Kaunas University of Technology
Faculty of Civil Engineering and Architecture

Development of an Information Data System for Automated Project Evaluation and Management in 4D and 5D Environment

Master's Final Degree Project

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Kaunas, 2025

Kaunas University of Technology

Faculty of Civil Engineering and Architecture

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Construction Management (6211EX007)

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Master's Final Project Assignment

Study program: Construction Management
Topic of the final degree project (theme in Lithuanian language):
Informacinės duomenų sistemos, skirtos automatizuotam projektų vertinimui ir valdymui 4D ir 5D aplinkoje, kūrimas
The topic of the final project approved by the Dean 's Decree No.: 5th December 2024 No. V25-09-24
(In Lithuanian):
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(In English):
Development of an Information Data System for Automated Project Evaluation and Management in 4D and 5D Environment
Initial data for the work:
-
Other additional information relevant to the task (as required):
-

Assigned parts:	**Parts of the final project:**
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(Contribution 100 %)	*position, name, surname* *Confirmed electronically*
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Summary

Master thesis work is dedicated to the construction of an automatic information system managing time and price in construction, particularly of high-speed railway bridges. This system combines various advanced tools to contribute to project management efficiency, such as 3D modelling with Revit, automation with Dynamo scripts, centralised data storage with SQL Server, and project progress and resource allocation visualization in real-time with Power BI. AI tools as ChatGPT API are integrated for reporting automation and decision making. The approach resolves issues like matching the Bill of Quantities (BOQ) with 3D object models, full synchronization of real-time data and automating singular known structures, such as anti-uplift guided bearings. It ensures efficiency, helps avoid mistakes, and can update the project schedule and cost dynamically. Through the validation of this system with a real-life railway bridge project, this research shows that the system can be applied to the future infrastructures and illustrates the scalability of the system. The master thesis also recommends building on the proposed system towards lifecycle automation, sustainability integration, advanced AI applications, and agile data interoperability within the construction industry.

Farhad, Sharifli. Informacinės duomenų sistemos, skirtos automatizuotam projektų vertinimui ir valdymui 4D ir 5D aplinkoje, kūrimas. Magistro baigiamasis projektas / vadovė doc. dr. Eglė Klumbytė; Kauno technologijos universitetas, Statybos ir architektūros fakultetas.

Studijų kryptis ir sritis (studijų krypčių grupė): Inžinerijos mokslai, Statybos inžinerija (E05).

Reikšminiai žodžiai: 4D/5D BIM, Dynamo automatizavimas, statybos valdymas, „Power BI" vizualizacija, pažangos stebėjimas realiuoju laiku, išlaidų ir rizikos valdymas.

Kaunas, 2025. 57 p.

Santrauka

Magistro baigiamajame darbe nagrinėjama automatinės informacinės sistemos, valdančios statybos, ypač greitųjų geležinkelio tiltų, laiką ir kainą, kūrimas. Šioje sistemoje derinamos įvairios pažangios priemonės, padedančios didinti projektų valdymo efektyvumą – 3D modeliavimas naudojant „Revit" programinę įrangą, automatizavimas vykdomas naudojant „Dynamo" programinės įrangos scenarijus, sukurta centralizuota duomenų saugykla naudojant „SQL Server", projekto eigos ir išteklių paskirstymo vizualizavimas realiuoju laiku naudojant „Power BI". Ataskaitų automatizavimui ir sprendimų priėmimui integruotos dirbtinio intelekto priemonės – "ChatGPT API". Šiuo metodu išsprendžiamos tokios problemos, kaip kiekių žiniaraščio (BOQ) suderinimas su 3D objektų modeliais, visiškas realaus laiko duomenų sinchronizavimas ir išskirtinių konstrukcijų, pavyzdžiui, priešpriešinių valdomų guolių, automatizavimas. Jis užtikrina efektyvumą, padeda išvengti klaidų ir gali dinamiškai atnaujinti projekto grafiką bei sąnaudas. Patikrinus šią sistemą realiu geležinkelio tilto projektu, šiame tyrime parodoma, kad sistema gali būti taikoma ateities infrastruktūroms, ir iliustruojama sistemos apimtis. Magistro darbe pateikiamos rekomendacijos naudoti pasiūlytą sistemą, siekiant automatizuoti gyvavimo ciklą, integruoti tvarumo vertinimą, taikyti pažangias dirbtinio intelekto programas ir užtikrinti lanksčią duomenų sąveiką statybos pramonėje.

Table of contents

List of figures

List of tables

List of abbreviations and terms

Abbreviations:

BIM – Building Information Modeling

BIMI - Building Information Modelling Implementation

LCA – Life Cycle Assessment

4D BIM – 4D Building Information Modeling (Time Dimension)

5D BIM – 5D Building Information Modeling (Cost Dimension)

BOQ – Bill of Quantities

SQL – Structured Query Language

API – Application Programming Interface

AI – Artificial Intelligence

CAD – Computer-Aided Design

WBS – Work Breakdown Structure

CSV – Comma-Separated Values

KPI – Key Performance Indicator

Gantt Chart – A visual scheduling tool

GIS – Geographic Information Systems

QTO – Quantity take-offs

QS – Quantity Surveying

Introduction

The complexity of infrastructure project management poses significant challenges in today's construction industry. Large-scale construction projects, such as railway bridge projects require coordinated efforts from project staff to manage the time, cost, and resources of the project. As technology advances today, Building Information Modeling (BIM) has become an indispensable tool to overcome these challenges. Initially defined the BIM as 3D modeling, but it has evolved to include time (4D) and cost (5D) information, this becoming an integrated platform that brings together project schedules and financial information. This advancement has revolutionized construction project management, improved decision-making processes, and enabled real-time monitoring of project developments.

4D and 5D have the highest impact on the project management aspect, as they enable a direct connection between the construction schedule and cost estimation concerning the model in all 3D. When project teams can view the steps of construction associated with cost data, they are better equipped to foresee delays and costs before work starts so that likewise they may respond accordingly when challenges arise. Progress tracking and automation of tasks such as quantity take-offs (QTOs) have further streamlined project management processes, reducing manual effort and the probability of human error. Construction becomes increasingly data-driven, the ability to integrate time, cost, and resource data into a dynamic model is changing the project performance[1].

Besides enhancing efficiency, the utilization of BIM in project management additionally aids real-time monitoring. For example, as that data is collected on construction sites in real-time it can be funneled back into the BIM model to manage how projects are really advancing versus their planned schedule. By using this initiative-taking approach, the problem is spotted early and can be managed with immediacy avoiding cost overruns or missing milestones. Through the studies conducted recently, we were able to realize BIM has become a unique key tool in current construction management with its features like creating details from real-time facts/figures of modifications and movements inside them automatically as well as visual representation of project performance [2] [3].

As large-scale infrastructure or transportation projects involve various activities, resource scheduling, and organization planning continuously, then the roles of 4D & 5D in such situations will be more significant. BIM has been stated to increase collaboration between the different project stakeholders, reduce wasted time due to rework, and improve many aspects of construction workflow studies confirmed this statement with statistically significant results for each part [4] [5]. Nevertheless, the implementation of BIM technologies faces difficulties such as problems related to data integration, high initial investments, and skilled staff for using complex systems [6]. However, the advantages inherent to BIM are also immense especially when framed in time and cost dimensions thus making them favorable tools for railway bridges as well.

This thesis deals specifically with 4D and 5D BIM-based automation for the assessment, monitoring, and management of railway bridge construction projects. The project integrates BIM with automation tools like Dynamo and Power BI so that progress remains visible in real-time, and costs are automatically tracked. Connecting the construction schedule and financial data into a 3D model allows the research to gain more insight and improve project efficiency. This solution, which is being worked on Dynamo scripting and Power BI dashboarding will provide a dynamic, automated that offers real-time visibility to help address one of the key challenges in construction management. The project also leverages automated reporting via ChatGPT API for faster delivery of information and decision-making.

Goals and Task

The overall aim of this thesis is to design and perform an evaluation analysis for the automation in railway bridge construction project management using 4D & 5D BIM. The system will incorporate project schedules and cost data with the 3D BIM model, which enables real-time tracking of progress, costs, and automatic reporting. The thesis automates these processes to increase project efficiency, reduce delays and risks, and controls the cost of projects.

The main tasks and challenges to achieve this goal:

1. 3D Modeling of the Railway Bridge **-** The bridge model will be developed using 2D AutoCAD files, which will form the basis of 4D and 5D BIM integration.

2. Creating a Dynamo script for 4D and 5D BIM **-** The Dynamo script will be specifically designed to automatically extract time and cost data from this Revit model.

3. Design and develop Power BI dashboard **-** 3D model, schedule and cost will integrate Power BI to visualize real-time project progress, including schedule updates and cost tracking.

4. Integrating real-time site data **-** Integrating daily progress data into Power Bi from an online platform where daily construction staff fills.

5. Integrating AI for automatic reporting **-** ChatGPT API will be integrated into the Power BI Dashboard to automate the project reports. This AI system will summarize key project data information including activity completion and delays, cost variances, etc., and will share with the project coordinator teams in real-time without the need for manual reporting.

1. Literature Review

1.1. Introduction to BIM, 4D/5D modeling, and automation

BIM has forever changed the way we design and construct buildings with its offering of a complete digital model, or prototype, as it pertains to both real-world functions and physical aspects that make up each building. In the last several years the evolution in BIM has been from 3D visualization to becoming much more of an integrated system which includes not only Time (4D modeling) but also Cost (5D modeling). The addition of time and cost dimensions in the digital model has made project management easier and helps with perfect execution. This chapter discusses the basics of BIM, how 4D and 5D modeling changes everything for construction managers today, and automation and AI in the industry.

1.1.1. Evolution of BIM: from 3D to 4D and 5D

BIM only started as a 3D model that showed the visualization of buildings and structures. But, with the entry of 4D and 5D modeling, this entire procedure has been treated as a change. With 4D BIM (which contains time-related information), we can visualize the construction schedule, and these will be presented along with a physical model. This makes it much easier for the project managers to better anticipate, plan activities more precisely, and predict delays with less error in resource allocation. As a result of research, incorporating 4D BIM into the construction process has played a role in revolutionizing how we plan for building work and creating ever-more dynamic tools for managing materials; labor, and machinery [7].

Cost estimation and management introduce into the model based on 5D. This seamless integration enables project teams to tie financials directly back into their 3D and 4D models so that cost implications are always part of the construction life cycle. The provision of geospatial data in BIM, through its coupling with Geographic Information Systems (GIS), improves the accuracy of cost estimation [3] as illustrated in the literature which includes research on terrain analysis and infrastructure layouts. This integration has helped to enhance the efficacy of projects by aligning design and execution as per spatial constraints [8].

Fig. 1. BIM model dimensions [41]

1.1.2. Integration of BIM and GIS for enhanced project evaluation

One of the most significant advancements in BIM technology is its linkage with GIS functionality. This integration helps to get an amplified view of spatial data and design models are combined for better visual understanding. Based on literature, it emphasizes how BIM/ GIS can help for better planning and decision-making in large-scale infrastructure projects especially related to Urban planning & transportation [3]. Stakeholders can use new construction approaches in our simulations to help ensure the future environment matches their needs not only during the design phase but also by enabling them to visualize how a new building interacts with its surroundings [3] [7].

Using BIM and GIS data in combination, project stakeholders enjoy superior cooperation because architects, engineers, and planners can share and analyze their data or results with no effort. In addition, the interaction between BIM and GIS is constructive for project management, whereby the former system allows for providing construction project updates in real-time, elimination of risks related to possible delays, and better communication across the staff.

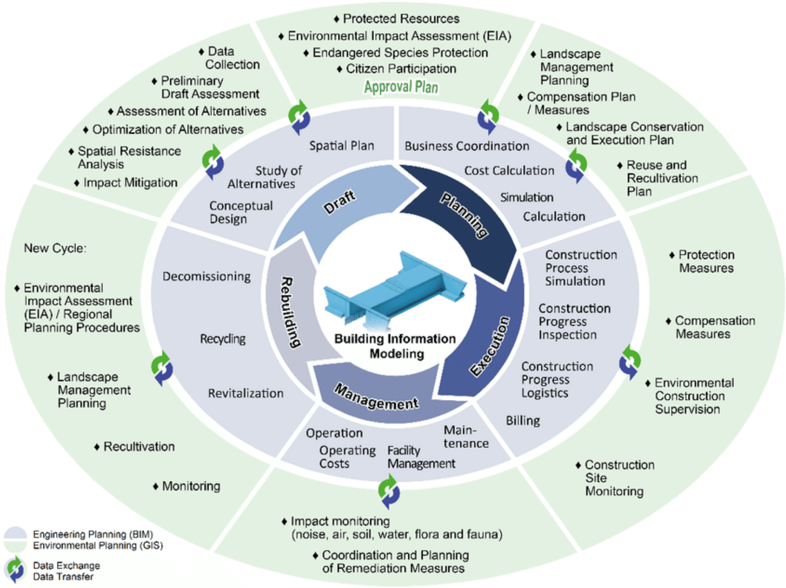

Fig. 2. Data exchange and transfer in the integrated BIM/GIS [42]

1.1.3. 4D BIM for logistics and time management

Time management has always been a big concern in the construction industry. The use of 4D BIM has improved the capability of project teams to monitor and manage timelines. By associating construction schedules with the 3D model, 4D BIM gives you a picture of what a project is going to do. This not only can spot possible bottlenecks but also makes team coordination easier. According to literature 3, through the application of the 4D BIM management model, organizational efficiency has been improved in aspects such as Gantt charts and resource allocation; it also increases productivity by integrating site layout planning with equipment selection procedures. The introduction of 4D BIM has increased resource efficiency in the building industry, site layout design, and handling material [7] [9] [10].

The ability to simulate construction activities temporally provides a critical tool for increasing the coordination of work on site. This means that by modeling multiple scenarios, project managers can chart what would be the best way of resourcing and delivering materials thus minimizing down time as well as improving site safety. Particularly effective for large–impact-scale, where material delivery needs to be prompt in order of which the project does not get stuck.

Automation and AI in BIM for Enhanced Efficiency

The emergence of automation and AI in BIM processes is adjusting the construction project management landscape. Artificial Intelligence (AI) and specifically machine learning are becoming a significant enabler in enhancing project performance. AI algorithms can analyze massive data and come out with a pattern of predictive insights, then it does have a huge impact on the construction decision-making process. As mentioned in literature, in which AI and ML are used to automate boring jobs (like scheduling or resource management) that result from a huge labor force [11] [12].

Automation by AI also plays a major role in increasing the safety standards of construction. Construction sites can be monitored for danger day and night simply by combining sensor data with AI systems. This allows for better detection of potential threats, which allows project managers to step in before incidents happen. Automation further boosts project-wide efficiency by removing the need to use manual processes and conferring a higher accuracy level accompanied by standard execution of important activities.

1.2. The impact of 4D/5D BIM on time and cost management

Building Information Modeling (BIM), especially in 4D and 5D modeling, has dedicatedly influenced the way it eases time and cost planning on-site for any modern construction project. The time-related information is integrated into 4D BIM and enables easy project scheduling (and helps reduce delays ultimately) with the cost data being incorporated in 5D BIM: Making it an ideal tool for enhanced life cycle tracking of costs on a particular project. The impacts on time and cost management are then discussed in the next chapter, where current literature is reviewed with exemplification or case studies from construction application areas [13] [14] [15].

1.2.1. 4D BIM and time management

One of the main keys to delivering any construction projects is correct scheduling and efficient time management. Extending this, traditional project management programs often fail to integrate modern construction demands and it needs, which goes onto means delivery times elongate thus inefficiencies persist. This concept is taken care of by 4D BIM which integrates schedule data such that the construction activities can be visualized dynamically with time, over a 3-dimensional model. That enhanced visualization allows project managers to prepare better, detect delays that are about to happen, and optimize the handling of activities [16] .

The development of scheduling using BIM has positively impacted construction coordination and time management [4]. Results show that 4D BIM offers improved sequencing and refreshing remedies for a better realization of task performance. One example is linking the 3D model information within your project timeline, to flag risks like clashes or resource needs at an early stage of the process. This way you can make timely changes, and the project flow is more fluid with fewer delays.

