stages. Building and Environment, 153(February), 158–167.

Roberts, M., Allen, S., & Coley, D. (2020). Life Cycle Assessment in the Building Design Process –A Systematic Literature Review. Building and Environment, 185(August), 107274.

Röck, M., Hollberg, A., Habert, G., & Passer, A. (2018). LCA and BIM: Integrated Assessment and Visualization of Building Elements' Embodied Impacts for Design Guidance in Early Stages. Procedia CIRP, 69(May), 218–223.

Savaşkan, M. O. (2015). Yüksek Enerji Performanslı Konut Yapıları için BIM Tabanlı Bir Açık Kaynak Bilgi Sistemi Modeli. Yüksek Lisans Tezi, İ.T.Ü. Fen Bilimleri Enstitüsü, İstanbul.

Seghier, T., Lim, Y.-W., Ahmad, M., & Williams, O. (2017). Building Envelope Thermal Performance Assessment Using Visual Programming and BIM, based on ETTV requirement of Green Mark and GreenRE. International Journal of Built Environment and Sustainability, 4. https://doi.org/10.11113/ijbes.v4.n3.216.

UNEP. (2020). 2020 Global Status Report for Buıldings and Construction: Towards a ZeroEmissions, Efficient and Resilient Buildings and Construction Sector. https://globalabc.org/sites/default/files/inlinefiles/2020%20Buildings%20GSR_FULL%20REPORT.pdf.

Van De Hoef, Joran M. (2022) Integration of Building Information Modelling and LifeCycle Analysis in Early Structural Design; a Parametric Study, Master Thesis, Eindhoven

University of Technology, Structural Engineering and Design Department of the Built Environment, Eindhoven, Holland.

URL1: https://www.oneclicklca.com/building-lca-resource-hub/.

URL2: https://www.advenser.ae/bim-services/.

URL3: https://knowledge.autodesk.com/searchresult/caas/CloudHelp/cloudhelp/ENU/BPA-BPAWorkflows/files/GUID-43DAB177- 3A4F-496C-BECB-2591FD04FC10-htm.html.

URL4:https://www.yesilbinadergisi.com/yayin/696/surdurulebilir-yapilar-kapsamindatasarim -analiz-ve-simulasyon-icin-autodesk-cozumleri_20927.html#.YVVvdZpByUk.

URL5: https://www.ingridcloud.com/wind-simulations/wind-energy/.

URL6: https://www.bimteknoloji.com/fikir/bim-kisayolu-yok/.

URL7: http://www.sayisalmimar.com/kurslar/sertifikalar/surdurulebilir_bim.pdf.