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Research Article

Advancing BIM Processes for Composite Structural Systems: A Case Study of an Incubation Center in Turkiye

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Abstract

The parameters planned for construction projects to be realized in the construction industry are sensitive to cost estimation errors. Developed countries have increased the performance of contractor firms by making the use of BIM technology mandatory to meet the increasing requirements of the construction industry. However, traditional approaches, still used in many countries, are prone to error. This study aims to develop 3D to 5D BIM models for an incubation center project in Türkiye, where BIM technology is not yet mandatory and no official standards have been published. The composite project structure consists of reinforced concrete & steel structural systems. The project has been procured within the scope of Turkish Public Procurement Law. Autodesk Revit and Tekla Structures were used for 3D modeling. The 3D-BIM model at the LOD 400 level was obtained. The obtained quantity data were then processed on the work program, prepared in Primavera P6, and a time and cost schedule were prepared for 52 production items. The 5D-BIM cost simulation was designed via Autodesk Navisworks Manage. The results indicate that the construction cost estimations, which can be obtained by using the 5D-BIM method and financial risk management methodology together, will be beneficial for the tender stakeholders.

Keywords: *Composite Structural Systems, Building Information Modeling, 5D-BIM, LOD 400*

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Kompozit Yapısal Sistemler için BIM Süreçlerinin Geliştirilmesi: Türkiye'deki Bir Kuluçka Merkezi Örneği

Öz

İnşaat sektöründe planlanan parametreler, maliyet tahmin hatalarına karşı hassastır. Gelişmiş ülkeler, inşaat sektörünün artan gereksinimlerini karşılamak için Yapı Bilgi Modellemesi (YBM) teknolojisinin kullanımını zorunlu hale getirerek yüklenici firmaların başarısını artırmıştır. Ancak, birçok ülkede hala kullanılan geleneksel yaklaşımlar hataya açıktır. Bu çalışma, Türkiye'den bir kuluçka merkezi projesi üzerinde 3B'den 5B'ye BIM modelleri oluşturmayı amaçlamaktadır. Türkiye henüz BIM teknolojisini zorunlu hale getirmemiştir ve yayınlanmış bir standart bulunmamaktadır. Kompozit proje yapısı betonarme ve çelik yapısal sistemlerden oluşmaktadır. Proje, Türk Kamu İhale Kanunu kapsamında ihale edilmiştir. 3D modelleme için Autodesk Revit ve Tekla Structures kullanılmıştır. LOD 400 seviyesinde 3D-BIM modeli oluşturulmuştur. Elde edilen metraj verileri daha sonra Primavera P6'da hazırlanan iş programına işlenmiş ve 52 imalat kalemi için zaman ve maliyet çizelgesi hazırlanmıştır. 5D-BIM maliyet simülasyonu Autodesk Navisworks Manage aracılığıyla tasarlanmıştır. Sonuçlar, 5D-BIM yöntemi ve finansal risk yönetimi metodolojisinin birlikte kullanılmasıyla elde edilebilecek inşaat maliyet tahminlerinin ihale paydaşları için önemli avantajlar sağladığını göstermektedir.

Anahtar kelimeler: *Kompozit Yapı Sistemleri, Yapı Bilgi Modellemesi, 5B-YBM, LOD 400*

1. Introduction

Due to poor performance, construction projects are vulnerable to errors and face challenges such as inaccurate quantity take-offs, delays in completion, cost overruns, and inefficient energy use (Aibinu & Venkatesh, 2014; Bayram & Al-Jibouri, 2018; Crowther & Ajayi, 2021; Maqsoom, Aslam, Ismail, Thaheem, Ullah, Zahoor, & Vatin, 2021). The requirements that arise due to the rapidly developing and changing technology affect construction and other industries (Kahraman, 2022). According to a study, the global output of the construction industry is projected to increase by 42%, reaching $15.2 trillion between 2020 and 2030 (Oxford Economics, 2021). The growing share of the construction industry in the global economy causes increasing competitive conditions, forcing the firms to explore all possible options within the framework of increasing product & service quality. This growing demand fosters digitalization in the sector, giving rise to the concept of Construction 4.0, which promotes faster production, higher quality, and cost-efficiency (Chen, Huang, Liu, Osmani, & Demian, 2022)." Various studies have shown that a highly sophisticated digital process increases the quality of important factors such as design freedom and productivity in the construction industry (Zareiyan & Khoshnevis, 2017).

In recent years, modern and innovative technologies have emerged in the field of construction project management, which is vital for the development of either public or private industry. Among these technologies, Building Information Modeling (BIM) has revolutionized the Architecture, Engineering, and Construction (AEC) industry by offering a comprehensive and integrated approach. The highest contribution of this approach to the global construction industry ensures faster adoption of the system (Emara, 2022). BIM extends beyond conventional 3D design systems to include additional dimensions such as time (4D), cost (5D), environmental impact (6D), and maintenance (7D) (Fábrega Ferrer, 2022). Through case studies, researchers and industry professionals have highlighted the following advantages of using BIM (Hong, Hammad, & Nezhad, 2022): the removal of project collision risks (Bensalah, Elouadi, & Mharzi, 2019), improved reuse of design information throughout a project (Almuntaser, Sanni-Anibire, & Hassanain, 2018), and increased prefabrication engagement (Jang & Lee, 2018).

BIM usage is increasing rapidly around the world, and the 10th National BIM Report, prepared by the UK-based National Building Specification (NBS) with the participation of more than 1,000 industry representatives, includes the following important findings (NBS, 2020):

- BIM adoption increased from 43% in 2011 to 73% in 2020.
- In the last 10 years, the view that BIM is only a 3D drawing tool has disappeared and other dimensions of BIM have started to be applied.

- The participants agree that digital transformation will continue to change the milestones of the construction industry.
- The two main obstacles to the BIM system are seen as; (i) The customer demand is not sufficient, and (ii) The non-suitability of BIM for relatively small structures.

Developed countries have enhanced contractor performance by mandating the use of BIM technology to meet the evolving demands of the construction sector. A study performed by Ullah et al. (2019) emphasized that the adoption rate of BIM increased to 79% in the USA, 78% in Denmark and Canada, and 74% in the UK (Ullah, Lill, & Witt, 2019). The rapidly increasing use of BIM in developed countries, unfortunately, is not reflected in developing countries at the same rate. The traditional approaches, still used in many countries, are prone to error. However, the construction industry, which is considered the locomotive in developing countries, requires the aforementioned advantages of BIM much more.