Also, literature reports on the implementation of 4D BIM for minimizing project delays through resource optimization [17]. Using time-based information with the model helps project managers to see how resources are allocated over different phases of a project, which in turn allows them to better plan for both labor and material. This level of planning helps minimize any potential delays that might arise due to a lack of resources or scheduling issues.

1.2.2. 5D BIM and cost management

In any construction project, cost management is a major issue because this can result in significant consequences that could end up negatively affecting important aspects of the projects. 5D BIM - 5D is the most detailed path of managing costs where cost data can be tied to all three previous models. This integration makes the construction real-time cost estimation, tracking, and control in line with the project budget during the building process [18].

Literature 12 studies the effect of 5D BIM in cost management and it is found that utilization of 5D enables more accurate and rapid estimation [19]. By attaching cost information to elements of the 3D model, teams can generate fully detailed quantity take-offs and cost estimates automatically. These reduce the time and effort to perform manual cost calculations and increase accuracy in forecasting costs. In addition, the use of 5D BIM enables us to evaluate more accurately cost-saving approaches at early design stages through modelling alternative methods and materials.

As explained in literature, one of the significant advantages that this creates is its capacity to restrict cost blowouts especially when undertaking major infrastructural projects such as rail construction and preparing for a whole new adventure [20]. The reasons that this study outlines are that 5D BIM allows more efficient financial control during the life cycle of a project, considering it provides true cost information and allows to be monitoring of expenditures constantly. Budgeting is done in this attribution to ensure that any budget overrun does not get noticed when it has grown out of its hand look. This keeps the project manager taking necessary action before cost gets uncontrollable.

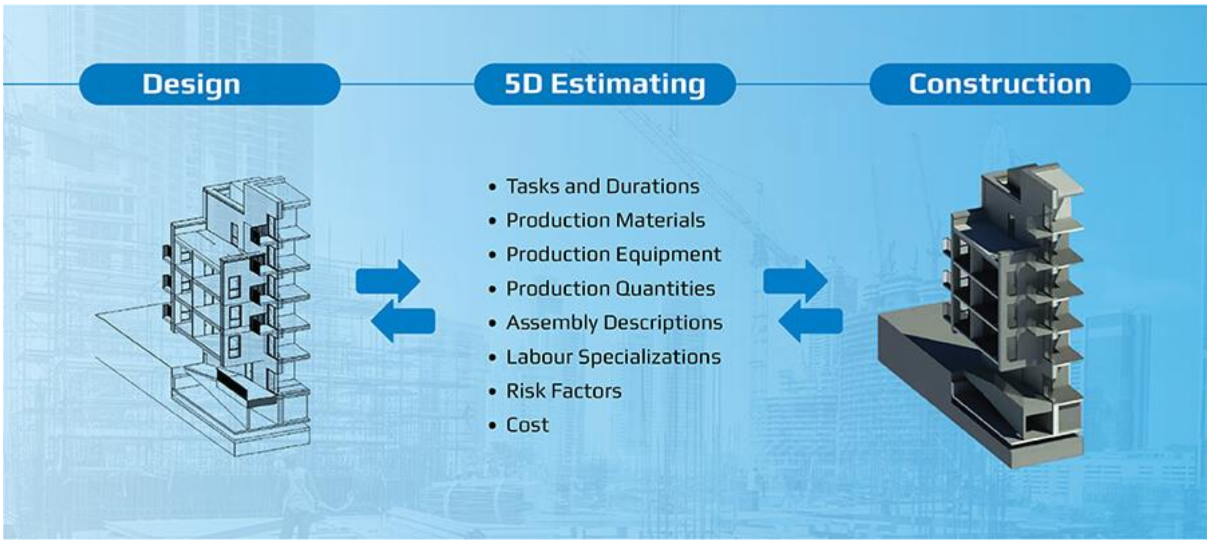

Fig. 3. Benefits of 5D BIM for construction [43]

1.2.3. Case studies and practical applications of 4D/5D BIM

As we can see from a few case studies, 4D and 5D BIM have become more effective in time management, linking it to cost functionalities helping project managers to confidently execute the projects faster. Another study case described that incorporating 4D/5D BIM into construction projects can decrease delays by almost half, thereby decreasing the cost of managing a project as well [4]. When implemented into real-world projects, these findings can provide evidence of the value that pioneering BIM methods bring to construction.

The next case, which elaborates on the impediments and advantages regarding the entry of the construction industry for 5D BIM [21]. Among the key challenges cited in the study are resistance to change and special training. But it also highlights the massive cost savings that can be realized by 5D BIM in terms of reductions in rework and improvements made to collaboration amongst project stakeholders.

This part of the content offers a specific case study on applying 5D BIM to railway projects. It points out that by supplying much more exact cost data via 5D BIM, the technology was used to prevent overruns of costs in project [20]. It emphasizes that 5D BIM must be brought into the project from the very first moment of its creation right through until handing over– from design and development, through operations on site with an overlay suitable for contractors (and at times also including proprietors) until final completion. All this should be practiced in order that the movement towards continual cost management is made kinder.

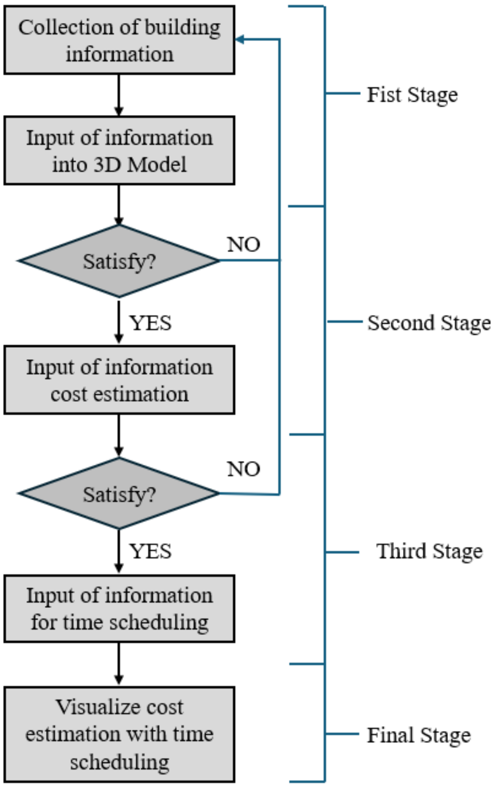

Fig. 4. 5D BIM process flowchart [44]

1.2.4. Benefits and challenges of implementing 5D BIM

No one can doubt the advantages of 5D BIM in cost management, but it is not as easy to apply. The obstacles to 5D BIM adoption like software being not user-friendly and non-acceptance of change from project stakeholders have been reflected in the literature [21]. No two BIM software are created equal and purchasing a new BIM implementation can be expensive, as is the need for additional training.

But the long-term advantages of effective 5D BIM exceed this. 5D BIM provides greater cost accuracy with lesser chances of crossing the budget range, thus ensuring timely and in-budget completion. As detailed in the literature, the capacity to model alternative cost scenarios and monitor expenditure on the fly provides project managers with more control over costs which translates into improved project delivery [19].

Table 1. 5D BIM – Benefits and Challenges (prepared by the Author)

Category	Benefits	Challenges
Cost Savings	Significant reduction in project costs by automating cost management.	High initial investment in software, hardware, and training [3][5].
Time Management	Reduced project delays due to real-time monitoring [5].	Lack of standard practices for real-time scheduling [3].
Resource Optimization	Improved resource allocation and utilization [3].	Resistance from employees accustomed to traditional methods [4].
Stakeholder Collaboration	Enhanced communication and collaboration between project stakeholders [3].	Difficulty in data interoperability between various tools [3].
Risk Mitigation	Real-time identification of risks and design flaws [5].	Legal issues regarding BIM data ownership [5].

1.3. Risk management through automation in BIM

Identifying, analyzing, and controlling potential problems that may interfere with the cost of a project or timely delivery, etc. is another essential ingredient for any construction work to be risk management as well in Building Information Modeling (BIM), automation has led to breakthroughs in risk managing processes. The utilization of automation in BIM means that risks can be tracked and managed as they are discovered (ex. errors within the design, safety issues, logistical concerns). This chapter will dive into how automation in BIM can help reduce these risks, and further enhance the efficiency of a project deliverable using 4D & 5D modeling [22] [23 [24].

1.3.1. Automation in BIM for risk management

The pragmatic use of BIM for risk management is a fully growing area, which affords project managers the ability to interface with some complex construction projects. BIM-based risk management offers a digitized channel to incorporate risks into every stage of project planning, design, and implementation. As indicated by article, BIM has the capability of managing many types of internal and external risks activities [25]. With the help of automated hazard identification tools, however, risks like design errors or delays in material delivery can be identified early on at one of these single "bottlenecks," significantly improving both efficiency and safety for construction projects [26].

Because of BIM, all the project stakeholders (from architects and engineers to contractors) can collaborate in real-time which helps them better coordinate. As a result, the probability of misunderstandings, a common cause for risks such as exceeding budgets or delays in workflows — drastically drops. This way risk management tools are embedded with BIM models to monitor the risks through the entire project life cycle, and all along helping mitigate them before they reach a critical stage of exposure.

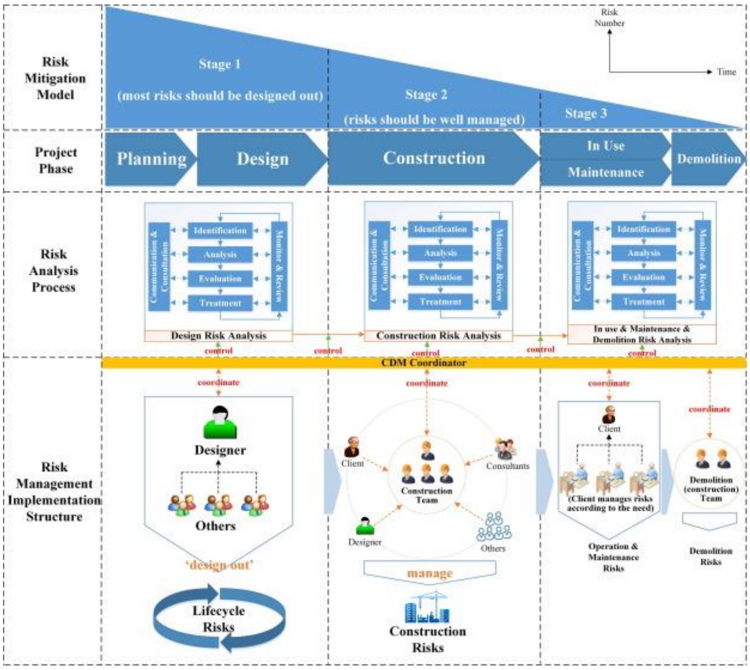

Fig. 5. Risk mitigation model across project phases [45]

1.3.2. Real-Time progress monitoring and risk mitigation

Real-time progress monitoring can lead to the early detection of variances from planned activities, thereby making it possible to reduce cost overruns and delays [27]. The everyday progress and utilization of construction activities as well as resources can be dynamically tracked via automated monitoring systems, which when combined with 4D BIM models help teams to keep in control by making schedule adjustments or workflow alterations on time before any potential risks occur [29].

Sensors and machine learning algorithms, for example, are being used on construction sites to monitor safety risks. These onboard systems can collect data on site conditions, such as equipment utilization or worker practices and indicate potential risks. With this information linked to the BIM model, project managers can actively avoid any safety risks and thereby prevent accidents that could have otherwise occurred on-site.

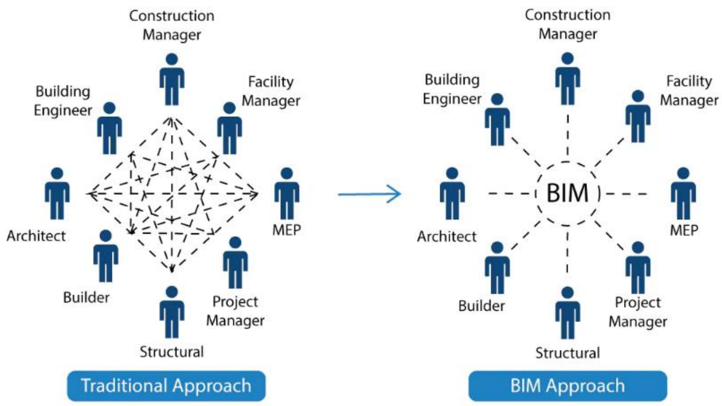

Fig. 6. Flow of data in traditional and BIM model [46]

1.3.3. The role of 4D/5D BIM in risk management

The role of 4D and 5D BIM models in risk management is critical because it allows linking project scheduling 4D and cost data 5D with overall risk management process. Some of the simulations most successfully performed can be seen in the literature, which shows improved accuracy when potential risks are introduced into a BIM system [28]. Project teams can, for example, use 4D BIM to model various construction scenarios and gain an understanding of whether one or more delays are likely because of unforeseen risks — such as inclement weather conditions or insufficient available labor. Thus, the owners can plan contingencies for these risks with minimal slippage in the project schedule.

In the same way 5D BIM models let project administrators understand how particular risks will intervene with costs as soon as a contract starts. One of the major risks in construction is cost overrun. This 5D BIM gives you a real-time analysis of costs as well give costing predictions if there are risks. This way, project teams can associate risks with each of the 5 dimensions in real-time/automated mode to assess their financial effect and hence control cost escalation by making informed decisions.

1.3.4. Case studies and examples of BIM-based risk management

Many case studies have illustrated how this BIM-based automation can help in construction risk management. As an example, BIM is implemented to avoid safety risks using automated hazard detection systems in a large-scale infrastructure project [25]. Sensors were put in place around the construction site, connected to the BIM model—to track worker movements and identify potential safety issues. This data was being fed in real-time back into the BIM system, enabling project managers to take immediate action against safety risks and preventing accidents on site, improving Site Safety ways.

BIM based progress monitoring to address schedule risk due to delay in complex construction projects is discussed under the article, which summarizes as follows [27]. The project team detected early deviations from the plan, to re-allocate resources on time by relying on automated real-time data collections through drones and laser scanners. Taking the initiative to start saving time and ensure keeping on schedule.

1.3.5. Challenges in implementing BIM-Based risk management

However, with the benefits of digital technologies come problems in developing BIM-based risk management systems. Indeed, as observed in the literature, one of the main obstacles is that it can be difficult to integrate a multitude of software platforms into risk management [28]. Most of the construction projects are still using 2D drawing and project management software which is not as integrated as a BIM system. This inability to interoperate can limit the full penetration of BIM-based risk management tools.

There is also a learning curve to utilizing BIM for risk management. Project managers and teams need to be trained in how best to use the tech, but there might also be resistance when trying new methods. Nonetheless, evidence of how the long-term links to diminishing risks and encouraging project interferences overshadows the costs of training individuals for new tools into their workflow [25].

Table 2. BIM-based risk-management: Benefits/Challenges (prepared by the Author)

Category	Benefits	Challenges
Cost Savings	Reduces cost overruns by improving accuracy and forecasting	Initial setup costs can be high
Safety Improvements	Enhances safety through better risk identification and mitigation	Requires buy-in from all stakeholders for safety protocols
Training Requirements	Encourages upskilling of workers in modern tools	Requires significant investment in training personnel
Efficiency	Increases efficiency in risk identification and resolution	Initial adoption can cause temporary slowdowns
Data Management	Enables real-time data sharing for better decision making	Complexity in managing large datasets and interoperability
Implementation Complexity	Provides long-term benefits despite the initial challenges	Can be difficult to integrate with legacy systems

1.4. Challenges in implementing 4D/5D BIM

Behind the new reality lies a few central advantages that 4D and even more, in some cases, 5D BIM can bring for construction project planning — as well as cost control and risk alleviation. But there are some challenges with embedding these technologies. We can explain these challenges by data integration, implementation costs are extremely high, and the systems used do not use a standard way to get necessary information because there is still resistance to change in the construction industry. This chapter will primarily examine the significant challenges that have prevented several organizations from transitioning to 4D and 5D BIM, based on a brief review of recent related research to paint an overall picture as it relates to discouragements faced by stakeholders.