In Türkiye, a developing country, the construction sector remains active through credit support and government incentives, even during periods of economic instability. In terms of gross domestic product (GDP), the construction industry in Turkiye has a considerable impact on the country's economy—approximately 30% (Elmalı, & Bayram, 2022).

The acceleration in industrial requirements and the constructional revolutions have created frontier research trends within the scope of BIM. In this context, the literature review is presented below for different BIM dimensions.

Lin (2014) proposed a "Construction BIM-based Knowledge Management" (CBIMKM) system tailored for general contractors. The system was applied to a building project in Taiwan. The findings indicated that by employing the BIM technique and web technologies, the CBIMKM system can be used as a visual 3D-based knowledge management platform (Lin, 2014). Aibinu and Venkatesh (2014) conducted a survey involving 180 Australian construction firms to evaluate their experiences with 3D-BIM applications. It was found that BIM features are not commonly used by firms due to some problems, such as concerns about the integrity of 3D models provided by designers and/or incomplete information in models. Akponeware and Adamu (2017) aimed to identify the causes of clashes in BIM-based coordination systems to achieve clash avoidance for BIM in the UK. Isolated working; involving mechanical, electrical, and plumbing (MEP) 3D-BIM systems was found as the primary reason. Bayram (2020) sought to compare two commonly used BIM-based software tools. The quantity data was obtained using traditional methods. It was stated that the quantities determined using the BIM-based software are obtained much faster and more practical than the traditional method, and the accuracy rate is quite high. Akhmetzhanova, Nadeem, Hossain, and Kim (2022) pointed out that processes for detecting and resolving clashes with BIM are attempting to advance concurrently in the Kazakhstan BIM environment.

Gledson and Greenwood (2016) attempted to determine how contracting firms in the UK had modified their current construction planning procedures by utilizing 4D-BIM to enhance project delivery and timeliness. A survey was applied to 136 professionals. The study included information on the perceived value of 4D-BIM, the scope of its application, and the planning components that served as its primary targets. Jupp (2017) utilized workflows to integrate 4D modeling and analysis technology and created a customized framework for environmental planning and management. Scheduling & simulation, modeling of environmental equipment, modeling of construction site layout, modeling & visualization of environmental impact significance, and rule-checking capacity were all listed as five functional prerequisites. Crowther and Ajayi (2021) investigated the impacts of 4D-BIM on construction projects. A survey study was conducted and three topics, namely project reliability, project monitoring, and project diagnosis were discussed. Rashidi, Yong, Maxwell, and Fang (2022) aimed to unearth novel experimental findings by combining 4D-BIM and virtual reality (VR) technologies during construction planning among construction professionals at light steel frame (LSF) projects. Except for the variable of 'project schedule and sequencing', all the considered variables showed significantly positive differences.

Xu (2017) created a 3D model of a building and performed a construction simulation and overlap analysis. It was stated that the 5D-BIM methodology increases the quality of construction, reduces costs, and contributes to green building technology. Arif and Khan (2020) investigated a Business Incubation Centre as a case study, however, its application was limited to block masonry, slab-level concreting, and column-level concreting. The current study presents a broader perspective on different dimensions of BIM for these types of projects, i.e. 81 production activities were considered. Aragó, Hernando, Saez, and Bertran (2021) aimed to define the new processes, roles, and skills required by the quantity of information obtained through 5D-BIM models. They stated that the quality of the quantity take-offs has been increased by creating a 5D-BIM model of four different construction projects. Ranjbar, Ansari, Taherkhani, and Hosseini (2021) aimed to present a new cash flow methodology to the construction industry by using the 5D-BIM. Because of their study on a sample project, they determined that the contractor firms developed the decision-making mechanism by estimating the possible cash flow process while managing the construction projects. Maqsoom et al. (2021) developed a RwH assessment system in Pakistan through BIM. It was found that the chosen sites can capture anywhere between 48

L/person/day and 56 L/person/day of rainwater annually. Uddin, Wei, Chi, Ni, and Elumalai (2021) examined BIM implementation for green building assessment by taking into account the accessibility of local building supplies. The results demonstrated significant energy savings for buildings as well as a significant decrease in embodied energy and carbon footprint when local building materials are used. Changsaar, Abidin, Khoso, Luenhui, Yaoli, and Hunchuen (2022) investigated the possible advantages of incorporating BIM into the energy performance (EP) analysis of a building. Autodesk Revit was used to create the 3D-BIM model and EP analysis and simulations were performed via Autodesk Green Building Studio (GBS). This study concludes that including BIM in EP analysis enhances the accuracy of all EP measurements.

More recently, Öz, Cevikbas, and Öcal (2023) purposed to identify the significance of 4D-BIM elements in the construction sector and define them. Sixteen 4D-BIM features were identified, which were crucial for project planning. Akbay, Ökten, and Üstüner (2023) mentioned that the Turkish construction industry has still not achieved the expected digitalization, and the sector's involvement in digital transformation will provide a competitive advantage. Bozkurt, Ersoy, and Yaşa (2024) emphasized that Turkiye is still not adapted to BIM-VR technology, as evidenced by the fact that the majority of studies on BIM-VR integration are from other nations. Hussain, Moehler, and Walsh (2024) integrated the 5D-BIM into mega rail projects. Inzerillo, Acuto, Pisciotta, Mantalovas, and Di Mino (2024) performed a time-cost analysis in terms of 4D BIM and 5D-BIM for a railway station. Alothman and Vilventhan (2025) implemented BIM in metro rail projects, to convert the traditional project delivery process into a digital project delivery process (DPDP).

The literature review indicates that the studies related to 3D-BIM focus on design integrity like quantity take-off, clash detection, etc. 4D-BIM studies involve the potential impacts and project delivery as well as flawless scheduling. Finally, 5D-BIM studies efforts to improve the quality of the quantity take-offs and the construction, as well as cost and risk reduction.

Technoparks emerged and expanded as fresh economic engines that put science into action (Dilrabo, 2022). Research centers, such as enterprise support centers, technology commercialization centers, and incubation centers, play a part in fostering government, business, and academic collaboration (Lee, Lee, & Oh, 2017). Incubation centers are designed to assist and support start-ups and spin-offs, which inevitably energize nearby companies and industries (Sung, & Kim. 1998). No effort has been observed for the construction process of incubation center buildings in the literature, which is of great importance for Technoparks.