1.4.1. Data integration and interoperability issues

A major obstacle to the adoption of 4D and 5D BIM is data integration; BIM data should thereby be collected, which requires the contributions of architectural parties, engineers as well as contractors smoothly to enter the integrated platform. This process is typically complex across different software systems and data formats, resulting in compatibility problems. Between referring to the literature, this lack of standardization in BIM technology, especially between different platforms, causes lots of issues which related directly to data interoperability and causes delays and inefficiency during construction process [30] [31] [32]. Nowhere is this of greater concern than in major projects, involving multiple different disciplines and considerable inter-disciplinary data exchange.

This also gets worsened by no industry wide standards for data management. Since there are no standardized data exchange protocols, the project relies on ad hoc locks for different software systems to communicate and share detailed information. This often results in the information being decoupled which can lead to inefficiencies, data loss or misinterpretation and prevent 4D and 5D BIM from realizing its full potential.

1.4.2. High costs of implementation

Another significant barrier to the widespread adoption of 4D and 5D BIM is related to high costs. These advanced BIM systems cost a lot to invest in hardware, software, and staff training. For small and medium-sized construction firms obtaining BIM software as well as the infrastructure to support their use is costly [33]. Beyond the costs of deployment, there are also regular updates to software packages and an ongoing requirement for data storage — as well as arranging the training required by employees which will add to the cost.

There are the economic benefits of 4D and 5D BIM (better cost & project management) which may prove fetching to some, but hard cold cash is not something you touch directly, so they get skunked out as making a case for ROI can be difficult in this regard. The substantial costs and learning curve to fully incorporate BIM into existing workflows make a case for why companies might not be in any rush to adopt the technology, especially when working within markets with slim profit margins.

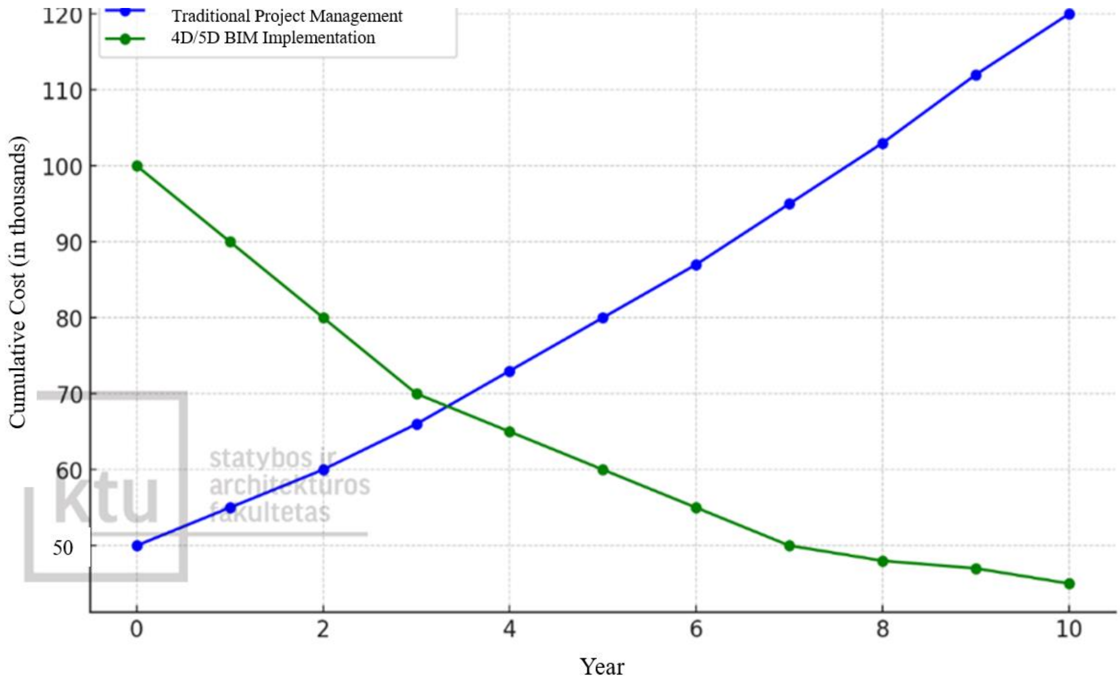

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Fig. 7. Cost comparison: Traditional PM vs 4D/5D (prepared by the Author)

1.4.3. Lack of standardization and compatibility issues

One of the recurring problems which face construction across the board is a lack in standardization when it comes to BIM workflows and processes. Without integration, 4D and 5D BIM implementations are limited [34]. The first issue arises because various stakeholders generally rely on different software tools which may not be completely interoperable with each other. Such a disconnected form of project management leads to information having to be changed and adjusted in-between transitions; therefore, streams do not even need to be predicted.

Apart from the software, the implementation of 4D and 5D BIM in different projects comes with its own set of processes that still do not have an industry standard. Without any concrete direction or tried-and-true solutions, project teams frequently struggle to find the most appropriate way to assimilate BIM into operational processes. This lack of clarity can lead to an uneven use of BIM tools, which in effect drowns any downstream advantages gained from the implementation of these more sophisticated modeling practices.

1.4.4. Resistance to change in the construction industry

Resistance to change in the culture of construction leads creates a serious challenge, and it is this that constitutes by far the most significant barrier for 4D and 5D BIM. Industry professionals are also used to traditional ways of doing project management and are often skeptical about new technologies since they change the way things have been done. The article states that older professionals resist change because of their nonuse of digital tools and familiarity with traditional ways of cost estimation, project scheduling et cetera [34].

A lack of training and education regarding the benefits of BIM compounds this resistance. Lack of clarity on how 4D and 5D BIM can improve project outcomes means professionals see technology as either unnecessary or too complex. To counteract this resistance, some training programs must be in place, and even awareness about the benefits of BIM especially for senior professionals who are frowned upon involved in decision-making.

1.4.5. Challenges in cost control and management with 5D BIM

The implementation of 5D BIM in construction projects can change the quantification and management of cost, still there is a lot to face because at this moment some obstacles surround it. One of these is mentioned in the literature, which discusses the challenges in integrating cost data with the BIM model and preserving it up to date throughout the entire life cycle [33]. If the costs are inaccurate or are less than, 5D BIM can fail as a cause of constructing cost data that is primarily used in appraisals deadbolts estimation process and lack completion.

Moreover, it requires the specific training and qualification to manually implement 5D BIM in cost management. A large part of the problem is that a vast majority within the construction industry do not have adequate skills and competencies to utilize full potentialities inherent in 5D BIM [32]. If unaddressed, this skills gap can lead to technology being underused and thwart the full potential of cost control for integrated financial performance.

Therefore, 4D and 5D BIM provide a huge benefit for the construction sector but on the other hand their implementations have some obstacles. Major impediments to adoption include data integration challenges, high costs, a lack of standardization, and resistance from customers used to "following the prescription". Addressing these challenges will only be possible through the joint efforts of stakeholders such as standardization regarding BIM, greater investment in training and education towards new sustainable technologies without a clear near-term ROI and changing management within an industry which has traditionally been late on embracing smart procurement methods.

1.5. Applications for 4D/5D BIM in large infrastructure projects

One aspect of BIM technology is 4D and 5D Building Information Modeling (BIM) processes for large infrastructure projects, which deepens real-time monitoring while reducing delays in project management. Including time (4D BIM) within the 3D model shows stakeholders a visual representation of how construction will occur, and cost data (5D BIM) provides greater fluidity in financial tracking across all project stages. This chapter will go to the extent how these technologies have been used in large-scale infrastructure projects like metro rail systems, highways and other complex infrastructures implemented.

1.5.1. 4D BIM in metro and railway projects

Metro and railway projects are always among the most complex types of infrastructures as thousands of technical and logistical challenges come along with them. As described in the article, use of 4D BIM for metro rail systems has improved project management and scheduling [35]. By integrating 4D BIM function the real-time simulation of construction sequences shows in terms and photos how jobs are progressing, with possible delays visible as they happen. 4D BIM connects the 3D model with a project schedule, making it easy to see how work is coordinated between numerous stakeholders for large-scale projects like metro rail systems.

For example, the implementation of 4D BIM tools like ELECOSOFT Power Project software in India's metro rail systems has resulted in more accurate scheduling as well as delay management [35]. This has enabled the project team to better distribute resources and hedge against delay risks, ultimately resulting in more efficient project delivery. The versatility of the software in handling complex metro rail systems demonstrates how 4D BIM can be the ultimate solution to combat the specific complexities arising out of underneath and above-ground construction.

1.5.2. 5D BIM in highway construction

When talking about the role of 5D BIM in highway construction projects, it provides a lot more than just managing costs, it assists in resource planning but helps eliminate delays and any type of loss. Demonstration of the application by means of an example using this kind for the Yancheng Expressway project in China where real cost updates are happening on a daily basis providing all stockholders see will have it carriage forth consciously amid construction work [36]. This combination with the cost data in a BIM model led to the more accurate deployment of resources by the project team, they were aware beforehand where financially unattractiveness could occur and secured that budget allocations have been staying within proper borders. The true 5D BIM model was most effectively used for the cost aspect of complex components, such as bridges, tunnels, and interchanges that have a difficult work package approach to accuracy in measuring for clients.

Besides cost control, 5D BIM also enabled more coordination between the members of the project. Cost data was linked to the 3D model allowing project teams to create accurate cost estimates and see how design modifications affected costs in real time. This contributed to a more well-grounded process of deciding what and how, as opposed to the expensive trial & error designs phase. The Yancheng Expressway project provides an example of how 5D BIM can offer a solution for costs on large infrastructure projects, making them run more efficiently and effectively in the delivery phase.

1.5.3. Real-time monitoring and automation in 4D/5D BIM

The use of 4D and 5D BIM in large infrastructure projects allows real-time monitoring for construction activities, which is a great benefit. As mentioned in the literature, real-time monitoring tools that complement traditional scheduling methodologies and 4D/5D BIM models offer live project progress data for resource use as well as cost [37]. Directing and Initiating: It requires less management of the construction activities due to an action-taking approach where project managers can pinpoint issues right away before they become bottlenecks or budget problems.
In Riyadh, 4D BIM was used automatically to track the progress of various phases during construction such as excavation, foundation work and building erection in North-South Railway Station project. Because the project team was able to simulate various construction scenarios four months beforehand,

it fine-tuned its scheduling and resource usage which made for a more efficient way of building [37]. They also tracked material, labor, and equipment cost updates in real-time using 5D BIM which kept the project on budget too.

Table 3. Comparison of traditional project management methods and 4D/5D BIM in terms of time savings, cost efficiency, and real-time monitoring capabilities (prepared by the Author)

Category	Traditional Project Management	4D/5D BIM
Time Savings	Limited time savings due to manual processes	Significant time savings through automation and scheduling integration
Cost Efficiency	Moderate cost efficiency; prone to budget overruns	Higher cost efficiency due to accurate forecasting and cost tracking
Real-Time Monitoring	Manual updates and delayed monitoring	Real-time monitoring with integrated data and live updates

1.5.4. BIM software and tools for large infrastructure projects

All BIM software platforms are being used to conduct 4D and 5D BIM on large infrastructure projects. In metro rail projects ELECOSOFT Power Project usually used in linking 3D models to project schedules for real-time simulation and delay management [35]. Tools such as Bentley Open Roads Designer and Navisworks are used in highway construction for integrating 3D model, time data (4D) with cost information to improve project possibilities [36]

Automation tools such as Autodesk Dynamo for enabling scripting can also make 4D and 5D BIM workflows more effective. With Dynamo, we can make repetitive tasks non-repetitive as well — making the routine; no more updating estimates for cost, or task scheduling based on real-time data is something that others do. This will help to reduce a lot of manual workloads performed by project teams. Project types, including building projects exploitation Dynamo are common, however there are numerous applications which will offer equal profit in applied science kind like structural analysis and environmental impact assessments.

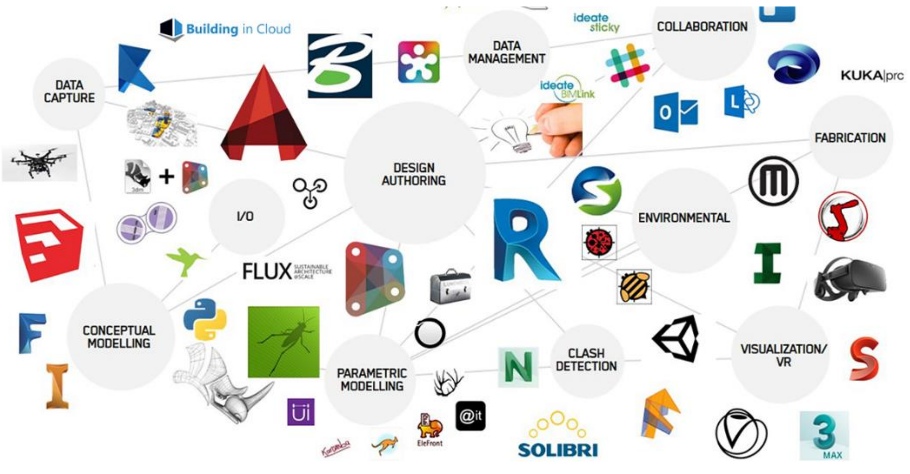

Fig. 8. BIM software tools relationship [47]

1.6. Automation of quantity surveying and cost control through 5D BIM

The industry has moved rapidly in the adoption of 5D Building Information Modeling (BIM) which automates Quantity Surveying (QS), triggering cost control and quantity take-offs based on quantities such as mass, weight, or volume. 5D BIM: Including cost data directly into the 3D model for automatic quantity take-off and enable real-time tracking of costs throughout the life cycle of a project. In this chapter, we will look further at how 5D BIM increases the responsibilities and function of a quantity surveyor by obtaining automation in labor-intensive duties while enhancing precision & cost control efficiency.

1.6.1. Automation of quantity surveying (QS) and quantity take-Offs (QTO)

Quantity surveying is the process of controlling and managing costs in construction projects, which has historically been a very labor-intensive procedure consisting mainly of hand measurement or quantity take-offs. All such processes are automated with the help of 5D BIM. Based on articles, we can generate a bill of quantities, and the quantity is accurate, saving a process from errors related to human measurement requirements [5]. Technology also connects cost information to every part of the 3D model — ensuring that any design changes are automatically adjusted in cost. And the ability to dynamically update this information now makes it much easier for QS professionals, which helps them manage their costs more effectively [34] [38] [39].

Traditional quantity surveying was the process of estimating quantities and costs of a construction project on multiple occasions due to design changes that could result in manual reworks. This edit is reflected in 5D BIM automatically across the model – and throughout the cost data [40]. Right from the design phase, QS professionals can now have a holistic view of cost implications with any change in designs made simply to be able to advise on cost capable alternatives at costs early. One of the major advantages of 5D BIM is pointed out in the literature, it gives capability to manage real-time cost data [40].

1.6.2. Enhancing cost control with 5D BIM

This also completely reforms the process of cost control by allowing real-time management to take place since 5D BIM uses live data. In the literature, it was explained that BIM 5D assists quantity surveyors with continuous monitoring of project expenses, and future forecast costs using live data from the model [40]. This is of particular benefit when it comes to major infrastructure projects, where minor cost overruns can quickly escalate.

For rail projects, for example which are well-known to exceed costs 5D BIM has been successful in keeping cost overruns down. Regarding cost-management initiatives, 5D BIM can be employed on rail infrastructure projects as shown in the literature to track material consumption, labor, and sequencing-related costing items [20]. Through posting real-time financial information, 5D BIM can help the project group make intelligent choices and apply restorative activities before expenses turn out of control. It makes the project more financially accountable and physically related.

1.6.3. The role of quantity surveyors in the 5D BIM environment

The implementation of 5D BIM in construction processes is not just completely replacing quantity surveyors but enhancing their jobs [34]. This empowers QS professionals to analyze cost data at a deeper level, provide insights on trends and thus give actionable interpretations which eventually helps with delivering projects successfully.

In the second place, the 5D BIM model facilitates running various cost scenarios which enables QS professionals to better inform savvy stakeholders toward meeting prices more efficiently. Agreed to run some pricing on other materials or types of construction and make a recommendation for the project team based around it. On a staggered basis, the decision-making initiation-taking approach for contractors is vice versa with Quantity Surveyor.