The goal of this study is to develop a 3D to 5D-BIM process for a completed incubation center project from Erciyes Technopark. The technopark's activities add to the region's scientific and/or technical culture, provide employment, and add value (Dilrabo, 2022). There are 73 Technology Development Zones actively working in Turkiye, as of June 2024. The selected incubation center is located within the borders of the Technology Development Zone of Erciyes University (ERU-TDZ) in Kayseri province, located in the Central Anatolia region. BIM technology is not yet mandatory in Turkiye, and there is no published BIM standard. Therefore, there is no path to follow for project managers yet. Another importance of this study is that previous studies generally considered singular reinforced concrete or steel structural systems. This study considers both and presents BIM processes for a composite structural system.

2. Material & Method

This study focuses on an incubation center project located in the Erciyes University Technology Development Zone (ERU-TDZ) as shown in Figure 1. The total area of ERU-TDZ is 156,382 square meters. The employer of the incubation center project is Erciyes Technopark.

Figure 1. Incubation Center Building, Technology Development Zone, Erciyes University.

The incubation center building, designed to support firms in conducting research and development (R&D) activities, has a ground floor area of 800 m^2 and a total construction area of 2000 m^2. The building consists of eight workshops, one shelter, one generator room, one hydrophore room, and one outbuilding. Each workshop was designed to have a ground floor area of 100 m^2 and a mezzanine floor area of 50 m^2. Each workshop consists of one office, one kitchen, one toilet, one disabled toilet, one warehouse, and one production area. The structural system of the foundation and basement floor of the building were designed as reinforced concrete, and the ground and mezzanine floor were designed as steel construction. The 2D architectural floor plans of the building are presented in Figure 2.

The case-construction project of this study has been procured within the scope of the Turkish Public Procurement Law, no 4734. Designers utilize technology (like Revit, for example) as part of the BIM process to produce various building models (Uddin et al., 2021). The 3D modeling of the composite structure was carried out using Autodesk Revit and Tekla Structures. The 4D and the 5D models can be simulated; this simulation helps investors optimize time and budget by improving constructability based on time and cost (Cheng, Tan, Song, Liu, and Wang, 2017). The obtained quantity data from the 3D-BIM model of the project were then processed on the construction schedule, prepared in Primavera P6 software, and a time and cost schedule was prepared. The 5D-BIM cost simulation was designed via Autodesk Navisworks Manage 2020 software, which allows it to combine the 3D model. A flowchart has been provided in Figure 3 to visualize the application process of this study.

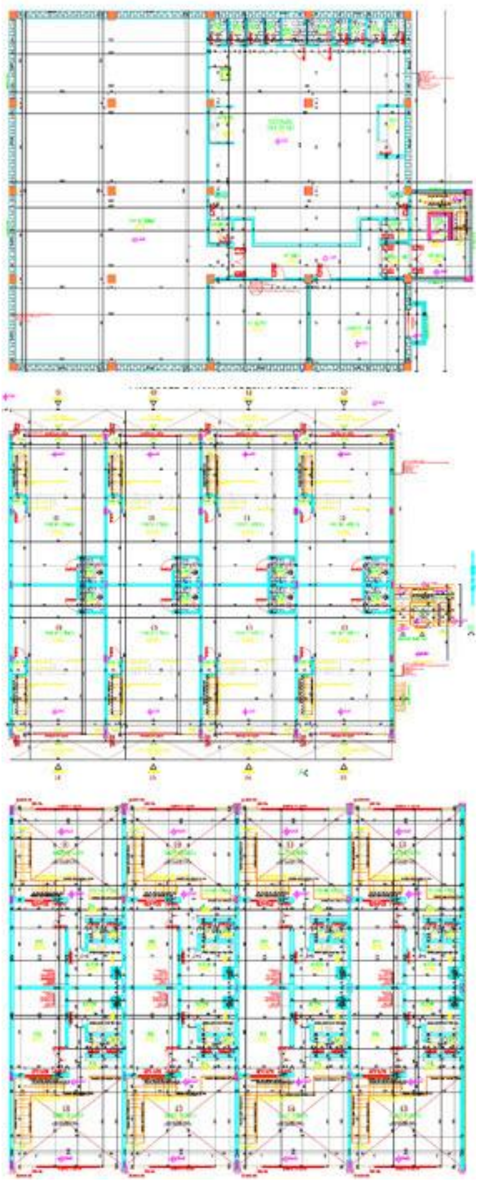

Figure 2. Basement, Ground and Mezzanine Floor Plans.

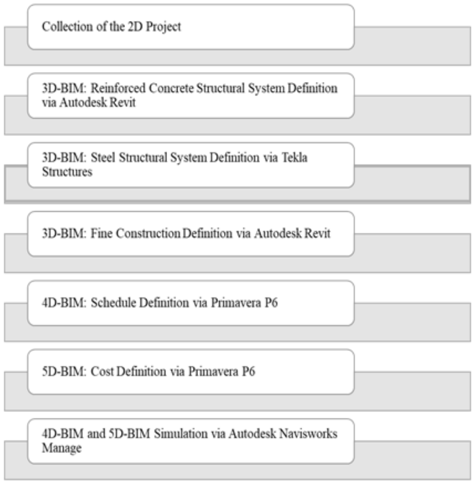

Figure 3. Workflow of the Application Process.

3. Case Study

Quantity take-offs were derived from a 3D-BIM model developed based on the original 2D architectural drawings of the incubation center. The structural modeling was performed via both Autodesk Revit and Tekla Structures software, and a guide was created on the use of Industry Foundation Class (IFC), a common data management system of BIM. The 3D-BIM model of the Incubation Center Building was created following the 11 steps below.

- A building template was selected on Revit that allows architectural and static models to be considered together.
- General settings; e.g. unit of measurement, display settings, etc. were adjusted.
- Elevation lines and axles, representing floor heights were drawn under the project.
- Reinforced concrete construction elements;

foundation, column, beam, floor, and stair were modeled.

- Reinforced concrete reinforcements were modeled.
- The basement floor was modeled in detail, including both wall elements and interior finishes.
- Ground and mezzanine steel structural systems were modeled via Tekla Structures.
- The composite structural system of the mezzanine floor was modeled.
- The fine works of the ground and mezzanine floors were modeled.
- The sandwich panels of the roof and the facade, composite coatings, and other productions were modeled.
- Final arrangements were performed on the model by creating the building's environmental topography.

Continuous foundations were designed in three sizes: 100×80 cm, 80×80 cm, and 30×50 cm. C16/20 was used for lean concrete, while C25/30 was selected for the structural elements. Afterward, reinforced concrete column (60x60 cm), beam (60x60 cm), floor (d=20 cm), and stair elements were modeled under the frame structural system of the 2D static project. Reinforcement models have been created at the LOD 400 level, considering features such as diameter, length, overlap length, stirrup spacing, and miter as shown in Figure 4.

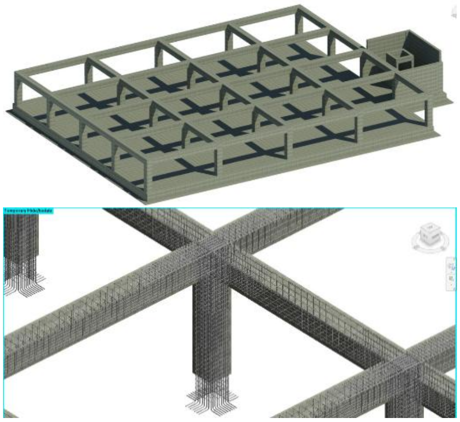

Figure 4. Reinforced Concrete Structural System and Column & Beam Reinforcement Modeling.

Fill material were designed to cover the exterior facades of the basement floor, and the exterior walls that will bear the load of this material were designed as stone walls (50 cm). Besides, the inner walls were designed as G3 class gas concrete (10 cm and 20 cm). Thus, the modeling of the wall elements of the basement floor with all components was completed. Afterward; screed (5 cm), ceramic (30x60 cm for toilets and bathrooms, 60x60 cm for the remaining), fire door (100x210 cm), aluminum door (80x210 cm), kitchen cabinet, and basalt coating productions were modeled as shown in Figure 5.

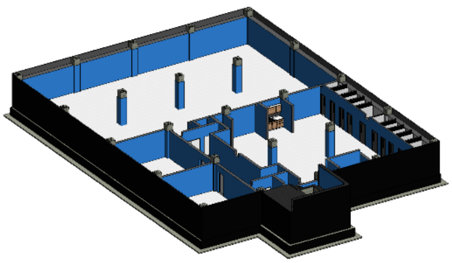

Figure 5. Basement Floor Modeling.

The steel structural components for the ground and mezzanine floors were modeled in Tekla Structures and subsequently transferred to Revit using the Industry Foundation Classes (IFC) format. The modeling of remaining productions on the ground floor was performed on this drawing. IPE 400 and IPE 200 column profiles, IPE 400 steel truss beam profiles, IPE 330 and IPE 160 steel beams (mezzanine floor structural system) were modeled together with their connection details as shown in Figure 6.

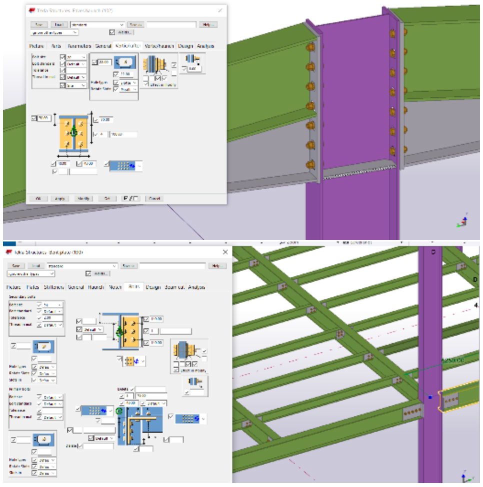

Figure 6. Column-Beam Connection Modeling.

Purlin and diagonal profiles of the mezzanine floor were modeled as CC 200 purlin profiles and CHS 88.9X3.2 & CHS 168.3X4.0 diagonal profiles. The facade cladding was designed as a sandwich panel in the 2D architectural project. The structural system of the panels was designed as an IPE 140-type profile in the 2D steel construction project. The window, sensual door, and fire door gaps in the facade tile were designed in the 3D models according to their actual dimensions. Finally, the anchor elements that connect the steel structure with the reinforced concrete structure, were modeled as shown in Figure 7.

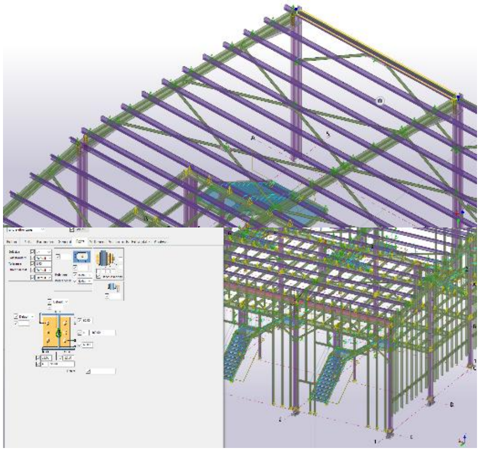

Figure 7. Purlin & Diagonal Structural Elements and Facade Tiling & Anchor Modeling.

Upon completion of all the planned drawings, a steel construction 3D-BIM model at the LOD 400 level was obtained. The model created in Tekla Structures has been exported thanks to the program's compatibility with the IFC system as shown in Figure 8.

The design of the composite structural elements, located at the mezzanine floor was also performed as shown in Figure 9. This structural system consists of a 1 mm galvanized corrugated steel, mesh steel, and C25/30 concrete production. Q257/257 mesh steel drawings were also modeled. After the modeling of the reinforced concrete productions was completed, fine production on the ground and mezzanine floors were modeled. The inner walls were applied as G3 class gas concrete (10 cm and 20 cm).

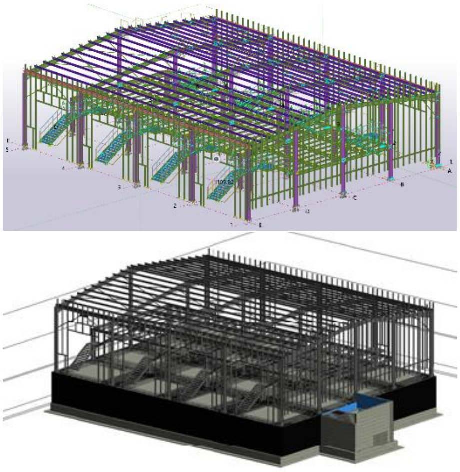

Figure 8. Steel Construction 3D-BIM Model and Transfer from Tekla Structures to Revit.