1.6.4. Real-time cost tracking and forecasting

5D BIM is the way that supports better cost forecasting, one of the essential parts of controlling costs throughout construction projects. Through the integration with 3D and 4D BIM models, accurate cost data can be appended to real-time costs for today's tracking as well as forecasting project future expenditures based on progress reached in each period. The best use of real-time cost tracking systems is demonstrated in rail projects over decision-making and time organization for such high-value, complex work can lead to budget problems especially when actual costs exceed approved budgets [20]. 5D BIM, because of ongoing financial updates, means project budgets will not be exceeded and there should therefore be no nasty shock at the end when it comes to payment.

The potential to be transformative in large-scale infrastructure projects size of but details for implementation are as discussed at the literature review part. BIM is not anymore, a mere 3D modeling platform, it grew to become an integrated time (4D) and budgeting (5D) tool that has transformed the way projects have been planned, managed, and executed. Through 4D-5D BIM, construction teams can more accurately anticipate delays time as well are better manage resource selection and financial oversight. The review also delineated notable drawbacks of adopting 4D/5D BIM, primarily those known as data integration limitations; cost burden and industry-wide reluctance towards change. That said, given the advantages derived by these BIM models in measuring and estimating with automation quantity surveying and controlling cost does provide massive efficiency/greater accuracy within projects .

One of the key takeaways from the literature is monitoring in real-time and automating to mitigate risks as per project management plan. Automated systems also allow for immediate feedback on construction schedules and costs and better forecasting of what the future may hold. This is extremely important in the context of complex, high-cost infra projects like railways and bridges, where overruns can significantly affect project completion prospects.

In the next chapters the method section of this thesis is going to be enlarged based on results reviewed. This paper will describe how BIM tools and automation in high-speed bridges project is developed. In this job, 4D and 5D BIM will be employed as well, the method emphasizing time-cost management automation by applying tools like Dynamo scripting to optimize process or integrating data into Power BI for real-time visualization. This methodology is designed to overcome the issues identified in literature and so as provide a systematic way of evaluating project performance, also it helps effective accomplishment of projects.

2. Methodology

As large-scale infrastructure projects have become more complex construction, due to that companies must use sophisticated digital tools to manage aspects of the building process. It is difficult for traditional project management to synchronize time, cost, and real-time field data. This thesis will address those issues by automatizing the project evaluation process with Autodesk Revit, Dynamo and Power BI integration as well artificial intelligence (AI) tools.

This study primarily aimed to develop a decision support system for the automated project appraisal in 4D (time) and 5D (cost) BIM. In addition, risk analysis will be carried out after the integration of Dynamo scripts and graphs on construction of a high-speed railway bridge will be generated using Power BI. The integration of project management data with digital tools eliminates the need for manual entry and facilitates information flow across all phases.

One of the key novelties in this project is an automated real-time project report generation which uses AI based tools like ChatGPT API. This system uses an analysis of the data to summarize project progress and feedback early warning signals of risks. AI driven reports prevent potential risks such as time delays, utilization of resources or cost overruns.

In addition, integrating the field data extracted from statyboszurnalas.lt. In Power BI we enable to monitor the real-time and reporting of our project. This thesis adds to the body of knowledge on public contracting, associated with large-scale infrastructure projects such as highspeed railway bridges.

2.1. Research design and framework for automation of project evaluation

2.1.1. Introduction

Thesis develops a methodology that integrates 4D and 5D BIM (Building Information Modeling) technologies to automate the project evaluation process in large-scale infrastructure projects. The main objective of the research is to monitor and evaluate project performance in real-time, optimizing time, cost, and resource allocation management. These tools are used to streamline and optimize the process of managing a project in this framework, using 3D design modeling (Revit), task automation with Dynamo and problem solving based on visualization methods like Power BI.

There are several innovative elements in the thesis. One of them is the integration of field data obtained through statyboszurnalas.lt into Power BI to track project progress in real time. Another innovation is the integration of artificial intelligence tools such as ChatGPT API to automate project reporting. Artificial intelligence analyzes project performance, identifies risks such as potential delays and cost overruns in advance and offers solutions.

2.1.2. Quantitative research approach

The present research is a quantitative study that incorporates the handling of data intensive processes on infrastructure projects. In the project, an automated evaluation system will monitor and analyze measurable parameters such as time, cost, and resource utilization. By analyzing data, it allows the performance of projects to be measured and compared. This is where 4D and 5D BIM integration comes into play for planning, resource management, scheduling as well at cost calculation to be automated.

In this project, the data collected must be analyzed by using quantitative research approach. The data is collected and dynamically processed with the help of tools like Revit and Dynamo Power BI; this gives room for faster feedback that leads to early corrections right through project delivery. This research aims to increase the performance of construction projects by data-supported decision making.

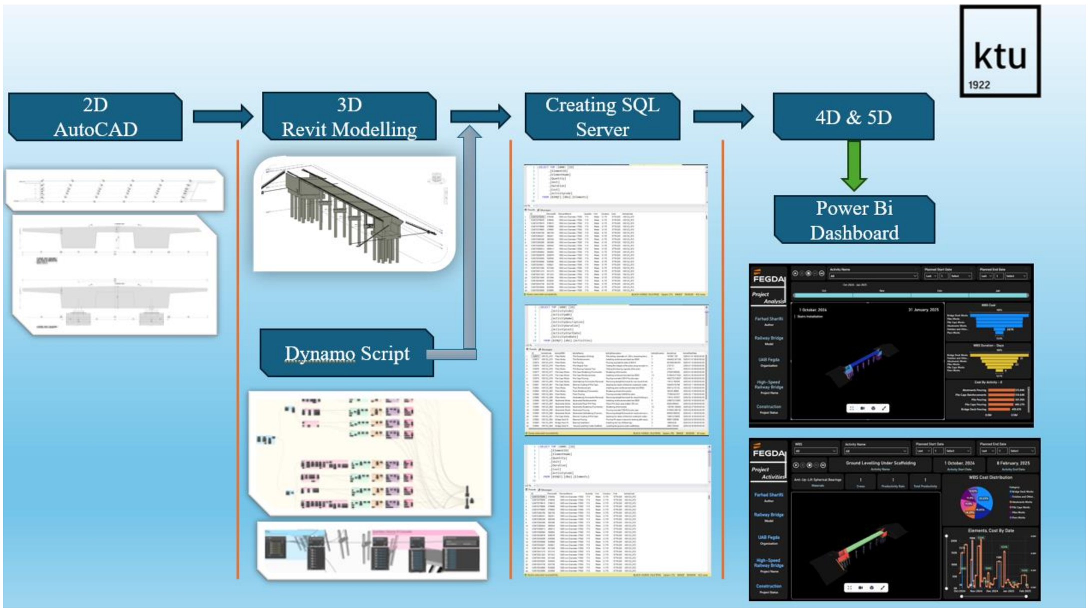

Fig. 9. Research Design and Data Flow (prepared by the Author)

2.1.3. Data collection process

This research is based on the following data sources:

1. AutoCAD Drawings – 2D Auto cad file was originated as the base for conducting project design, it is converted into a Revit model in initial stages of designing. The conversion is an essential step that generates a digital copy of the structural elements in a project.

2. BOQ (Bill of Quantity) – A comparison between 3D model and the BOQ are conducted to show various project activities in line with cost/time analyses. The connection between the BOQ and 3D model enabled smooth functioning of project data management to get a better accuracy level.

WB	ID	Activity Name (Dynamo)	Activity	Unit	BOQ QTY	Unit rate	€ 6,320,671.9
WBS_1	1.04		RAILWAY BRIDGES				
WBS_2	1.04.01		BR6168 (RAILWAY BRIDGE)				
WBS_3	1.04.01.02	Part 1	Piles				
Act	1.04.01.02.01	1- Pile Excavation	Pile drilling, diameter of 1.80m, recovering the casing pipe	m	492	330.23 €	161,977.82 €
Act	1.04.01.02.02	3- Pile Pouring	Concrete class C30/37 (Piles)	m3	1252.01	393.56 €	491,233.72 €
Act	1.04.01.02.03	2- Pile Reinforcement	Reinforcement steel bar B500	kg	153904.9	2.58 €	368,813.58 €
Act	1.04.01.02.04	4- Pile Testing	Pile integrity test, acoustic	pcs	29	74.39 €	2,157.31 €
Act	1.04.01.02.05		Pile bearing capacity test (compression)	pcs	1	21,521.10 €	21,521.10 €
WBS_3	1.04.01.03	Part 2	Pile Caps				
Act	1.04.01.03.01	1- Caps Shuttering of Formorks	Blinding concrete C16/20 under foundations (h=100 mm)	m3	54.43	275.83 €	15,013.43 €
Act	1.04.01.03.02	3- Pouring of concrete	Concrete class C30/37 in foundations	m3	1578.65	305.90 €	482,909.04 €
Act	1.04.01.03.03	2- Reinforcements	Reinforcement steel bar B500	kg	196959.58	2.58 €	508,155.72 €
Act	1.04.01.03.04	4- Deshuttering of Form works	Straight formwork for non-visual finishing of concrete and formwork removal	m2	554.35	72.03 €	39,929.83 €
Act	1.04.01.03.05	5- Bitumen coating of Pilecaps	Bitumen coating for concrete waterproofing (two layers)	m2	977.1	37.65 €	36,787.82 €
WBS_3	1.04.01.04	Part 3	Abutments				
Act	1.04.01.04.01	4- Pouring of Concrete	Concrete class C35/45 for abutments	m3	1431.97	388.99 €	557,022.01 €
Act	1.04.01.04.02	1- Reinforcement	Reinforcement steel bar B500	kg	100396.55	2.58 €	259,023.10 €
Act	1.04.01.04.03	3- Shuttering Formworks	Straight formwork for non-visual finishing of concrete and formwork removal	m2	1019.15	72.03 €	65,588.36 €
Act	1.04.01.04.04	5- Deshuttering of Formworks	Straight formwork for visual finishing of concrete and formwork removal	m2	1181.02	72.03 €	85,068.87 €
Act	1.04.01.04.05	6- Bitumen coating	Bitumen coating for concrete waterproofing (two layers)	m2	899.44	37.65 €	33,863.92 €
Act	1.04.01.04.06	2- Place PVC	PVC drain pipe slotted 160 mm	m	80.4	39.26 €	3,156.50 €
Act	1.04.01.04.07	7- Finishing of Abutments	Filter fill from imported material, included transport up to 20 km.	m3	55.81	34.89 €	1,280.81 €
Act	1.04.01.04.08		Anti puncture geotextile (300 g/m2)	m2	1115.26	4.38 €	4,436.15 €
Act	1.04.01.04.09		Drainage composite board	m2	1115.26	19.61 €	18,632.64 €

Fig. 10. BOQ Structure (prepared by the Author)

3. Site Progress Data (statyboszurnalas.lt) – Logs on construction were pulled out on a daily, weekly, or monthly basis and integrated into Power BI from CSV files. This provides project information that can be monitored in real time, and the progress reports are updated dynamically.

Table 4. Data Sources and Integration Methods (prepared by the Author)

Data Source	Integration Method
2D AutoCAD Files	Converted into a 3D Revit model, providing the basis for structural elements like piles, foundations, piers, and columns.
BOQ (Bill of Quantities)	Matched with the 3D model for detailed quantity take-offs (QTO), ensuring accurate planning of resources and costs.
Statyboszurnalas.lt Data	Provided in CSV format, capturing the quantity of work completed and approved by the responsible engineer, integrated into the 4D BIM model for progress tracking.

2.1.4. Integration of BIM, Autodesk Revit, and Power Bi

Revit, Dynamo and Power BI integration at this stage are huge to automate the basics of project management. Revit represents the project in 3D while Dynamo quotes automated volume calculations, schedules and costs reports of different structural elements like piles, foundation thickening slabs walls, columns piers head beams etc. The data is then visualized by using Power BI, the targets are monitored as well.

The dynamo scripts we used in this research provided a significant step toward automating the project management concepts. A new example of the Dynamo script that calculates these forced costs is a concrete volume per pile, construction time required for excavation and reinforcement work to be done which all are calculated in terms of their monetary cost. Likewise, other structural elements have equal automation scripts.

Integrating artificial intelligence to carry out the project performances analyses and reporting on this automatic data. Analyzed the project data in ChatGPT API platform and caught risk indications with solution suggestions.

2.1.5. Novelty in the project

The results of this study represent a substantial advancement in the field of construction project management.

1. Integration of AI API – The automated reporting function, which employs the ChatGPT API, assesses project performance and identifies potential risks, such as time delays and cost overruns, at an early stage. Project managers are equipped with tools to implement proactive solutions.

2. Real Time Data Integration – With the integration of statyboszurnalas.lt data into the BIM model, project progress is dynamically monitored and synchronized with up-to-date field data.

3. Full Automation of 4D/5D BIM – Dynamo scripts, project activities, cost and time schedules are mostly automated, and this automation increases project efficiency by reducing manual work.

4. Risk Analysis and Reporting – After the planning of structural elements and cost estimations, project risks are assessed using AI-based analysis and visualized in Power BI.

Table 5. Innovations in 4D/5D BIM Automation (prepared by the Author)

Aspect	Traditional Approach	Automated 4D/5D BIM Approach in This Project
Time and Cost Management	Manual schedule and cost updates using traditional software (e.g., MS Project, Primavera) and spreadsheets.	Automated time and cost updates based on real-time data from Dynamo scripts linked to the 3D model and BOQ for accurate time and cost management.
Resource Allocation	Resource management handled manually by site supervisors using static schedules and rough estimates.	Automatic resource allocation through Dynamo scripts that adjust labor and machinery based on the updated project schedule and completed work.
Real-Time Data Integration	No real-time updates; data is manually input and often delayed.	Real-time data from statyboszurnalas.lt is integrated into the 4D model through Dynamo, allowing automatic progress updates.
Reporting Automation	Reporting requires manual compilation of data, causing delays and potential for errors.	Automated reporting using Dynamo, streamlining the updates of progress and resource usage in real time.
Risk Mitigation	Risk identification happens after the fact, with mitigation being reactive rather than proactive.	Risk mitigation is automated through Dynamo scripts, with schedule and resource adjustments made in real-time based on-site progress.

3. Research

3.1. Tools and technologies for automating 4D/5D BIM

In this section, we will discuss the main tools and techniques used to automate the evaluation and management of the project. Revit, Dynamo, and Power BI are used as primary tools to automate resource allocation, cost estimation, and schedule, among other tasks. All scheduling, resource management, and cost planning have been entirely automated through Dynamo scripts, so no traditional project management software (i.e., Primavera or MS Project) has been used.

Revit for 3D Modeling

Through Revit, the 3D modeling of the project is built. Revit was used to model different structural elements such as piles, foundations, piers, columns, abutments, slabs of a bridge, decks, Anti Up-Lift Guided spherical bearings and the stairs next to bridge, and drainage systems (drainage collectors). Having this 3D model serves as a visual and data-driven representation of each structural element, which will now serve as the basis of increased automation.

This enables real-time updates and coordination between various aspects of the project. For example, if a pier or column needs to be redesigned, all the elements/distances linked to them update automatically, keeping the accuracy and consistency of the model over an entire project.

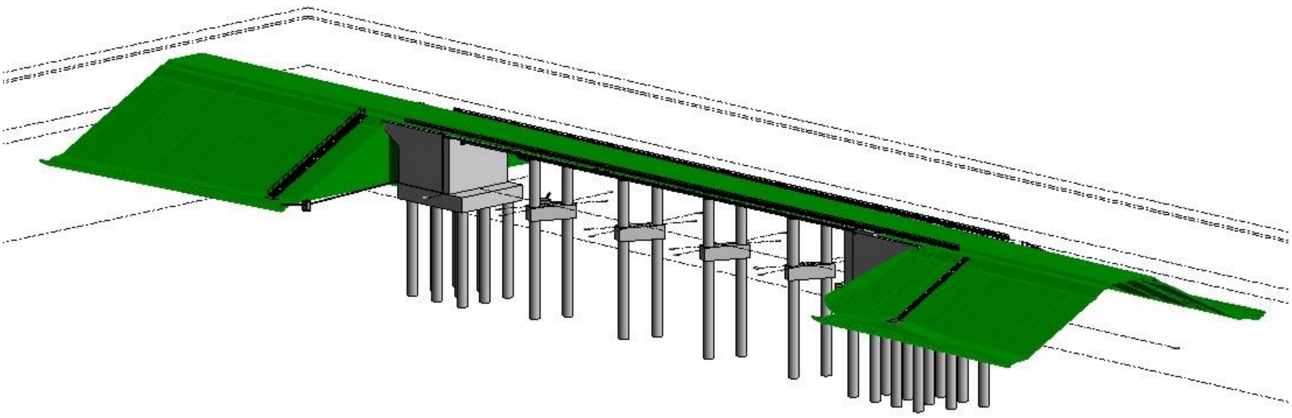

Fig. 11. Autodesk Revit – 3D Model (prepared by the Author)

Automation with Dynamo Scripts

The main tool of automation in this project is Dynamo. Dynamo scripts were used to automate tasks like volume calculation, time estimation, resource allocation, and cost estimation. Another of the key benefits of using Dynamo is that it removes the need for manual intervention, simplifying project management. Using Dynamo, the following tasks were automated:

1. Piles – Dynamo scripts were utilized for calculating the concrete volume needed for the piles and the labor and machinery required for pile excavation and concrete pouring. To illustrate, Dynamo hosts nodes like Element. Name and String. It contains filtering pile elements by name (e.g., by diameter), and then Solid.Volume is used in determining the volume for each pile, which is important for cost calculation and estimating resources. For detailed calculations refer to Appendix A. Figure 12 shows a Dynamo script that filters structural foundation

elements in a Revit model using the keyword "Diameter". This is the method used to recognize pile elements according to their diameter. Here is a detail of each node and its function:

1. Categories Node.

Purpose: Intention of an element category in Revit model to process. In this case, the category reads: "Structural Foundations.".

Function: Outputs all structural foundation elements e.g., pile caps and footings from the Revit model.

2. All. Elements of Category Node.

Purpose: Returns all elements that are part of the Structural Foundations category.

Output: A full list of all structural foundation objects in the Revit model.

3. Element. Name Node.

Function: Extract the identities of each structural foundation element in the list.

Output: A list of element names, usually corresponding to the Type Name or similar descriptor string.

4. Code Block "Diameter".

Purpose: Specifies the keyword for filtering the element names.

Inputs: The FilterCriterion is the string "Diameter".

Output: Next to the comparison node the string "Diameter"

5. String. Contains Node**.**

Purpose: This checks if each structural foundation element name contains a keyword ("Diameter").

Inputs: Development tools A list of element names from the Element. Name node. The string "Diameter" is in the code block.

Outputs: List of bool values, True if each element name contains the word 'Diameter', else False.

6. List. FilterByBoolMask Node.

Purpose: Filters the structural foundation elements using the boolean list generated by the String. Contains node.

List: The complete listing of elements of a structural foundation.

Mask: These are the boolean values which function as the filter criteria.

Output: A filtered list with only the base structure parts whose names contain "Diameter".

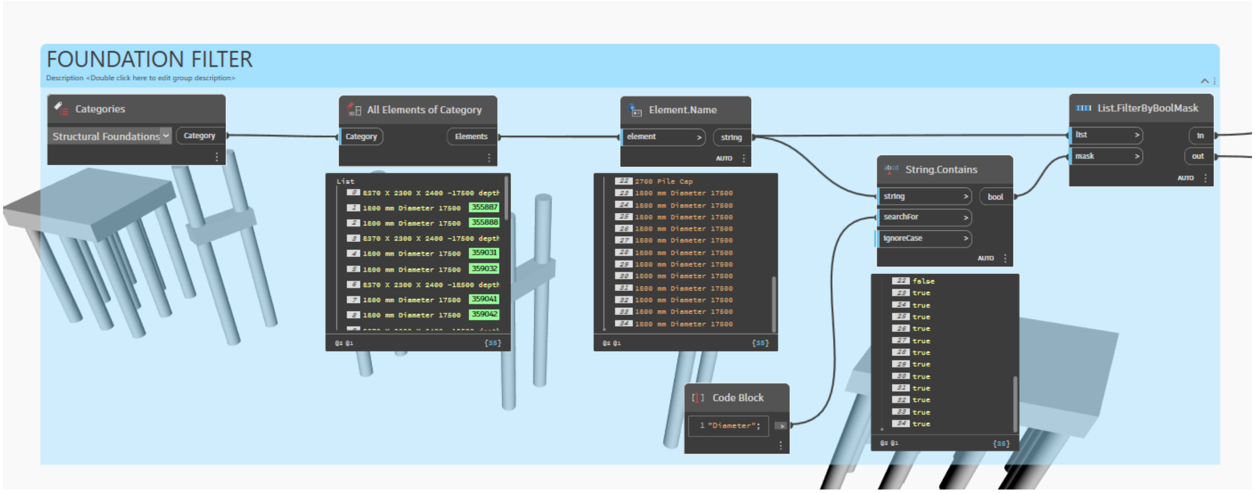

Fig. 12. Dynamo Script – Foundation Filter (prepared by the Author)

Figure 13 shows that the Dynamo graph automates the volume of concrete calculating each pile from the Revit model. Detailed explanation is as follows:

1. Piles (Left Group in Figure 13).

Purpose: This collection is used to gather all the pile elements from the Revit model where the concrete volume is to be calculated.

Inputs: Piles node being a direct list of piles from a filtered list of structural foundation elements as in the previous diameter example.

Output: Selecting the pile elements for further processing as volume calculation.

2. Element Geometry Node.

Purpose: This node receives 3D geometry for each pile element.

Inputs: The pile elements from the "Piles" group.

Output: A list of hard solids geometries for each pile, describing their physical geometries in 3D.

3. Solid Volume Node.

Purpose: This node computes the volume of the geometry of each pile.

Inputs: The 3D solid geometries from the "Element. Geometry" node.

Outputs: Volumes list corresponding to each pile's geometry in cubic millimeters.

4. List.Flatten Node.

Purpose: This node is used to unnest volumes list into a single list. Sometimes, they return volume to a nested list and this node converts it to plain list.

Inputs: "Solid.Volume" node takes the list of volume.

Outputs: List of volumes of each pile element.

5. Convert by Units Node.

Purpose: It converts the volumes from cubic millimeters to cubic meters, which is more common to use when calculating how much concrete is needed (measured in cubic meters).

Inputs: Volumes from List.Flatten node in cubic millimeters. Converting factor from cubic mm to cubic m.

Outputs: These piles are transformed into a list of volumes, now all piles in m^3 meaning the volume of concrete required.

6. Quantities (Volume of Concrete) Group (Right Group in Figure 13).

Purpose: This group summarizes the final cast amount of concrete for pile elements in the project.

Inputs: Pile geometries final volumes in m^3.

Outputs: Volume of concrete needed for the total or separated pile.

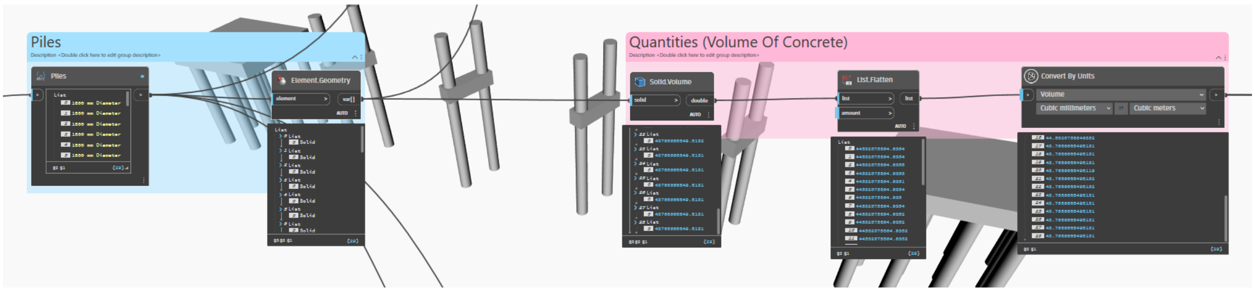

Fig. 13. Dynamo Script - Automated Calculation of Concrete Volumes for Piles (prepared by the Author)

Figure 14 graph automatizes project planning by connecting 4D and 5D, scheduling the cost of pile pouring (concrete). Here is a close examination of this section of the script:

1. Labor (Left Group in Figure 14).

Purpose: Defining the number of available labors for the pouring task of the pile.

Inputs: List specifies amount of labor, with potential of 1 or 2 labor.

Outputs: The result of this task is calculated in its later stage when the duration of the task is calculated using labor productivity.

2. Productivity m^3/day per labor.

Purpose: This node describes the productivity rate based on the volume m^3 a labor can pour in one day.

Inputs: Represents the production 115 m^3/day.

Outputs: It is combined with the number of laborers to estimate total productivity.

3. Division of Volume by Productivity.

Purpose: Concrete volume for piles is divided by total productivity as number of labors × m^3 per day per labor.

Inputs: Amount of pile volume that was calculated in the first part of the script (in m^3), labor and their productivity rate.

Outputs: Result shows how long it will take to pour concrete for the piles (in days), based on the number of laborers that are available.

4. Duration.

Purpose: The node is intended to compute the pile pouring process duration.

Inputs: The result from the division step (volume/productivity).

Outputs: Required duration to complete the tasks.

5. Rounded Duration.

Purpose: This node rounds the calculated duration.

Inputs: Overall duration in days.

Outputs: The rounded value, representing the total number of days for pouring the piles' concrete.

6. Unit Rate Euro/m^3.

Purpose: This node specifies the cost per cubic meter (unit rate) of the concrete being poured.

Inputs: A cost is given as 1395.86 Euro per cubic meter.

Outputs: This unit rate will be used to calculate the overall cost based on the concrete volume.

7. Cost (Euro) Calculation.

Purpose: To calculate the cost of each pile this node multiplies the concrete volume.

Inputs: Unit rate and volume of concrete as Euro per m^3.

Outputs: Cost for each pile (cost for pouring concrete).

8. Total Cost (Euro).

Purpose: Node sums the separated pile costs to provide overall cost of concrete.

Inputs: The previous step's sorted list of individual pile costs.

Outputs: Total cost for a pile pouring in Euros.

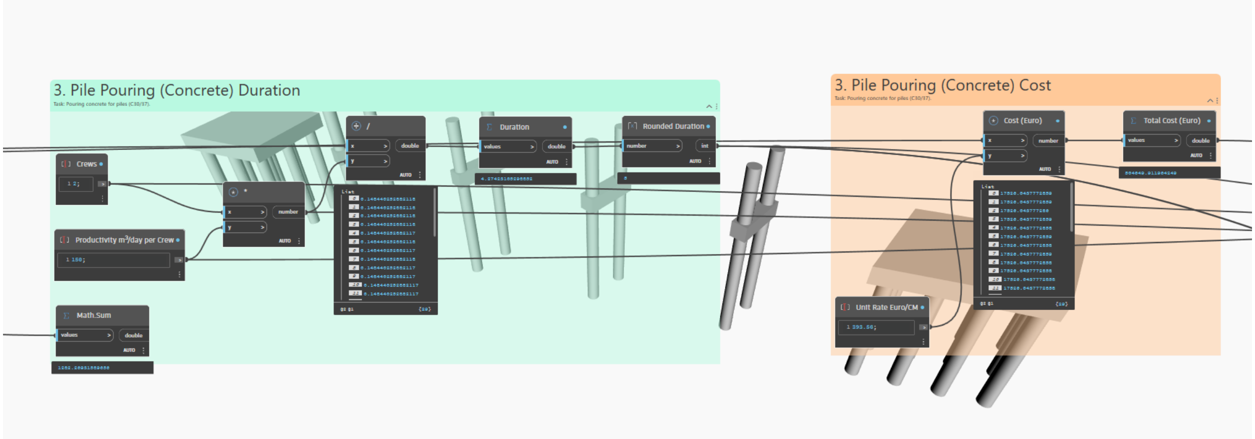

Fig. 14. Dynamo Script – Automation 4D/5D for Pile Pouring (prepared by the Author)

Figure 15 shows Dynamo graph generates activities and resources automatically for the pile pouring during the project planning (4D and 5D) process. Explanation of every component of the graph:

Pile Pouring Activity Data (Left Group in Figure 15) handles the activity data for the compressive pile pour, which is necessary for the schedule and cost element integration.

1. Unique Activity ID.

Purpose: This node stores the unique pile pouring activity ID.

Inputs: A string containing the activity code, in this case “V00123_674”.

Outputs: This code will go through further processing later for calculations or to enter a database and will be converted into a number for integration with systems externally.

2. String.GetNumber.

Purpose: This function extracts the activity code so this can be more easily handled when scheduling activity or calculations.

Inputs: The activity code string is V00123_674.

Outputs: Numeric value (123674) for adding engine into project databases.

3. String.ToNumber.

Purpose: Converts the extracted number of strings in a numerical format to use in calculating.

Inputs: Extracted by “String.GetNumber” node.

Outputs: To make the numeric activity ready for the other process.

4. WBS Activity.

Purpose: Summarize and categorize the activities.

Inputs: The string “Piles Works” belonging to the WBS level this activity belongs.

Outputs: This is used for project management and tracking purposes.

5. Activity Name.

Purpose: Storing the description of activity name.

Inputs: This activity is labeled as Pile Pouring.

Outputs: The name that is used to identify the task in a project schedule.

6. Activity Description.

Purpose: Detailed description of the activities explains the involvement of the tasks.

Inputs: “Pouring concrete for piles (C30/37)” — providing information on the pile pouring.

Outputs: Using this description identifies the project in documentation without having to use a more verbose name.

7. List.Create.

Purpose: This node compiles a list of the collected activity data elements like ID, WBS, Name, Description, etc. for the storage data.

Inputs: Combined structured list of all activity.

Outputs: A single list that holds all activity data to be used elsewhere in the graph or exported.

Pile Pouring Resources Data in the right group of Figure 15 shows gathers the data relating to the resources needed for the pile pouring activity like material, labor, and equipment.

1. Activity Code.

Purpose: Provides unique identification to link the resources to the correct activities as in “Activity Code” in the left group.

Inputs: The same string used in the activity data.

Outputs: The code that connects the resources to the related activities.

2. Materials.

Purpose: Defining the material needs for the pile pouring.

Inputs: Defining the material type which in the case specified as “Concrete C30/37 grade”.

Outputs: List of material in order to cost and schedule the pouring work of the pile.

3. Labor.

Purpose: Outlines the task labor resources needed.

Inputs: In this case resources defined as “1 Concrete pump operator, 4 Concrete Laborers”.

Outputs: The information is used to assign personnel, calculated as labor cost.

4. Equipment.

Purpose: Required equipment for the activities.

Inputs: In this case equipment defined as “1 Concrete pump, 2 Concrete mixers/trucks, 1 Vibrator”.

Outputs: It is used for equipment allocation and estimating the cost.

5. List.Create.

Purpose: This node compiles all resource data (materials, labor, equipment) into a structured list for further use.

Inputs: The combination of various resource elements (materials, labor, equipment).

Outputs: Separate lists of resource data based on the pile pouring activity.