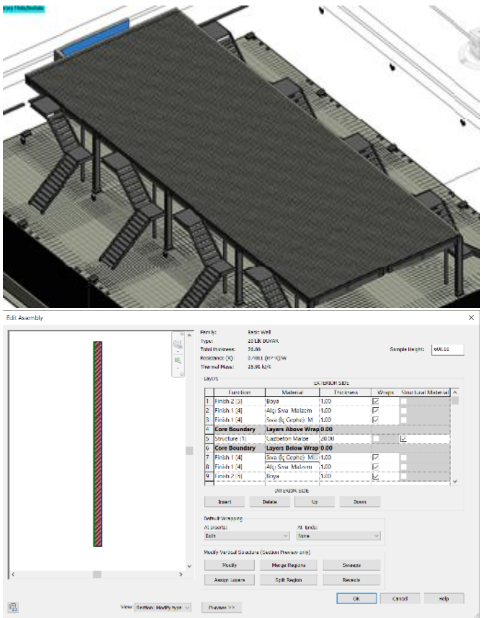

Figure 9. Composite Structural System Modeling on the Mezzanine Floor.

After the completion of the wall modeling; door, window, screed, ceramic and parquet, windowsill, wooden cabinets in the kitchen, kitchen counter, and ceiling cladding productions were modeled as shown in Figure 10. Aluminum window and suspended ceiling productions were downloaded and imported to the model from the BIMobject website, as they were not available in the Revit library (BIMobject, 2021a; 2021b). After the modeling of the productions on the ground and mezzanine floors was completed; rainspout, roof and exterior sandwich panels, fire doors, sectional doors, and composite coating were modeled. Finally, the field concrete in the architectural project and the topography of the building were modeled for landscaping. The field concrete was modeled as C25/30 and Ø257/257 mesh steel reinforcement.

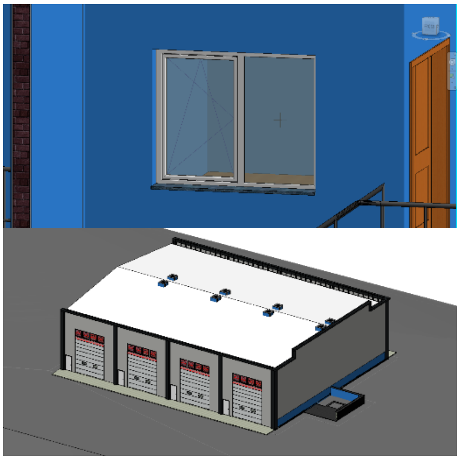

Figure 10. Fine Construction and Interior Wall (20 cm) & Layers Modeling.

After the 3D-BIM model of the Incubation Center Building was completed, the quantity lists were prepared. The quantity lists were obtained from Revit & Tekla Structures. The bill of quantities of a total of 52 production items has been created. The arranged quantity data were used to prepare the work program. To prepare the 4D-BIM models obtained by adapting the time dimension to the 3D-BIM model, work definitions published by the Turkish Ministry of Environment, Urbanization, and Climate Change were used. The resource analysis was performed and the activity durations were determined. The resource analysis process is summarized below in seven stages:

- The work definitions, suitable for the present production items, designed in the 3D-BIM model were determined.
- Pose analysis, the required resources for unit production of each item, was determined.
- The critical source of each production item was determined.
- The work period for a single team was considered as 8 hours per day.
- It was calculated in how many days the critical resource could complete the work time calculated.
- The team composition for the operative resources was determined.
- The activity duration for each production item was ensured.

To prepare the work program within the scope of the Incubation Center Building Construction Work, the Enterprise Project Structure (EPS) information and sub-EPS information were initially arranged in Primavera P6 software as shown in Figure 11. The Work Breakdown Structure (WBS) of the project was created in two parts rough works and fine works. The activities, durations, predecessors, and the required resources in terms of material, workforce, and equipment, were defined and added. The sub-activities within the same main activity group are separated according to production order. For example, the production of C25/30 concrete was defined into four separate activities: foundation, basement, ground, and mezzanine concrete. Thus, 81 activities were defined; including 30 activities for the rough works WBS and 51 activities for the fine works WBS. The duration of the project was found as 286 calendar days, which was planned to start on January 04, 2021, and be completed on October 17, 2021.

Figure 11. Activity Descriptions and Creation of Relationships.

To prepare the 5D-BIM models obtained by adapting the cost dimension to the 4D-BIM model, unit prices published in 2021 year by the Turkish Ministry of Environment, Urbanization, and Climate Change were used. The cost analysis of the Incubation Center Building was performed by using the resource analysis and the unit prices.

The quantities determined for each activity were defined on the software, production per day, and total activity costs were calculated. To make cost controls, the cumulative cost values were examined. In line with the data obtained, cost analyses were prepared and it was shown how the cost values changed daily via construction phase simulations within the framework of the 5D-BIM model.

The 5D-BIM model of the Incubation Center Building was prepared via Navisworks Manage software. To create time and cost simulations, the 3D model prepared in the Revit and the work program data created in the Primavera P6 were used. A simulation was created by integrating these data into the Navisworks as shown in Figure 12. The simulation shows the information of the 5D-BIM model, at what date, at what cost, and at what level, according to the prepared construction schedule.

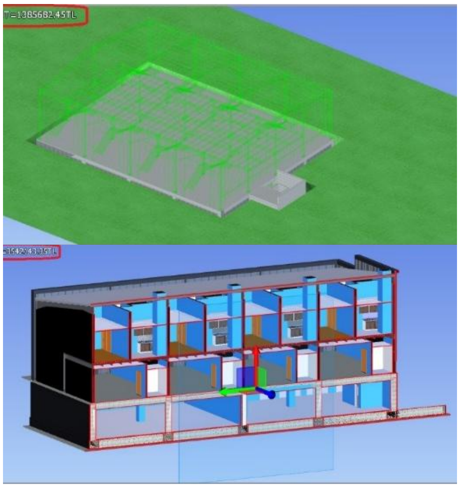

Figure 12. Steel Construction Simulation and Completed 5D-BIM Simulation.

No calculation was made on the total quantity of the activities included in the construction schedule while preparing the cost analyses. Separate calculations were made for each resource that belongs to the activity as shown in Figure 13. The main reason for making analyses at this level of detail is to enable a more detailed investigation of the construction schedule. Within the scope of this target, the total cost of the Incubation Center Building Work was determined as 3,542,139.42₺ (100%), of which 1,812,391.12₺ (51%) is rough works and 1,729,748.30₺ (49%) is fine works.

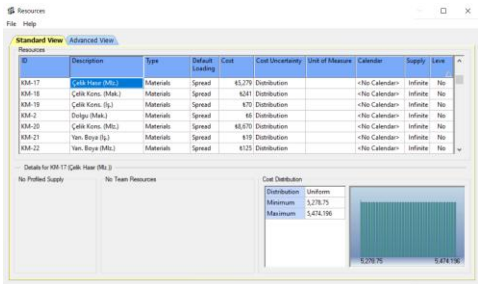

Figure 13. Cost Definitions on PRA.

The resource costs for the steel construction of the Incubation Center Building on the other hand was determined as 716,462.71₺ (100%); in which equipment cost was 19,212.33₺ (3%), labor force was 5,593.10₺ (1%), and material cost was 691,657.28₺ (96%).

4. Discussion

The findings of BIM implementation in Turkiye align with those performed abroad (Lin, 2014; Xu, 2017; Arif & Khan, 2020). However, the number of studies on BIM applications is very high, especially in developed countries, and limited in Turkiye despite the requirement. Despite its increasing popularity, it can also be stated that the studies originating from Turkiye in recent years are theoretical rather than a practitioner's guide (Bayram, 2020). Therefore, the expression of the lessons learned from the different dimensional BIM modelings for an Incubation Center Building is seen as significant. The encountered problems in the 3D-BIM modeling process (via Autodesk Revit and Tekla Structures), 4D-BIM, and 5D-BIM modeling process (via Oracle Primavera and Autodesk Navisworks) were discussed below respectively.

- In 3D-BIM modeling, Revit allows elements within the same family to automatically join. However, this functionality does not apply consistently to certain components, such as beams (Bayram, 2020). Although this situation does not change the quantity take-off, it prevents the creation of detailed reports. The solution is a time-consuming method that requires separating and reconnecting all the beams from each other.

- The automatic join feature may unintentionally alter the properties of other structural elements, leading to inconsistencies in the model (Changsaar et al., 2022). For example, while the plaster-paint layer drawing of the reinforced concrete column is made, if there is a layered wall element (containing a plaster-paint layer) on one side of the same column, the gas concrete material, which is the main element in the wall layer, becomes smaller in length. The solution is to close the join command temporarily and then complete the drawing.

- In the section drawings included in the architectural project, the assignment of plaster-paint layers on the surfaces of reinforced concrete beams to the beam surface is only possible by changing the basic settings of the reinforced concrete beam in the library (Uddin et al., 2021). It is required to copy the reinforced concrete beam in the library and perform operations on the obtained copy since the change to be made on the beam in the library causes all the beams in the project to change.

- The modeling phase of all the reinforcements in the project has a time-consuming and sophisticated structure due to the excess of details (Bayram, 2020). These difficulties may cause the designer not to prefer the reinforcement modeling process.

- Tekla Structures software includes easy-to-understand menus to create the main structural elements. However, auxiliary commands such as copy, move, divide, merge, point assignment, and geometric drawing are difficult to use.

- Tekla provides users with macros containing visual examples to facilitate the creation of structural connection details. However, the excessive number of adjustable parameters increases complexity and extends the modeling process. This situation causes designers to work on the same macros all the time and models emerge in similar patterns.

- Anchor structural elements that enable the steel columns to be supported by the reinforced concrete structural system can be modeled using macros. However, after the 3D model was created, it was detected that there would be difficulties in placing the anchor rods into the reinforced concrete column. As a solution, it was determined that the diameter of the reinforcements should be increased and the quantity should be decreased.

- Tekla allows modeling the steel banisters and various sheet metals. Three-dimensional models were also created for the steel stair banisters and rainspouts. The design revealed that varying profile diameters were required for different turning zones, increasing modeling complexity. This situation causes the design phase to become complicated.

- In terms of 4D-BIM and 5D-BIM modeling; 106 different types of resources, which were determined from the statistics of the Turkish Ministry of Environment, Urbanization, and Climate Change, were assigned to the activities created in Primavera. Primavera offers users the opportunity to define labor, material, and equipment resources and their quantity units (hour, number, square meters, volume, etc.). However, construction contracts under the Turkish Public Procurement Law (Law No. 4734) are prepared according to the “production measurement units” specified in standard work item definitions (pose analysis). For this reason, all of the resource types of the activities in the work program were determined as materials, and the production measurement units were defined as is in the work definitions. As an example, the production measurement unit for steel construction production is determined as "ton" in its work definition. The employer, Erciyes Technopark, pays the contractor under the calculations made in the "ton" unit for this production. Consequently, it would be better to estimate the labor cost in terms of "ton" instead of "hour", for the analyses to be performed to determine the tender bid prices.

- Within the scope of the study, since the working times were determined via resource analysis, the activity durations were defined manually and the one-day resource usage was calculated by the Primavera. Thus it can be determined which resource is needed, when, and how much. However, the accuracy of all data should be checked, since Primavera does not directly present the final output to users in case of changing the parameters that will affect the operations, such as defining the relations, determining the project duration, and calculating the budget. To obtain the working schedule, which reflects the changes made, various adjustments must be made and the program command must be run again. This situation affects revision processes by making it difficult to coordinate working schedule components.

- The created 3D-BIM model file can be saved in a format suitable for Navisworks by using the export feature of Revit. However, some adjustments are required on the 3D-BIM model prepared in Revit. This process has a complex structure since the setting menu includes too many tabs. Besides, there is not an adequate user manual on how to make these adjustments. Relying on trial-and-error methods to resolve these compatibility issues increases the complexity and duration of the process. For example, it was determined that not all of the layers on the imported model are selectable, only the outermost layers and the main layer are selectable. To solve this situation, the layered construction elements prepared in Revit were dismantled, and each layer was redesigned as a separate construction element.

- Similar problems were encountered during the file transfer process between Primavera P6 and Navisworks. Navisworks can import work programs prepared with Primavera P6 via web service. However, this feature works on a specific server. Therefore, Primavera P6 project output was obtained in MS Excel, edited in. CSV format, and transferred to Navisworks. This process is unfortunately a sophisticated process that involves changing various punctuation marks and may cause losses or inaccuracies in the transferred data. For the reasons mentioned, the model should be examined in detail after the data transfer process.

- The activities in the construction schedule and the construction elements must be associated to simulate the construction stages within the scope of 4D-BIM. For this purpose, the grouping feature of selected elements, suggested by Revit to the designers, was utilized. Since the created groups can be saved as a set in Navisworks, it simplifies the simulation preparation process. However, it would be much more beneficial to develop a tool that supports simultaneous synchronization between Revit and Navisworks to ensure a more effective process.

- The Turkish Public Procurement Law, which has been in force for nearly a quarter of a century, can no longer keep pace with technological developments. Therefore, updating it again in line with BIM processes is essential to ensure compatibility with BIM.

5. Conclusion

A large number of individuals with varied backgrounds, educational levels, and personal traits creates a complex environment in the project-based construction industry. In underdeveloped countries, construction project managers generally consist of managers who do not have an institutional and professional perspective and have no education or training in the field. This situation causes contractors to be standoff from technological developments. On the other hand, the construction industry is faced with managerial problems such as cost increases and delays, during intense economic fluctuations. This study aims to supply project managers with an integrated perspective and to explain practically why BIM should be used in construction projects.

The benefits of BIM are considerably more necessary for the construction industry, which is regarded as the locomotive in emerging nations. Turkiye has not yet made BIM mandatory and there is no published BIM standard. It is therefore expected that this study will be a resource of inspiration and a guide for emerging nations, which have not adopted BIM processes in the construction industry yet. This study develops a 3D to 5D-BIM process for a completed incubation center project from Erciyes Technopark, Turkiye. To eliminate the disadvantages of traditional methods, a more specific approach at the LOD 400 level was provided to the design, quantity take-off, schedule, cost, and construction phase simulation processes within the framework of the BIM approach. This study is also a guide for technoparks that will carry out the incubation center construction process. Previous research typically focused on steel or reinforced concrete structural systems. This study presents the BIM approach for a composite structural system and considers both. Finally, contrary to popular belief, this study shows that BIM is efficient in simple building structures.

The main limitation of this study is that; cost calculations were performed on the production items belonging to the construction work type of the sample construction project, therefore, indirect costs and profit margins were not considered. The reason is that 3D-BIM models of electrical and mechanical projects can be designed by professionals in the field and the costs vary according to the qualifications of the firms.

This study is generally a guide. It can be applied to different projects by following the application steps. To increase BIM awareness, it is expected that the consideration of different BIM dimensions in the scope of construction work tenders made by utilizing public resources will provide great benefits to public contractors, and will guide construction firms in the private sector. It is also expected that the 3D models of the structural elements will be combined on the same platform after they have been designed, using two different software, and will be a guide for the practical use of the industry foundation classes.

Declaration of Ethical Standards

Authors declare that all ethical guidelines including authorship, citation, data reporting, and publishing original research, were followed.

Credit Authorship Contribution Statement

Author 1: Software, Formal analysis, Investigation, Data curation, Writing – original draft, Visualization

Author 2: Conceptualization, Methodology / Study design, Validation, Investigation, Resources, Writing – review and editing, Supervision, Project administration, Funding acquisition

Declaration of Competing Interest

The author has no conflicts of interest to declare regarding the content of this article.

Data Availability

All data generated or analyzed during this study are included in this published article.

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6. References

Aibinu, A., & Venkatesh, S. (2014). Status of BIM adoption and the BIM experience of cost consultants in Australia. *Journal of professional issues in engineering education and practice*, *140*(3), 04013021. https://doi.org/10.1061/(ASCE)EI.1943-5541.00001

Akbay, R. B., Ökten, B. B., & Üstüner, Y. A. (2023). Şantiyelerde Bilgi Modellemesi ve Dijital Teknolojilerin Kullanımı. *AJIT-e: Academic Journal of Information Technology*, *14*(54), 298-319. https://doi.org/10.5824/ajite.2023.03.007.x

Akhmetzhanova, B., Nadeem, A., Hossain, M. A., & Kim, J. R. (2022). Clash detection using building information modeling (BIM) technology in the Republic of Kazakhstan. *Buildings*, *12*(2), 102. https://doi.org/10.3390/buildings12020102

Akponeware, A. O., & Adamu, Z. A. (2017). Clash detection or clash avoidance? An investigation into coordination problems in 3D BIM. *Buildings*, *7*(3), 75. https://doi.org/10.3390/buildings7030075

Almuntaser, T., Sanni-Anibire, M. O., & Hassanain, M. A. (2018). Adoption and implementation of BIM–case study of a

Saudi Arabian AEC firm. *International Journal of Managing Projects in Business*, *11*(3), 608-624. https://doi.org/10.1108/IJMPB-05-2017-0046

Alothman, A., & Vilventhan, A. (2025). Development of Building Information Model–Enabled Facility Management for Metro Rail Stations. *Journal of Construction Engineering and Management*, *151*(3), 05024018. https://doi.org/10.1061/JCEMD4.COENG-15868

Aragó, A. B., Hernando, J. R., Saez, F. J. L., & Bertran, J. C. (2021). Quantity surveying and BIM 5D. Its implementation and analysis based on a case study approach in Spain. *Journal of Building Engineering*, *44*, 103234. https://doi.org/10.1016/J.JOBE.2021.103234

Arif, F., & Khan, W. A. (2020). A real-time productivity tracking framework using survey-cloud-BIM integration. Arabian Journal for Science and Engineering, 45, 8699-8710. https://doi.org/10.1007/s13369-020-04844-5

Bayram, S. (2020). Yapı bilgi modellemesi (YBM) kapsamında geleneksel metraj ile yazılımın karşılaştırılması. *Yapı Bilgi Modelleme*, *2*(2), 58-65.

Bayram, S., & Al-Jibouri, S. (2018). Cost forecasting using RCF: a case study for planning public building projects costs in Turkey. *International journal of construction management*, *18*(5), 405-417. https://doi.org/10.1080/15623599.2017.1333399

Bensalah, M., Elouadi, A., & Mharzi, H. (2018). BIM integration into railway projects-case study. *Contemporary Engineering Sciences*, *11*(44), 2181-2199. https://doi.org/10.1002/9781119649229.ch4

BIMobject. Ceilings. (2021a). https://www.bimobject.com/en/category/construction/ceilings Accessed 25 January 2021.

BIMobject. Windows (2021b). https://www.bimobject.com/en/category/windows Accessed 25 November 2021.

Bozkurt, G., Ersoy, S., & Yaşa, E. (2024). Yapı Üretim Süreçlerinde BIM ve VR Uygulamalarının Entegrasyonunun Değerlendirilmesi. *Turkish Journal of Civil Engineering*, *35*(4), 117-144. https://doi.org/10.18400/tjce.1244122

Changsaar, C., Abidin, N. I., Khoso, A. R., Luenhui, L., Yaoli, X., & Hunchuen, G. (2022). Optimising energy performance of an eco-home using building information modelling (BIM). *Innovative Infrastructure Solutions*, *7*(2), 140. https://doi.org/10.1007/s41062-022-00747-6

Chen, Y., Huang, D., Liu, Z., Osmani, M., & Demian, P. (2022). Construction 4.0, Industry 4.0, and Building Information Modeling (BIM) for sustainable building development within the smart city. *Sustainability*, *14*(16), 10028. https://doi.org/10.3390/su141610028

Cheng, J. C., Tan, Y., Song, Y., Liu, X., & Wang, X. (2017). A semi-automated approach to generate 4D/5D BIM models for evaluating different offshore oil and gas platform decommissioning options. *Visualization in Engineering*, *5*, 1-13. https://doi.org/10.1186/s40327-017-0053-2

Crowther, J., & Ajayi, S. O. (2021). Impacts of 4D BIM on construction project performance. *International Journal of Construction Management*, *21*(7), 724-737. https://doi.org/10.1080/15623599.2019.1580832

Dilrabo, S. (2022). Innovative way of german economic development. The role of technoparks in the development of germany a leading economy. *International journal of trends in business administration*, *12*(1), https://doi.org/10.5281/zenodo.7199859.

Economics, O. (2021). Future of construction: A global forecast for construction to 2030. *September.[Online] Available at:*

https://resources.oxfordeconomics.com/hubfs/Future%20of%20Construction_Full%20Report_FINAL.pdf [Accessed 14 January 2024].

Elmalı, Ö., & Bayram, S. (2022). Adoption of BIM concept in the Turkish AEC industry. *Iranian Journal of Science and Technology, Transactions of Civil Engineering*, 1-18. https://doi.org/10.1007/s40996-021-00768-8

Emara, M. S. (2022). Toward a suggested proposed model for the use of building information modeling (BIM) in the implementation phase for landscaping. *Ain Shams Engineering Journal*, *13*(2), 101566. https://doi.org/10.1016/J.ASEJ.2021.08.009

Fábrega Ferrer, J. (2022). *Key Indicators for a Sustainable Building within Hilti* (Master's thesis, Universitat Politècnica de Catalunya).

Gledson, B., & Greenwood, D. (2016). Surveying the extent and use of 4D BIM in the UK. *Journal of Information Technology in Construction (ITcon)*, *21*, 57-71.

Hong, Y., Hammad, A. W., & Nezhad, A. A. (2022). Optimising the implementation of BIM: A 2-stage stochastic programming approach. *Automation in Construction*, *136*, 104170. https://doi.org/10.1016/j.autcon.2022.104170

Hussain, O. A., Moehler, R. C., & Walsh, S. D. (2024). A conceptual framework for 5d-bim cost control and management: A state-of-the-art review of mega rail projects in Victoria. *Computing in Civil Engineering 2023*, 613-621. https://doi.org/10.1061/9780784485231.073

Inzerillo, L., Acuto, F., Pisciotta, A., Mantalovas, K., & Di Mino, G. (2024). Exploring 4d and 5d Analysis in BIM Environment for Infrastructures: A Case Study. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *48*, 233-240. https://doi.org/10.5194/isprs-archives-XLVIII-2-W4-2024-233-2024

Jang, S., & Lee, G. (2018). Process, productivity, and economic analyses of BIM–based multi-trade prefabrication—A case study. *Automation in Construction*, *89*, 86-98. https://doi.org/10.1016/j.autcon.2017.12.035

Jupp, J. (2017). 4D BIM for environmental planning and management. *Procedia engineering*, *180*, 190-201. https://doi.org/10.1016/j.proeng.2017.04.178

Kahraman, E. (2022). Integration of financial risk analysis into 5D BIM system and BIM optimization with financial risk support [Finansal risk analizinin 5D BIM sistemine entegrasyonu ve finansal risk destekli BIM optimizasyonu]. M.Sc. Thesis, Erciyes University, Kayseri, Turkiye. (in Turkish)

Lee, S. J., Lee, E. H., & Oh, D. S. (2017). Establishing the innovation platform for the sustainable regional development: Tech-valley project in sejong city, Korea. *World Technopolis Review*, *6*(1), 5-1. https://doi.org/10.7165/wtr17b0904.16

Lin, Y. C. (2014). Construction 3D BIM-based knowledge management system: a case study. *Journal of Civil Engineering and Management*, *20*(2), 186-200. https://doi.org/10.3846/13923730.2013.801887

Maqsoom, A., Aslam, B., Ismail, S., Thaheem, M. J., Ullah, F., Zahoor, H., ... & Vatin, N. I. (2021). Assessing rainwater harvesting potential in urban areas: a building information modelling (BIM) approach. *Sustainability*, *13*(22), 12583. https://doi.org/10.3390/su132212583

National Building Specification. NBS' 10th National BIM Report (2020). https://www.thenbs.com/knowledge/national-bim-report-2020 Accessed 13 November 2021

Öz, İ., Cevikbas, M., & Öcal, C. (2023). Determination of Significance of 4D-BIM Features. *Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, *27*(2), 246-254. https://doi.org/10.19113/sdufenbed.1209834

Ranjbar, A. A., Ansari, R., Taherkhani, R., & Hosseini, M. R. (2021). Developing a novel cash flow risk analysis framework for construction projects based on 5D BIM. *Journal of Building Engineering*, *44*, 103341. https://doi.org/10.1016/J.JOBE.2021.103341

Rashidi, A., Yong, W. Y., Maxwell, D., & Fang, Y. (2023). Construction planning through 4D BIM-based virtual reality for light steel framing building projects. *Smart and Sustainable Built Environment*, *12*(5), 1153-1173. https://doi.org/10.1108/SASBE-06-2022-0127

Sung, T. K., & Kim, S. G. (1998, January). From" central" to" regional": new technopolies development in Korea. In *Proceedings of the Thirty-First Hawaii International Conference on System Sciences* (Vol. 6, pp. 242-251). IEEE.

Uddin, M. N., Wei, H. H., Chi, H. L., Ni, M., & Elumalai, P. (2021). Building information modeling (BIM) incorporated green building analysis: An application of local construction materials and sustainable practice in the built environment. *Journal of building pathology and rehabilitation*, *6*, 1-25. https://doi.org/10.1007/s41024-021-00106-5

Ullah, K., Lill, I., & Witt, E. (2019, May). An overview of BIM adoption in the construction industry: Benefits and barriers. In *10th Nordic conference on construction economics and organization* (Vol. 2, pp. 297-303). Emerald Publishing Limited. https://doi.org/10.1108/S2516-285320190000002052/FULL/EPUB

Xu, J. (2017). Research on application of BIM 5D technology in central grand project. *Procedia engineering*, *174*, 600-610. https://doi.org/10.1016/J.PROENG.2017.01.194

Zareiyan, B., & Khoshnevis, B. (2017). Interlayer adhesion and strength of structures in Contour Crafting-Effects of aggregate size, extrusion rate, and layer thickness. *Automation in Construction*, *81*, 112-121. https://doi.org/10.1016/J.AUTCON.2017.06.013