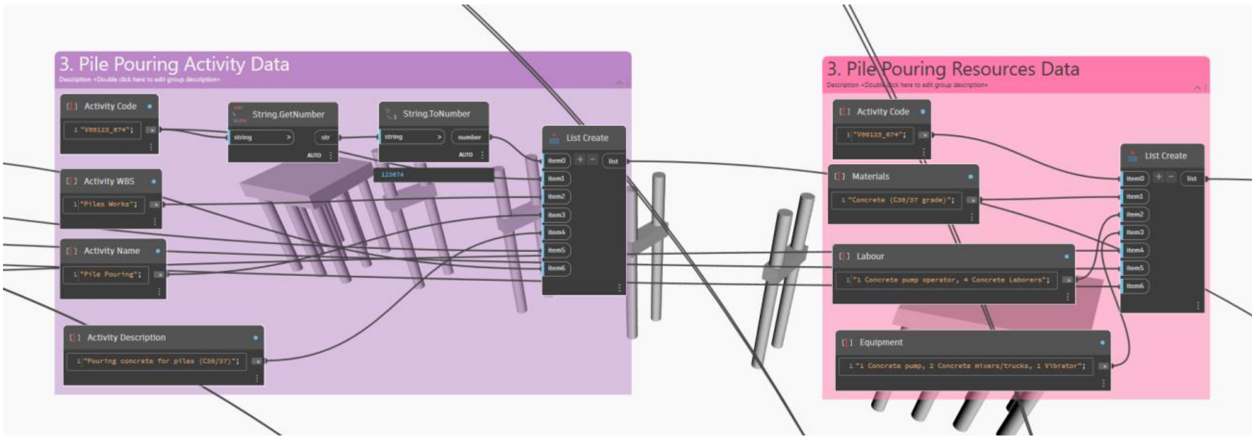

Fig. 15. Dynamo Script – Integration of Activity and Resource Data (prepared by the Author)

Same Dynamo scripts and formats run for the following elements:

2. Foundation – Automating material quantities, as well as providing duration estimates for processes such as formwork and concrete pours, and even tying cost estimates directly to the schedule.

3. Piers and Columns – Dynamo managed the volume and material calculations for piers and columns. The scripts also incorporated accurate cost estimates and time schedules, so the entire project timeframe and budget would automatically adjust as work is done.

4. Abutments – The design and material use and costing estimations in aid of abutment production were automated. Dynamo also took care of scheduling tasks such as reinforcement installation and concrete pouring for abutments.

5. Slabs, Decks, and Bearings – Volume and cost calculations for the various concrete slabs and decks were automated using Dynamo scripts. As an addition to the model, it encompassed the Anti Up-Lift Guided Spherical Bearings, with resource planning to install the bearings.

6. Stairs and Drainage Systems – The stairs next to the bridge and the drainage systems (collectors included) were also modeled in Dynamo. These scripts also automatically derive the cost and time requirements for the few components.

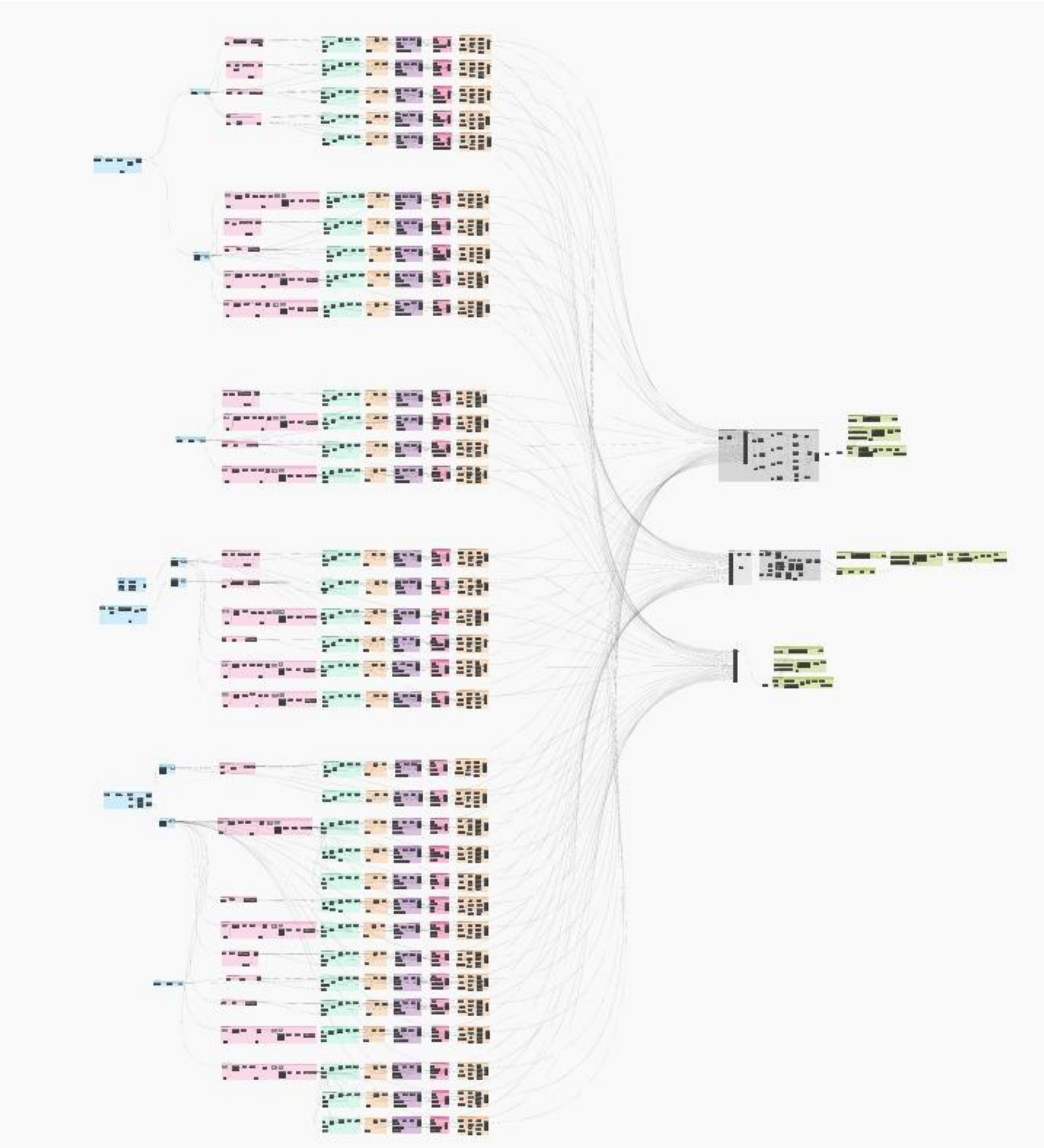

Fig. 16. Dynamo Script – Full View (prepared by the Author)

Power BI for Visualization and Real-Time Tracking

The project was visualized with Power BI to monitor its progress in real-time. Data from statyboszurnalas.lt importing in the form of CSV data format, such as daily/weekly/monthly based. All these were captured in the Power BI dashboard providing the project managers with a real-time view of the progress of the project. For detailed Power BI dashboards refer to Appendix B. The dashboard monitors key performance metrics including:

1. Actual vs Planned progress – The comparison of human-made schedule versus AI-generated timetable (from Dynamo) in Power BI's Gantt chart shows the progress of projects and the completion of individual task.
2. Resource allocation – Allows for real time tracking of labor, machinery and material usage ensuring that resources are optimally allocated across the project.
3. Cost estimation and budget tracking – The dashboard provides updates on costs, tracking planned vs. actual costs. The integration with Dynamo scripts ensures that cost estimations are automatically updated based on changes in the project's scope.

Power BI also provided the project team with real-time site inputs for piles, foundations, columns, and other elements, which allowed them to monitor progress on these structural elements. If the progress status was different than planned, this information updated automatically in a dashboard displaying discrepancies allowing for immediate changes to project plan.

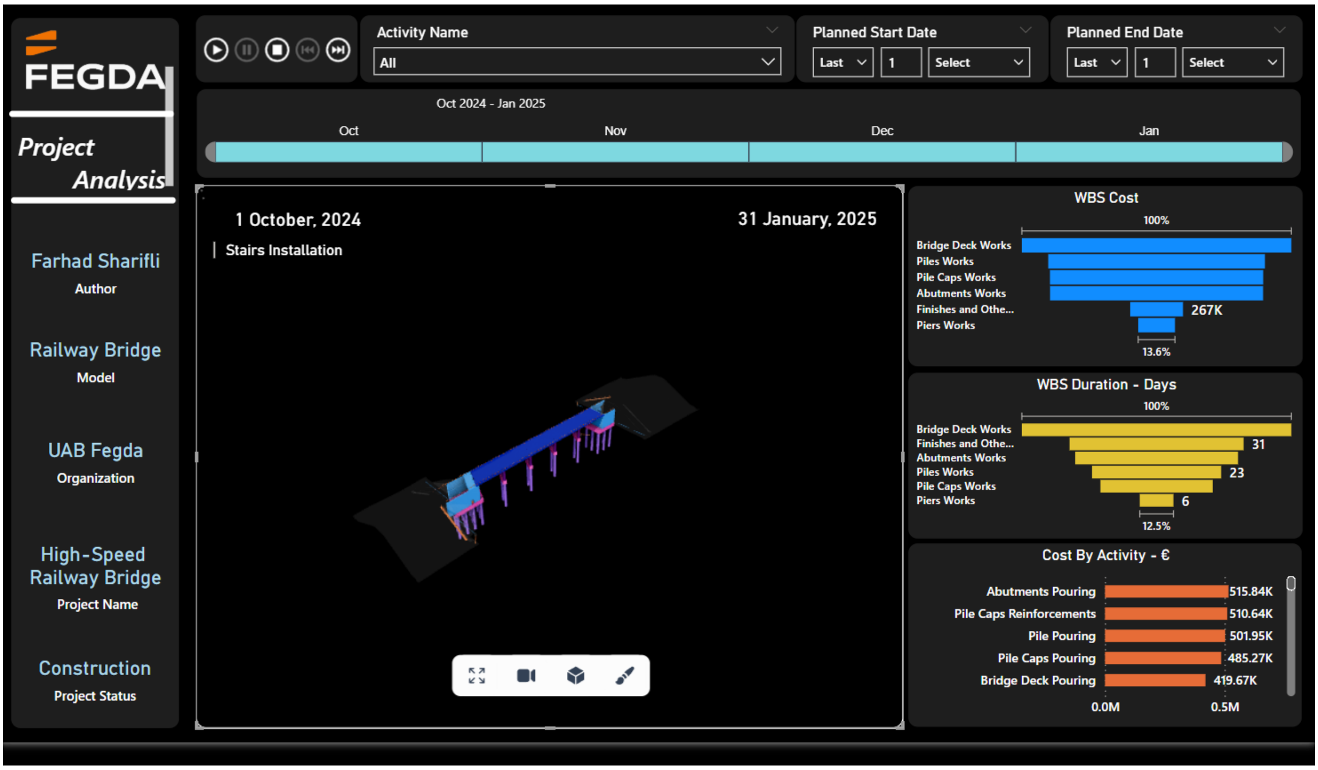

Fig. 17. Power BI Dashboard View (prepared by the Author)

Table 6. Key Performance Indicators Tracked in Power BI (prepared by the Author)

KPI	Description
Planned vs Actual Progress	Compares scheduled progress against actual progress tracked by statyboszurnalas.lt data.
Resource Allocation	Monitors the usage of labor, machinery, and materials in relation to planned allocations.
Cost Estimates	Tracks project cost estimates based on real-time progress updates against initial budget assumptions.
Schedule Deviations	Highlights any slippages or deviations in the planned schedule, allowing for immediate interventions.
Labor Productivity	Measures the productivity of labor based on the amount of work completed versus time spent.

Challenges in Integration and Solutions

Even though Revit, Dynamo and Power BI was a good flow for project automation, there were some data integration issues. One hard problem was how to make the data from Revit end up in our Power BI reports without losing information through Dynamo. The solution required the data to be pre-processed by Dynamo to enable visualization on Power BI.

Furthermore, the dynamo scripts had to be “simplified” based on what information was available in their current Bill of Quantities (BOQ). This includes correlating each activity identified in the BOQ to its equivalent 3D model element, so resource allocation as well as cost estimation is achieved.

To conclude, this integration proved incredibly powerful for automating such vital processes for the project, especially with 4D and 5D BIM solutions. Revit was a strong source of truth model for the project – its integration with other packages enabled instant model updates and generated accurate data representations. These processes were automated through Dynamo scripts and therefore eliminate manual labor in order to simplify resource allocation on site, cost estimations, or schedule setting. Further enhancements in project monitoring was an increase in project monitoring done through Power BI where visualization and monitoring in real time helped (and are helping) project managers take data driven predictive decisions for project performance. Therefore, the amalgamation of these complied tools leading to efficient, reliable, and themed feasibility management of construction projects enabled a persuasive groundwork in operational implementations for forthcoming projects.

3.2. Data integration and real-time progress tracking using 4D BIM

In this section, the integration of real-time progress data into the 4D BIM model is explained, focusing on how the data from statyboszurnalas.lt is processed using Dynamo to track project progress accurately. The data provides approved quantities of work completed, which is critical for ensuring that the digital model reflects the actual on-site progress.

3.2.1. Data collection from statyboszurnalas.lt

The “actual on site” progress data collected from statyboszurnalas.lt as CSV format includes the quantities of work completed and approved by the responsible site engineers and project stakeholders. This data includes:

1. Approved quantities for completed structural elements such as piles, foundations, piers, columns, decks, and other structural elements.
2. Updates on the construction progress, on the construction progress, aligned with specific milestones in the project schedule.

The data is delivered in CSV format and then processed to update the project’s 4D BIM model. The focus is on ensuring that the approved quantities are matched with the corresponding tasks in the BIM model to provide accurate progress tracking.

3.2.2. Real-time progress tracking in the 4D BIM Model

We use the 4D BIM model in Revit as a central point to track real-time progress of the project. This integration of each of those Dynamo scripts with Power BI allows the project to visualize the evolution of the work by showing how many different structural components were executed in comparison to the approved amounts. Dynamo provides real-time tracking which allows:

1. Real-time Project Status –The model visually indicates which of the structure elements (piles, foundations, piers, etc.) are finished and which are in progress. When approved progress gets populated as quantities from "statyboszurnalas.lt" are processed. For instance, if pile pouring is completed for 10% of the piles, then this model will also have shown that for that task it is 10% done, and to make it clearer to read, the Gantt chart will then be color-coded in Power BI as well.

2. Pro-active Schedule Management – It identifies any delays or issues associated with resource allocation. That keeps the project on schedule and provides real-time updates to the 4D BIM model and Power BI dashboard. For example, if there is a delay in the foundation pouring task, Power BI's Gantt chart will visually represent how that delay is affecting the overall schedule, with visual indicators marking the impacted areas.

Table 7. Progress Metrics Tracked in the 4D BIM Model (prepared by the Author)

Metric	Description
Approved Quantities	Represents the quantity of work completed and approved by site engineers using statyboszurnalas.lt.
Task Completion Percentage	Tracks the percentage of completion for each construction task based on approved data from the site.
Schedule Adjustments	Adjusts the project schedule in the 4D BIM model based on real-time progress and approved quantities.
Resource Adjustments	Updates the allocation of resources (labor, materials, machinery) based on the actual progress.
Project Milestones	Monitors the completion of key project milestones as planned in the 4D model.
Risk Management	Identifies potential risks (e.g., delays, resource shortages) based on real-time data and adjusts the project plan accordingly to mitigate risks.

3.2.3. Challenges in real-time data integration

One of the biggest challenges during the integration I faced was making sure that the confirmed quantities from statyboszurnalas.lt, and it was accurately matched to the BIM model's corresponding tasks. It was the utmost challenge, as this would require thorough mapping of the BOQ items with each part of the 3D model, so that the progress updates were applied correctly, repeatedly. Dynamo scripts were deployed as part of the solution, allowing the data to be pre-processed so that the relationship between each BOQ task and the relevant structural element in the model was correctly established. As another example, the pile excavation tasks were applied to those specific pile elements in Revit.

The second one was regarding CSV preprocessing from statyboszurnalas.lt with scripts in the Dynamo to guarantee their compatibility. The CSV files had to be formatted and processed to enable seamless integration into the 4D BIM model. Formatted properly, Dynamo would find it easy to process this data for a real-time update allowing the status of the project to always stay coordinated with what is on site. The first data was cleaned and structured in Excel before being imported into Dynamo and SQL Server. Such way, any errors in the data got fixed from the beginning and no wrong integration was performed.

Real-time monitoring data is incorporated in statyboszurnalas.lt and integration of this into the 4D BIM model has delivered significant impact in ensuring on-site conditions match what is represented digitally in the project. As a result, the system allowed accurate progress tracking, as the approved quantities were processed through Dynamo and the BIM model was updated. This adds to project transparency and facilitates proactive decision-making with a visualized progress indicator and automatic update of the Gantt chart in Power BI. Initially, it was difficult to map the BOQ tasks correctly with the model components and ensure that they would run correctly on the generated CSV file. So, it was adequately easy to determine and implement pre-processing steps and explicit scripting in Dynamo. This study has demonstrated how 4D BIM can be integrated with live data acquiring methods to improve accuracy and control over the time aspects of construction sites.

3.3. Cost management and risk mitigation through 5D BIM

5D BIM for Cost Management and Risk Mitigation Handling Bringing together the cost along with the 3D/4D model creates 5D BIM that helps automate cost tracking along with proactive risk management. This project showcases an integration of real-time cost updates, risk identification, and decision-making in large-scale infrastructure project, like bridge construction, by using tools like Dynamo, Power BI, et al. along with an integration of AI.

3.3.1. Dynamo & power bi - integrating cost data with the 3D/4D model

The 5D cost management process starts with the integration of cost data with the 3D/4D model itself. Cost calculation is automated by Dynamo scripts for different structural elements, like piles, foundations, piers, and columns. These scripts pull data from the model and BOQ for material and labor cost estimating, dynamically recalibrating as changes are made to the project model. When the volume of concrete for piles changes, for example, the cost of pouring concrete is calculated automatically in Dynamo. For instance, if the amount of concrete needed for a foundation modifies, Dynamo updates the price by multiplying a pre-registered cost parameter (for example, Euro per cubic meter). The modifications show up in the Power BI dashboard in real-time.

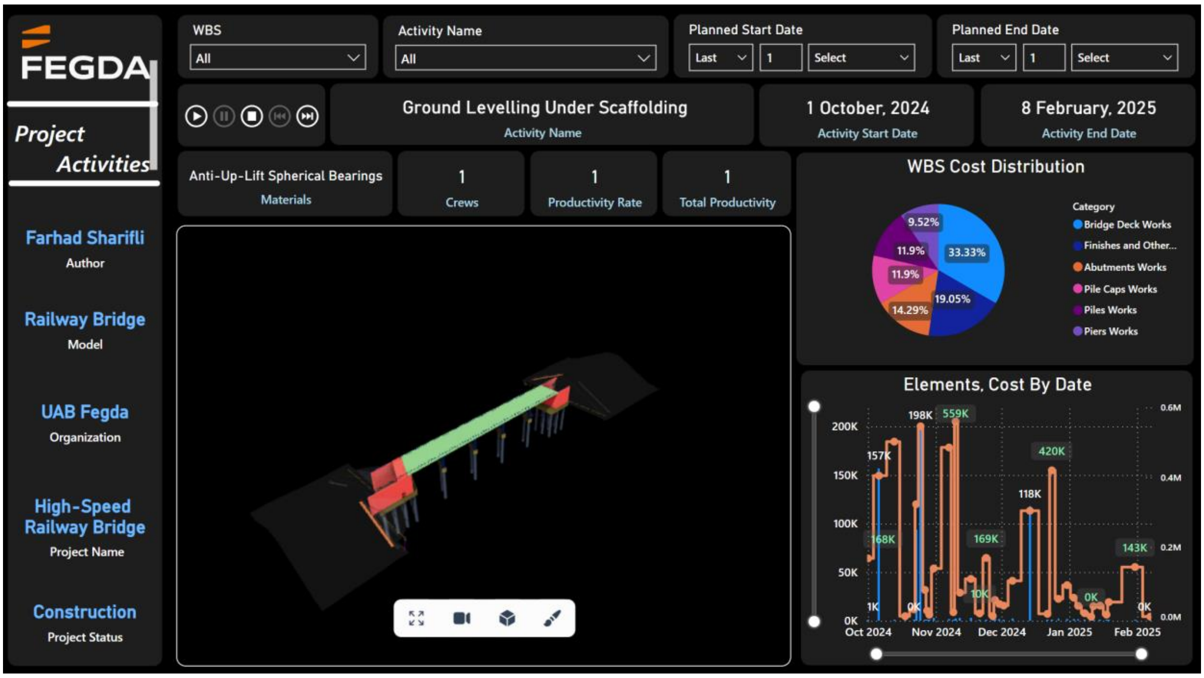

Fig. 18. Power BI Dashboard – WBS Cost Distribution (prepared by Author)

Once the cost for each element is calculated, data is sent to Power BI for real-time visualization. Power BI gives the project team cost estimates, actual costs, and budget variance metrics to keep the project on track financially. These elements can be integrated seamlessly so that the project can be updated right away, monitoring and keeping track of the real-time variances between planned and actual earnings.

3.3.2. Risk identification and mitigation

Risk management is an important part of 5D BIM, especially when it comes to managing economic risks arising out of project delays and budget overruns. 5D BIM offers the opportunity to detect schedule delays, cost overruns, and waste of resources risk by integrating cost and time data.

The project can be adjusted by actual progress automatically using Dynamo. For example, in case of delays in certain stages (like pile pouring) affecting subsequent phases (like foundation pouring), Power BI adjusts the overall project timeline in place of the delays.

In addition, Power BI facilitates visualizing risks by highlighting areas where costs are outside of the planned budget. By leveraging AI (ChatGPT API) the system can deliver actionable insights into the risks before they turn into delays or budget overruns, flagging activities that are likely to cause the said conditions. If the cost of labor for a task increases, on the report of the AI can signal to the project managers if it is a risk and propose actions to handle it, like adjusting the resources or changing the scope of the project.

Through this AI-driven reporting, the project management team can make better decisions, thus reducing risks before they impact the project's completion. Also, by offering predictive insights into the financial progress of the project, the AI component allows the team to be proactive instead of reactive to potential issues, keeping the project from taking more time or money than planned.

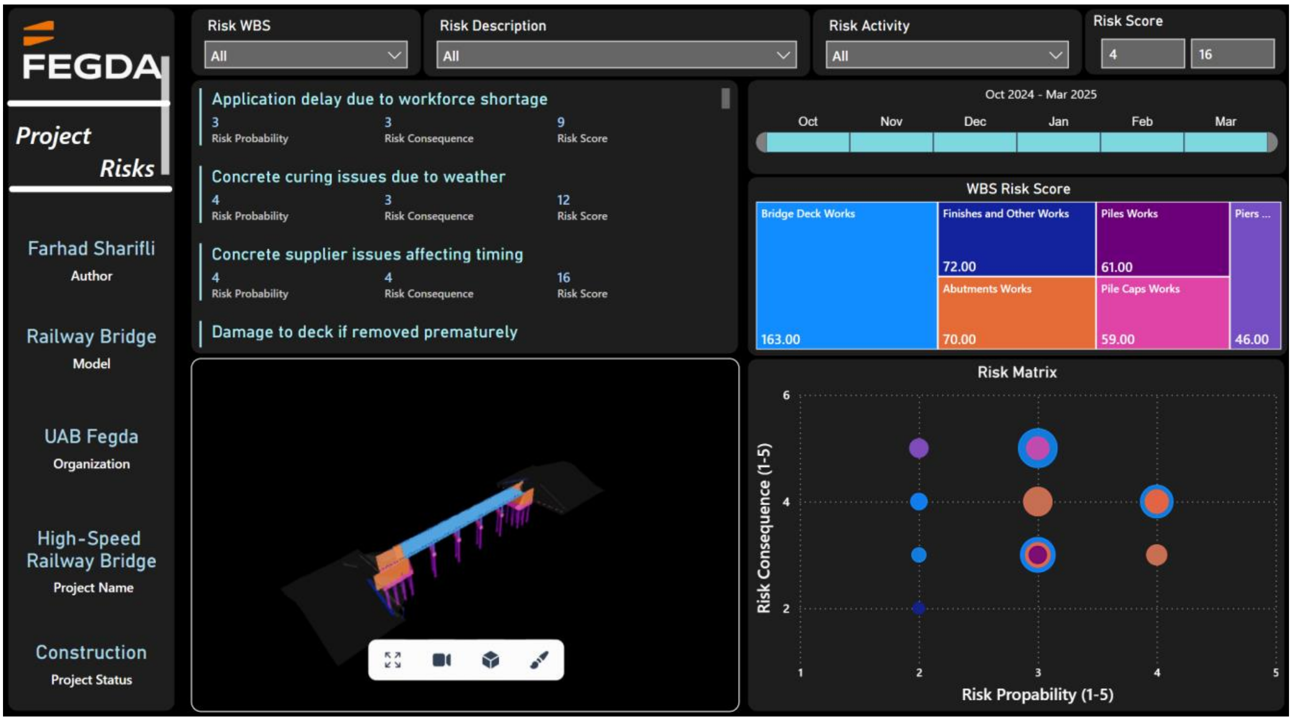

Fig. 19. Power BI Dashboard – Risk Management (prepared by Author)

These benefits included enhanced cost management through 5D BIM, which is a new practice for improving project risk management in construction projects. The real-time recalculation of costs, by automation of cost calculation in Dynamo integrated into Power BI and accurate real-time information, ensured that the data was kept accurate, and adjustments were made immediately when alterations in the project model occurred. By using this approach, the project team was able to keep track of the costs and prevent out of budget scenarios, which are usual difficulties in mega projects.

Besides cost management, AI tools integration improved the capability to predict potential risk early on, in the form of delays or a surge in labor or material costs. The system offered them insights and recommendations based on AI analysis, enabling the team to take timely measures to mitigate potential issues. If certain tasks were performed later than originally scheduled leaves in Power BI, you could add up to date with those modifications, so you can act proactively and try to mitigate the impact on project delays.

The implementation of 5D BIM, Dynamo, Power BI and AI provided a superior solution for cost control and risk reduction. This not only kept the project on budget and on time but also improved decision making and resource allocation. The same tools in use above and beyond the form of visualization, this technology enables tangible benefits that come from understanding and managing complex projects more accurately, more quickly, and more efficiently.

3.4. Practical application and novelty of the project

Using advanced 4D/5D BIM technologies, Dynamo Scripting, Power BI Dashboards and AI-powered automation, this project aims to solve some significant problems that arose within large infrastructure projects. Its uniqueness and practical contributions stem from its combination of techniques and instruments to improve decision making and support real-time project evaluations.

The contributions of this thesis are in the direction of enhanced cost and schedule management of the construction process. The 3D model was developed in Revit by manually translating 2D AutoCAD files, ensuring accuracy and paving the way for automated processes. More than 1,000 Dynamo scripts were tailored to specific needs such as resource allocation, cost tracking, and scheduling. They were able to save time and avoid expensive manual work.

To store the Dynamo scripts and 4D/5D BIM model data, a Microsoft SQL Server was configured. This part was used as the main system for keeping real-time project data. This enabled Power BI dashboards to analyze and visualize data directly. It made it easier to combine data from the other tools, such as statyboszurnalas.lt by its SQL Server and become a one-stop shop for all project data.

Finally, AI Tools make better decision-making in this project. The instance of ChatGPT API was integrated to get instant reports and analyses of risks and progress so that the project team can quickly respond to issues related to budget or schedule. These practical applications demonstrate how technology improves the efficiency and management of construction.

3.5. Results and discussion

Through the integration of 4D/5D BIM, Dynamo scripting, and Power BI dashboards, the project produced these key deliverables as important processes were automated using custom Dynamo scripts for tasks like calculating material quantities, assigning resources, and updating schedules. The scripts saved a substantial amount of manual work, so everything got processed quicker and with less mistakes.

Using Power BI dashboards to make progress tracking better and had real-time reports on planned and actual, and costs. Data from statyboszurnalas.lt was enabling adjustments of project fees based on real actual status. This enabled adjustments to prevent delays or scarcity of materials and resources.

One of the most interesting aspects of this project was that we could compare schedules made by the team and AI. This proved to be a useful exercise to compare their respective project data against an international benchmark of good practice to highlight where issues might be and to enable project managers to make better decisions based on transparent and trustworthy information.

Key Achievements:

1. Automated Processes with Dynamo Scripts:

Automatic calculations for quantities, costs, and resource distribution.

Increased efficiency and fewer errors with a manual process.

2. Real-Time Progress Tracking:

Data automatically updated from statyboszurnalas.lt.

Made it possible to compare planned vs. actual progress.

3. Improved Decision-Making:

Allowed for improved planning through the comparison of various schedule choices.

Assist in the early identification and resolution of potential issues, including budget overruns or material shortages that could impact schedule adherence and project completion times.

This project proved that combining powerful tools can create more efficient construction project management. It facilitated progress tracking, cost control and issue prevention through automating repetitive tasks, providing real-time updates, and enabling improved planning. Using the approaches above will help you replicate these types of projects with more efficiency and simplicity.

The outcomes of this project illustrate that integrating information using 4D/5D BIM with tools such as Dynamo and Power BI provides a significant benefit of streamlining all project management processes. The project had saved time and cost considerably by automating calculations for material quantity, schedules, and resource allocation that reduced manual work and erratic calculations in the process. Real-time progress tracking enabled accurate comparison of actual progress versus the planned progress, which helped in making sure the project was on track. Moreover, AI integration improved decision-making by early risk identification and providing actionable insights.

In this way, the significance of these tools on contemporary construction undertakings is underscored: Key achievements such as automation, real-time tracking, and improved decision-making. The project provided tangible outcomes and demonstrated a template for deploying new technologies at large-scale operations in the future. These findings underscore how 4D/5D BIM can enhance efficiency, minimize expenses, and facilitate proactive project management.

3.6. Conclusion and future research directions

This study demonstrates the potential impact that the implementation of 4D/5D BIM technologies, Dynamo scripts, automation and Power BI dashboards could have on facilitating the project management of large-scale infrastructure endeavors including railway bridges. These innovative tools allowed for significant time savings and better optimization through scheduling, cost management, and real-time progress tracking, some of the principal pain points of construction today.

An important contribution of this research is the integration of various technologies, such as Dynamo for scripting, SQL Server for centralized data storage and Power BI for visualization. It saved manual work while being fully accurate and scalable. But automation is highly dependent on manual preparation in the first stages. As such, tasks ranging from high fidelity 3D modeling in Revit, bespoke Dynamo scripts, SQL database design, and Power BI dashboard setup, were mission-critical to establishing a robust system that would function effectively throughout the project.

Another key thing about this project was that we brought in AI to improve decision-making. AI tools provided predictive analytics, proactively managed risks, and presented a comparison between schedules created by humans vs. AI. It helped project managers make decisions from straightforward data-driven insights. All these advances in technology, however, also highlight the need for researchers to continue fostering and applying the same human expertise in the incredibly early stages of planning to ensure that automation works.

Key Takeaways

1. Automated process.
2. Real-Time Integration and AI Insights.
3. Scalability and Adaptability.

3.6.1. Future research directions

Future research needs to include the automation of the entire life cycle; that is from design to maintenance of construction. Dashboards with sustainability metrics, such as tracking carbon footprints, can be built in to align projects with environmental goals. Technology, including advanced AI tools, may yet help improve resource planning, cost forecasting, and schedule optimization. This will help reduce the need to process data manually as it moves between platforms, while training programs will enable construction teams to adopt and develop skills in these technologies.

Key Points of future directions:

1. Life cycle Automation.
2. Sustainability Integration.
3. Advanced AI Models.
4. Streamlined Data Interoperability.
5. Training and Adoption.

To sum up, the process of manual modelling, scripting and database creation is still labor intensive at first, but results in a fully automated project management system, capable of scaling for multiple projects. It serves as a foundation for construction management approaches today and allows for more opportunities in integrating advanced technology to produce improved outcomes, less delays, and increased cost control. With such forward-thinking innovation and processes, the industry is moving towards the future of intelligent automation that will drive successive performance on complex infrastructure projects.

Conclusion

1. Thesis proved how modern software tools such as Dynamo, SQL Server and Power BI can be utilized to provide automation in developing an integrated data system for 4D and 5D BIM environments to tasks such as scheduling, cost estimation and resource allocation.

2. Structured project data in a centralized SQL database with real-time updates allowed to easy data synchronization between different systems and emphasized data management in construction workflows.

3. Power BI dashboards made it easier to visualize the project in terms of progress, scheduling, and resource allocation. This improved decision-making and resource maximization across project lifecycle

4. By synchronizing the 3D Revit model with the BOQ, costs and resources were efficiently tracked, aligning the design and construction phases more closely and achieving a seamless workflow.

5. The proposed approach demonstrates real application and scalability by being validated on a high-speed railway bridge project. These findings were also underscored in terms of how such systems can enhance efficiency and administer resource allocation, which makes them a viable solution for future construction projects.

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Appendices

Appendix 1. Bill of Quantities (BOQ)

The Bill of Quantity (BOQ) for this thesis project shows the breakdown of all the material, quantity, and resources used in this project. It is a base reference for cost estimation and scheduling through the 4D and 5D BIM context. A high-resolution version of the BOQ is attached for further reference.

Table 8. Bill of quantities (BOQ).

Row	WBS	ID	Alignment	Activity Name	Activity	Activity ID	Unit	QTY	Unit rate	€ 5,840,859.96
1	WBS_1	1.04		STRUCTURAL PART. RAILWAY BRIDGES - SK-05 01						
2	WBS_2	1.04.01		BR6168 (GELEZINKELIO TILTAS) / BR6168 (RAILWAY BRIDGE)						
3	WBS_3	1.04.01.02	1.2	Part 1	Piles					
4	Act	1.04.01.02.01	1.2.1	1- Pile Excavation	Pile drilling, diameter of 1.80m, recovering the casing pipe	V00123_672	m	490.5	330.23 €	161,977.82 €
5	Act	1.04.01.02.02	1.2.1.a	3- Pile Pouring	Concrete class C30/37 (Piles)	V00123_673	m3	1248.18	393.56 €	491,233.72 €
6	Act	1.04.01.02.03	1.2.1.b	2- Pile Reinforcement	Reinforcement steel bar B500	V00123_674	kg	142951	2.58 €	368,813.58 €
7	Act	1.04.01.02.04	1.2.2	4- Pile Testing	Pile integrity test, acoustic	V00123_675	pcs	29	74.39 €	2,157.31 €
8	Act	1.04.01.02.05	1.2.3		Pile bearing capacity test (compression)	V00123_676	pcs	1	21,521.10 €	21,521.10 €
9	WBS_3	1.04.01.03	1.3	Part 2	Pile Caps					

10	Act	1.04.01.03.01	1.3.1	1- Caps Shuttering of Formorks	Blinding concrete C16/20 under foundations (h=100 mm)	V00123_678	m3	54.43	275.83 €	15,013.43 €
11	Act	1.04.01.03.02	1.3.2	3- Pouring of concrete	Concrete class C30/37 in foundations	V00123_679	m3	1578.65	305.90 €	482,909.04 €
12	Act	1.04.01.03.03	1.3.2.a	2- Reinforcements	Reinforcement steel bar B500	V00123_680	kg	196959.58	2.58 €	508,155.72 €
13	Act	1.04.01.03.04	1.3.3	4- Deshuttering of Form works	Straight formwork for non-visual finishing of concrete and formwork removal	V00123_681	m2	554.35	72.03 €	39,929.83 €
14	Act	1.04.01.03.05	1.3.4	5- Bitumen coating of Pilecaps	Bitumen coating for concrete waterproofing (two layers)	V00123_682	m2	977.1	37.65 €	36,787.82 €
15	WBS_3	1.04.01.04	1.4	Part 3	Abutments					
16	Act	1.04.01.04.01	1.4.1	4- Pouring of Concrete	Concrete class C35/45 for abutments	V00123_684	m3	1431.97	388.99 €	557,022.01 €
17	Act	1.04.01.04.02	1.4.1.a	1- Reinforcement	Reinforcement steel bar B500	V00123_685	kg	100396.55	2.58 €	259,023.10 €
18	Act	1.04.01.04.03	1.4.2	3- Shuttering Formworks	Straight formwork for non-visual	V00123_686	m2	910.57	72.03 €	65,588.36 €

					finishing of concrete and formwork removal					
19	Act	1.04.01.04.04	1.4.3	5- Deshuttering of Formworks	Straight formwork for visual finishing of concrete and formwork removal	V00123_687	m2	1181.02	72.03 €	85,068.87 €
20	Act	1.04.01.04.05	1.4.4	6- Bitumen coating	Bitumen coating for concrete waterproofing (two layers)	V00123_688	m2	899.44	37.65 €	33,863.92 €
21	Act	1.04.01.04.06	1.4.5	2- Place PVC	PVC drain pipe slotted 160 mm	V00123_689	m	80.4	39.26 €	3,156.50 €
22	WBS_3	1.04.01.05	1.5	Part 4	Piers					
23	Act	1.04.01.05.01	1.5.1	3- Concrete Pouring	Concrete class C40/50 for piers	V00123_694	m3	176.92	407.18 €	72,038.29 €
24	Act	1.04.01.05.02	1.5.1.a	1- Reinforcement	Reinforcement steel bar B500	V00123_695	kg	20171.61	2.58 €	52,042.75 €
25	Act	1.04.01.05.03	1.5.2	4- Deshuttering of Form works	Curved formwork for visual finishing of concrete and	V00123_696	m2	392.4	132.07 €	51,824.27 €

					formwork removal					
26				2- Shuttering of Formorks						
27	WBS_3	1.04.01.06	1.6	Part 5	Deck					
28	Act	1.04.01.06.17	1.6.10.a	1 - Mixture Pouring of Bearing	R4 repair mixture (substrate bearing after equalization)	V00123_687	m3	0.58	2,389.00 €	1,385.62 €
29	Act	1.04.01.06.19	1.6.11.a		R4 repair mixture (substrate bearing after equalization)	V00123_688	m3	0.58	2,389.00 €	1,385.62 €
30	Act	1.04.01.06.21	1.6.12.a		R4 repair mixture (substrate bearing after equalization)	V00123_689	m3	1.15	2,389.00 €	2,747.35 €
31	Act	1.04.01.06.23	1.6.13.a		R4 repair mixture (substrate bearing after equalization)	V00123_690	m3	1.15	2,389.00 €	2,747.35 €
32	Act	1.04.01.06.16	1.6.10	2 - Bearing installation	Anti Up-Lift Free Spherical Bearing kN=7500	V00123_682	pcs	2	14,086.22 €	28,172.44 €

33	Act	1.04.01.06.18	1.6.11		Anti Up-Lift Guided Spherical Bearing kN=7500	V00123_683	pcs	2	14,086.22 €	28,172.44 €
34	Act	1.04.01.06.20	1.6.12		Anti Up-Lift Free Spherical Bearing kN=16000	V00123_684	pcs	4	14,086.22 €	56,344.88 €
35	Act	1.04.01.06.22	1.6.13		Anti Up-Lift Guided Spherical Bearing kN=16000	V00123_685	pcs	4	14,086.22 €	56,344.88 €
36	Act	1.04.01.06.09	1.6.6	3- scaffolding	Continuous falsework scaffolding The falsework is used in 1 phases/spans of the structure according to the table below The maximum volume of falsework used at the same time is 14.907,98 m3 (100%). The	V00123_691	m3	14907.98	30.31 €	451,860.87 €

					falsework is moved 0 times for a total of 1 phases. Falsework Span Volume (m3) 1 14.907,98 Total 14.907,98					
37	Act	1.04.01.06.10	1.6.6.a		Ground levelling under scaffolding	V00123_692	m2	1669.5	1.77 €	2,955.02 €
38	Act	1.04.01.06.11	1.6.6.b		Ballast for scaffolding support under precast concrete slabs (Crushed rock material mixed with sand 0-45)	V00123_693	m3	500.85	74.00 €	37,062.90 €

39	Act	1.04.01.06.12	1.6.6.c		Installation of precast concrete slabs for scaffolding suport The precast plates used for support the total area is 1.669,50 m2, but only 1.669,50 m2 (100%) are used at the same time, and then moved 0 times for a total of 1 phases. Falsework Span Area (m2) 1 1.669,50 Total 1.669,50	V00123_694	m2	417.38	25.41 €	10,605.63 €
40	Act	1.04.01.06.03	1.6.2	4- Shuttering of Formorks	Straight formwork for visual finishing of concrete and	V00123_695	m2	2064.69	72.03 €	148,719.62 €

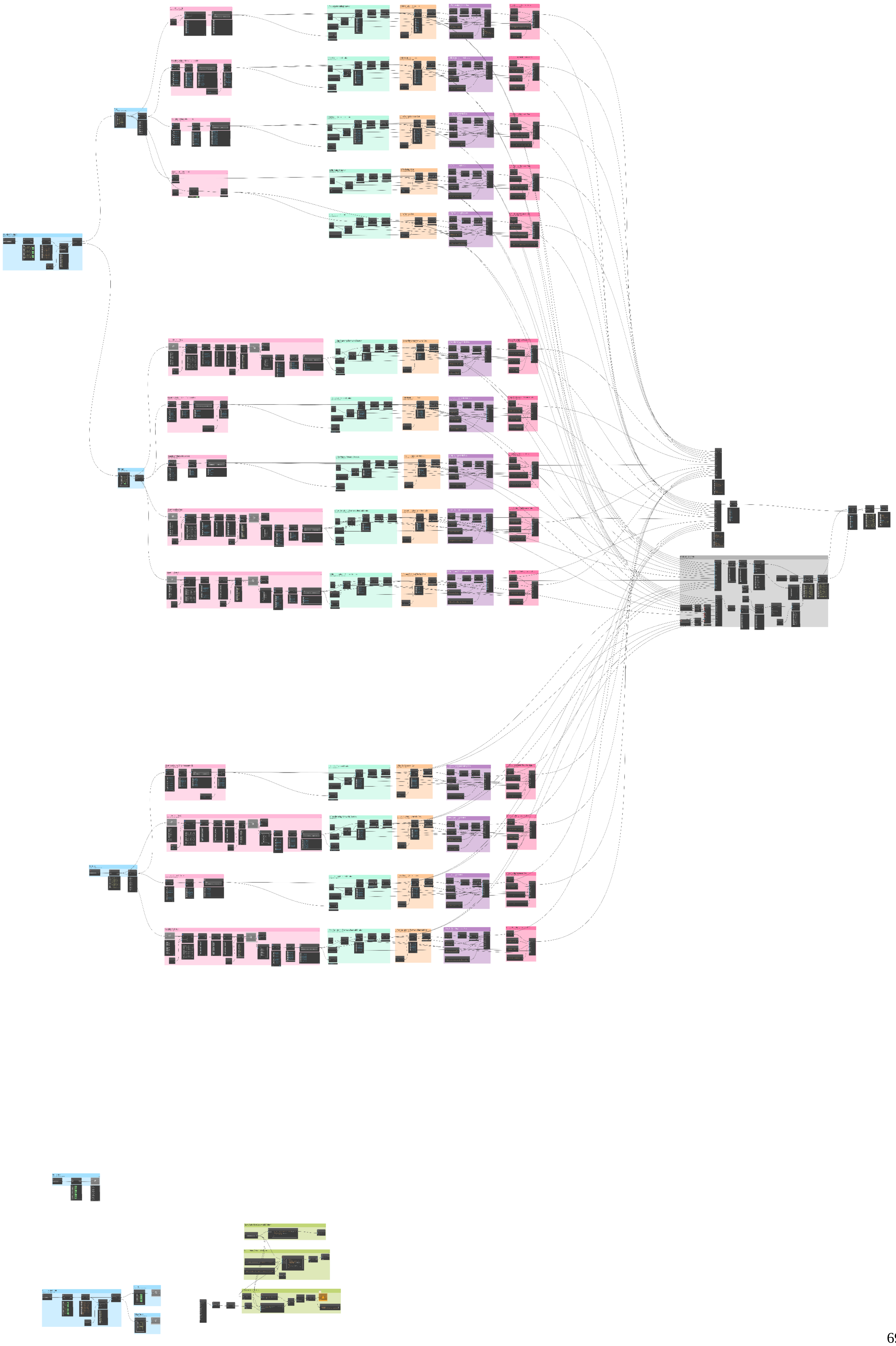
					formwork removal					
41	Act	1.04.01.06.02	1.6.1.a	5- Reinforcements	Reinforcement steel bar B500	V00123_696	kg	167912	2.58 €	433,212.96 €
42	Act	1.04.01.06.08.05	1.6.5.05		Reinforcement steel bar B500 (0,05 kg/kg)	V00123_697	kg	66	- €	- €
43	Act	1.04.01.06.07	1.6.4		Post-tensioned steel Y 1860 S7 in strands	V00123_698	kg	57740.5	6.68 €	385,706.54 €
44	Act	1.04.01.06.08	1.6.5	6- Anchoring	Post-tensioned steel 835/1030 MPA in bars	V00123_703	kg	1320	6.68 €	8,817.60 €
45	Act	1.04.01.06.01	1.6.1	8- Pouring	Concrete class C45/55 for deck	V00123_711	m3	1209.41	392.68 €	474,911.12 €
46				9- Deshuttering of Formorks		V00123_712				
47	Act	1.04.01.06.13	1.6.7	10- Isolation	Waterproofing on rail bridge deck. Elastomer bitumen membrane armed with geotextile (4mm) and protected with mineral granules	V00123_713	m2	1224.36	62.39 €	76,387.82 €
48	Act	1.04.01.06.15	1.6.9		Bitumen coating for	V00123_714	m2	1224.36	37.65 €	46,097.15 €

					concrete waterproofing (two layers)					
49	Act	1.04.01.06.14	1.6.8	11- Ashphalt	Asphalt protection (30 mm) above the deck waterproofing under the ballast	V00123_715	m2	1051	21.79 €	22,901.29 €
50	WBS_3	1.04.01.07	1.7	Part 6	Finishes and others					
51	Act	1.04.01.07.04	1.7.4	1 - Scuppers	Rail bridge deck scuppers	V00123_726	pcs	22	484.41 €	10,657.02 €
52	Act	1.04.01.07.05	1.7.5	2- Drainage Installation	GRP pipe 150 mm deck drainage	V00123_727	m	4.27	101.57 €	433.70 €
53	Act	1.04.01.07.06	1.7.6	2- Drainage Installation	GRP pipe 200 mm deck drainage	V00123_728	m	108.17	285.63 €	30,896.60 €
54	Act	1.04.01.07.07	1.7.7	2- Drainage Installation	GRP pipe 250 mm deck drainage	V00123_729	m	102.66	316.36 €	32,477.52 €
55	Act	1.04.01.07.08	1.7.8	2- Drainage Installation	GRP pipe 300 mm deck drainage	V00123_730	m	0	391.35 €	- €
56	Act	1.04.01.07.24	1.7.23	3 Stairs	Concrete stairs (C35/45), formwork and stainless steel fibers,	V00123_746	m	44.59	891.00 €	39,729.69 €

					supported by crushed limestone layer fr 4/16 h=100 mm wrapped in geotextil and steel railing, high 1,10 m					
57	Act	1.04.01.07.24.05	1.7.23.05	4- Railing	Steel railing (0,02t/m)	V00123_7465	m	272.24	517.89 €	140,990.37 €
58	Act	1.04.01.07.26	1.7.25	5- Doors	Doors at abutments as access for inspection. Made of steel, and protected against corrosion for at least C4 environment. Dimensions 1.00x1.90 m	V00123_748	pcs	1	1,008.52 €	1,008.52 €

Appendix 2. Dynamo Script for Automated Scheduling and Cost Control

High resolution image of the Dynamo script developed for this project. This script automates the scheduling and cost estimation processes relying on the 3D Revit model and design data. For clarity, only the essential nodes and workflow are highlighted, showcasing the integration with Power BI and other systems.



Appendix 3. Power BI Dashboard

A thorough perspective of project data, including Gantt charts, progress monitoring, and cost analysis, is offered via the interactive Power BI dashboard created as part of this thesis. Below is a link to the dashboard and a QR code for easy access.

Link:
https://app.powerbi.com/view?r=eyJrIjoiMDZkNmQ3OGEtNDBlMS00Y2NiLWE5NmMtZWNiMGJmNzFlODYwIiwidCI6ImZkMWJiNjgzLTZjODItNDI0NC04MzYxLWEwYjE2NDEwZGNhOSJ9&pageName=ReportSection98f60d70775aef788af2

QR Code: