Master of Science in Civil Engineering

Assessment of BIM Workflows for Construction Management

Case Study of Sevran Beaudottes Underground Station

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"Our deepest fear is not that we are inadequate. Our deepest fear is that we are powerful beyond measure. It is our light, not our darkness that most frightens us. You're playing small does not serve the world. There is nothing enlightened about shrinking so that other people won't feel insecure around you. We are all meant to shine, as children do. We were born to make manifest the glory of God that is within us. It's not just in some of us; it's in everyone. And as we let our own light shine, we unconsciously give other people permission to do the same. As we are liberated from our own fear, our presence automatically liberates others."

MARIANNE WILLIAMSON

'A RETURN TO LOVE'

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ABSTRACT

Building Information Modeling is a testament to the conviction that digitalization and automation are the new normal for the AEC (Architecture, Engineering, and Construction) industry. Laying out reliable solutions to realize integrated design, information-rich models, enhanced progressive-elaborated lifecycles of projects, and collaborative planning of construction projects. The conventional methods of the execution process in the construction industry have many limitations that lead to significant issues in the industry, such as lower productivity rates in contrast to other sectors and a high level of risk and uncertainty. However, BIM workflows for construction management became convenient project control and planning approaches. Over the years, 4D BIM planning and simulations played essential roles in the industry, providing the Business market with 3D visualized scheduling that scrutinizes the impact and limitations of the AEC industry's ordinary execution methods in its real-life context.

To provide the concerned audience with a framework for establishing project simulations and coordination objectives, Investigating, and detecting the capabilities and incompetence of building information modeling (BIM) software packages concerning 4D BIM planning and simulations can be instructional to all stakeholders concerned with construction management. This thesis presents a concise assessment of the current business market's most used and familiar workflow patterns. The methodology revolves around applying various workflow patterns on the BIM model of Sevran Beaudottes underground station. Aiming at identifying faults in data exchange and comparisons of tangible construction management functions by assessing workflows of exchanging the BIM model with coordination and 4D planning software packages, and Project scheduling programs. In addition to exploring the beneficial use of visual programming as an asset in creating simulation parameters. Concluding with a decision-making analysis, particularly the AHP (Analytical Hierarchical Process) method that considers the interoperability, the cost of BIM platform, and the time consumed to perform the workflow, and final-product collaborative sharing, as decision-making criteria. The results show that workflows typically depend on the BIM platform used and interoperability. Also, it discusses the critical role of visual programming in executing workflows. Consequently, it outlines a concrete framework for BIM practitioners.

However, experienced stakeholders suggest that productivity improvement depends not only on technological advancement (Industry 4.0) since the wrong manipulation could be counterproductive. At the same time, resistance to change represents an obstacle that must be faced in the adoption process. This is why it is crucial to understand the framework and how these workflows must be implemented. Thus, utilizing a proposed Autodesk Revit® Plug-in at the end of this research summarizes the thesis's key findings in the documentation that could hypothetically help the BIM practitioners to choose the best optimum workflow and reach the common goal of improving the AEC industry.

Keywords: BIM, 4D BIM, 5D BIM, 4D Planning, Assessment, Construction Management, Workflow, Decision Making, Collaboration, Simulation, Visualization, Lean Construction, IPD.

TABLE OF CONTENTS

ACRONYMS

- **3Ds:** File formats used by Autodesk 3ds Max® modeling, animation, and 3D rendering programs.
- **4D:** Fourth Dimension.
- **5D:** fifth Dimension.
- **AC:** Actual Cost.
- **AEC:** Architecture, Engineering, and construction.
- **AHP:** Analytical Hierarchy Process.
- **API:** Application Programming Interface.
- **BAC:** Budget at Completion Cost.
- **BIM:** Building Information Modelling.
- **BLS:** U.S Bureau of Labor Statistics.
- **BSI:** British Standards Institution.
- **CM:** Construction Management.
- **CPM:** Critical Path Method.
- **CSV:** comma-separated values (CSV) file is a delimited text file that uses a comma to separate values. Each line of the file is a data record.
- **DGN:** DGN is the name used for CAD file formats supported by Bentley® Systems, MicroStation and Intergraph's Interactive Graphics Design System CAD programs.
- **DMAIC:** Define, Measure, Analyze, Improve, and Control.
- **DWF:** Design Web Format (DWF) developed by Autodesk®.
- **DWG:** AutoCAD® Drawing File.
- **DXF:** AutoCAD® DXF (Drawing Interchange Format or Drawing Exchange Format).

- **EV:** Earned Value.
- **EVM:** Earned Value Management.
- **ICT:** Information Computer Technology.
- **IFC:** Industry Foundation Class.
- **IPD:** Integrated Project Delivery.
- **IR 4.0:** Industry 4.0.
- **LOD:** Level of Development.
- **MEP:** Mechanical, Electrical and Plumbing.
- **MPP:** extension associated with Microsoft Project® data file.
- **MPX:** Microsoft Project File Exchange Format.
- **NWC:** Navisworks® Cache file.
- **NWD:** Navisworks® Model file.
- **NWF:** Navisworks® File Set.
- **PRP:** Owned file used by Rational Rhapsody, a visual development program designed for system engineers and software developers.
- **PRW:** The file most commonly associated with Artlantis® Shader preview format files.
- **PSMS:** Project Schedule Management Software.
- **PV:** Planned Value.
- **R&D:** Research and Development.
- **RER B:** Réseau Express Régional (English: Regional Express Network).
- **RFP:** Request for Proposal.
- **SAT:** Standard ACIS Text, a SAT file is a 3D model saved in Spatial's ACIS solid modelling format.

- **SCPC:** Simulation, Coordination and Project Control Software.
- **SGP:** Société du Grand Paris.
- **SMEs**: Small and medium-sized enterprises
- **SPX**: Synchro Pro® project file.
- **SQL**: domain-specific language used in programming and designed for managing data held in a relational database management system
- **STP**: file extension is most likely a STEP 3D CAD file saved in the Standard for the Exchange of Product Data (STEP).
- **Timeliner:** a simulation tool associated with Autodesk Navisworks Manage® and Autodesk Navisworks Simulate®.
- **WBS:** Work Breakdown Structure.
- **XER:** file format used by the Oracle® Primavera P6 enterprise.
- **XLS:** Microsoft Excel Binary File format.
- **XML:** Extensible Markup Language (XML) is a markup language and file format.

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Background

Building Information Model: "is the digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onwards" [1]. In contrast, building information modeling is a process for generating building data to design, construct & operate the building and allowing all stakeholders to reach the same information about the building or Infrastructure through interoperability between technology platforms.

The construction industry has evolved from a traditional two-dimensional context in a three-dimensional environment in the construction industry space. A recent research paper conducted in China [2] demonstrates the standard functionality of BIM tools in the AEC industry. The inquiry results showed that 26.1% of BIM tools are used for model design, 24.5% for model checking, 16.1% for quantitative take-off, 13.6% for construction simulation, and 7.5% for construction management.

A similar survey [3] was conducted to study the use of BIM by the Architecture, Engineering and Construction Industry (AEC) in an educational facility project in the USA. Looking at five categories of stakeholders, namely architects, contractors, structural engineers, site and MEP engineers, the main applications of BIM have been 3D visualizations, documentation automation, and collision detection. Depending on the field of work of the discipline, architects and construction engineers believe that BIM provides value at the project design stage. In contrast, structural engineers and contractors have considered the benefits of using BIM both at the design stage and in the construction of projects. MEP engineers described that the use of BIM was of approximately the same value throughout the project. In this paper [4] the global use of BIM models has been studied.

In the AEC industry, many disciplines contribute to the project under consideration. Moreover, each discipline has its activities such as Geometry Development and 3D Design, Structural Analysis, Cost estimation, Planning, Facility management [5]. Moreover, working with different disciplines requires different software and file formats. Furthermore, the need to use more than single software is predominant. Nowadays, the most used file formats in the AEC are DXF, XML, SAT, STP, 3Ds, and IFC [6]. Furthermore, software packages often have limited support for data exchange. Therefore, an additional effort is required when data is exchanged between software packages due to incompatibilities. To avoid these incompatibilities, it is essential to describe the term "interoperability." The Institute of Electrical and Electronics Engineers (IEEE) defines interoperability as "the ability of two or more systems or components to exchange information and to use the information that has been exchanged" [7]. For a smooth workflow, "interoperability" is vital due to the properties of preventing recreation or reinput of data and facilitating the efficient use of information through workflow collaboration [8].

Researchers made investigations to assess the BIM use in construction project management, particularly RNF Sloot et al. [9] studied the effect of 4D BIM use on the procurement phase of a billion-euro canal lock expansion project in The Netherlands, where each of the competing contractors made use of 4D BIM tools to mitigate planning risks. The results demonstrate how using 4D BIM tools can significantly support the development of highly effective risk mitigation strategies.

Many studies have been made to develop approaches for construction quality management by using BIM, mobile computing & augmented reality (AR) to reduce the risk of construction quality management. Dong et al. [10] described a telematic workbench that facilitates the on-site crew to handheld mobile devices to collect defects and send them to the server to compare the visual information with the design model to judge the degree of acceptance.

Goals and Objectives

This master's thesis evaluates BIM applications for their expected usefulness for project management functions. It is intended to confirm the general theoretical requirements to be fulfilled by 4D BIM applications. Secondly, using the decision-making analysis of the available BIM packages that create the 4D BIM simulations effectively analyzes whether these tools fulfill the specified requirements.

Regardless of this primary goal, other goals are no less important. These are some of the research questions that this study also aims to answer finally:

- What are the problems facing the construction sector?
- What are some innovative concepts that can help solve these problems?
- What is BIM methodology and 4D / 5D technology?
- Is it possible to simulate the construction process before going to the construction site? If so, to what extent can the instruments chosen for this purpose be used?
- How can 4D BIM technology help in construction project management functions?
- Are the analyzed 4D BIM applications valid for construction and production management?

Thesis Organization

This thesis includes both theoretical and practical research. To develop the theoretical part, a comprehensive literature review is carried out based mainly on primary sources of information from scientific databases and other reliable electronic scientific journals and paper sources. This work consists of 5 different chapters (in addition to this introduction) to achieve the specific goals and objectives as shown below and in Figure (1):

- **Chapter One:** represents the literature review and completion of the theoretical part of the study.
- **Chapter Two:** represents a description of the case study.
- **Chapter Three:** In the practical part, there will be four types of workflows to achieve the 4D federated model, and the original BIM model is implemented in one of the available commercial BIM platforms: Autodesk Revit ® 2020. All other BIM platforms will be discussed later in the lifecycle of the thesis.
- **Chapter Four:** This is where the results of the methodological approach will be discussed and analyzed to inform the decision-making process on the optimal workflow model.
- **Chapter Five:** This is the stage in which the conclusions, opportunities and constraints that arise due to the previous evaluation are developed.

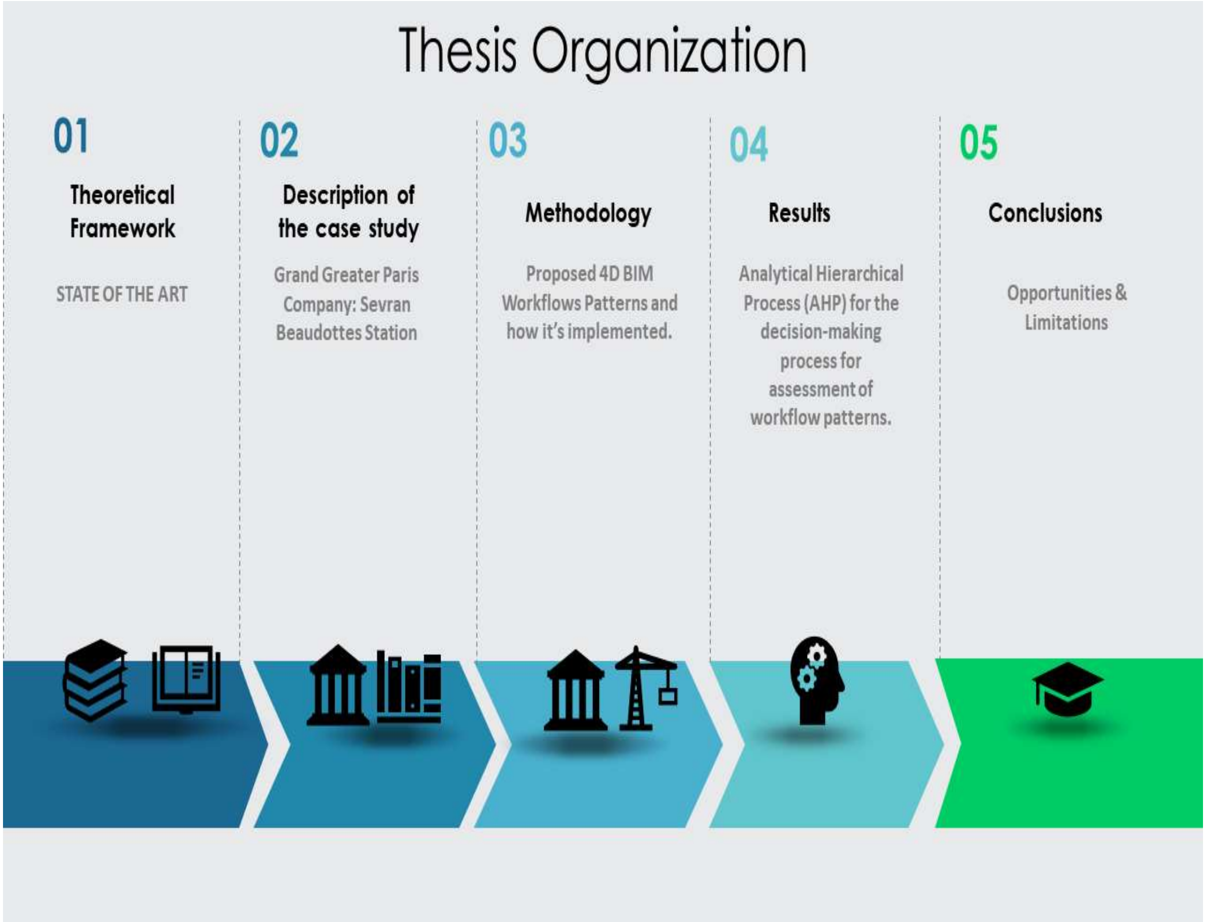


Figure 1 – Thesis Organization

Limitations and Assumptions

Since the thesis is based on a case study, it is assumed that the scheduled activities are done during the engineering phases, before the actual construction activities in real life, although the project has reached further phases during its life cycle.

Additionally, the BIM model is considerably large, and the scope of the project contains many work packages that could be simulated in a BIM context. However, it was interesting to visualize the simulation of temporary works construction and its contractions with on-site activities and traffic.

Since the research was carried out individually, one of the main limitations of the present study is that of not being able to simulate a collaborative environment in the practical part. However, due to the visual ingredient of the applications, it is assumed that they at least serve for a better understanding of processes when several people are dealing with them at a time.

CHAPTER ONE

1.1 State of the Art

1.1.1 The Construction Industry

The construction industry is vital for the economic growth of a country. It helps improve the quality of life of its citizens by providing necessary social and economic infrastructure such as roads, hospitals, schools, and other primary and improved facilities. Besides, the construction industry is a significant contributor to the economy of any country [12]. The nature of the sector is fragmented, unique, and complex and always faces chronic problems such as time overrun (70% of projects), cost overruns (average 14% of contract cost), and waste production (about 10% of the material cost). It is also considered one of the most significant pollutants to our environment. Construction faces a looming global crisis, a remarkable convergence of gross inefficiencies, and turbulent energy and raw materials consumption. While the specter of global warming has become a catalyst for a renewed interest in conserving energy and raw materials throughout the life cycle of buildings, the environmental challenge adds more urgency to a fundamental problem: the utter failure of the construction industry to keep pace with technological advancements and productivity gains for almost every other sector over the past 50 years [13].

The construction management has existed, necessarily, since the construction itself [11]. Separating construction management into one professional service contract began gaining attention in the 1960s. Over the years, CM has been seen as part of an engineer's skills and ancillary service that architects provide and a routine part of what building contractors do. The term "construction management" has been subject to confusion and conflicting claims. It has been used to describe the person, a person's job, the project delivery process, or the construction activity of any person working in the construction industry. Meanwhile, a new batch of creators was looking to sell CM as a professional service. The industry desired clarity, and the new emerging profession needed definition.

1.1.2 Major Current Characteristics of The Construction Industry

1.1.2.1 Global Trends in Supply and Demand

DK Smith et al. [13] stated in their book. It is estimated that around 40% of global raw materials are consumed through the construction of buildings. In the United States, the raw materials consumed by construction exceed 75% of the total. Alternatively, in other words, construction in the United States consumes three times more raw materials than all other economic and industrial activities combined. In 1900, every living American consumed two tons of raw materials per year. In 1995, the annual per capita figure had quintupled to 10 tons per capita. Regardless of global warming, simple economics dictates that we cannot maintain our current standard of living or the growing US population unless we reverse the steadily increasing consumption of raw materials. (See Figure 2). With construction accounting for three-quarters of the total, we cannot reverse the general trend in consumption unless we learn to build more with less.

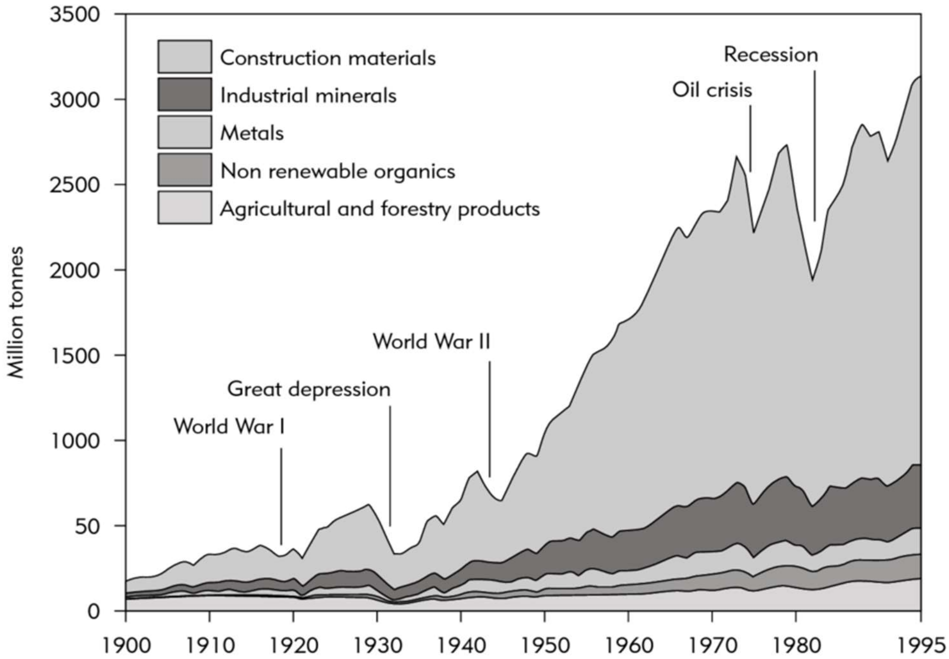


Figure 2- Raw Materials Consumption Chart (Source: U.S. Geological Survey.)

1.1.2.2 Construction Productivity Metrics

Paul Teicholz, professor in the Department of Civil and Environmental Engineering and founding director of Stanford University's Center for Integrated Facilities Engineering, developed the idea of a "construction worker productivity index" that combines BLS data for hours worked. Teicholz does not directly measure productivity; He measures productivity by comparing two unrelated points of macroeconomic data collected from two different US cabinet departments. Nevertheless, it may be the best available measure of construction industry productivity in the absence of more accurate data. Field with US Department of Commerce data on dollar contracts for new construction (see Figure 3). [13].

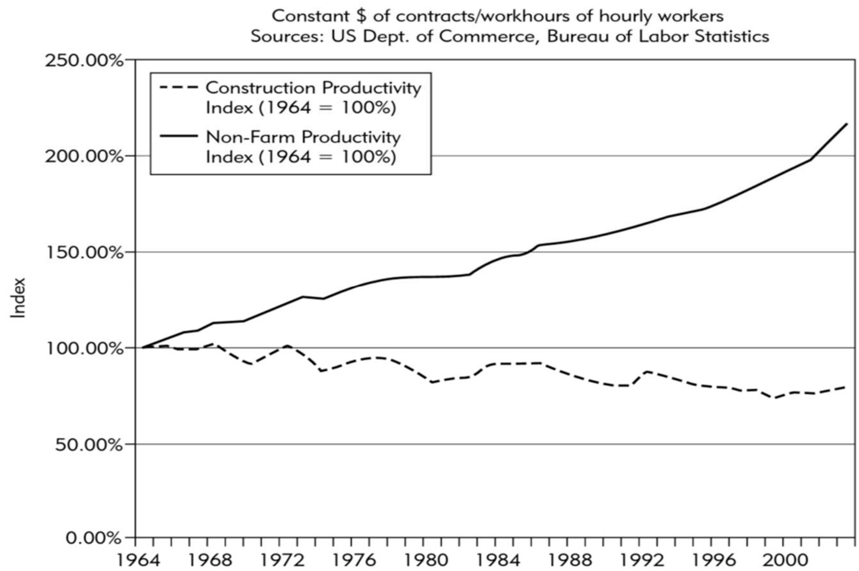


Figure 3 - Comparison of Labor Productivity Index between Construction and Non-Farm industries from 1964 to 2003 [14]

Among the essential general reasons that could cause this disruptive decline in productivity, the following facts have been suggested: (1) Low rate of use of Information and Communication Technology (ICT) in construction compared to other sectors, (2) Prevailing use of Design-Bid-Build (DBB) construction contracting techniques rather than a more collaborative approach and (iii) a large proportion of SMEs involved in the construction process which can hamper the adoption of new technology and investment in R&D [14].

1.1.3 Challenges in The Construction Industry

1.1.3.1 Time Overrun

Completing construction projects on time is an essential requirement. However, projects rarely seem to be completed on time [12]. This has become a global problem. A study showed that the Vietnamese government had recognized this issue as a major nuisance, especially with government-related funded projects [15]. In Nigeria, out of 3,407 projects, only 24 were completed on time, while 1,517 were delayed and 1,812 were abandoned [16]. Omoregie & Radford [15] reported that the minimum average percentage escalation period for projects in Nigeria was 188%. Similar research conducted in Bosnia and Herzegovina on 177 projects reported that the contractual finish date was not met in 51.40% of the projects. Al-Momani [17] surveyed 130 public projects in Jordan and found delays occurred in 106 (82%) projects. Frimpong et al. [18] found that 33 (70%) out of 47 projects in Ghana were delayed. While, in Saudi Arabia, 70% of projects faced time delays with an average time delay of 10% to 30% of the original duration of the project [19]. Endut et al. [20] studied the performance of 359 projects (301 new buildings and 58 renovations) in Malaysia. Of these, 301 are public, and 51 are private. The study found that only 18.2% of public sector projects and 29.45% of private-sector projects had a time deviation of 0% (no delay), while the average overrun rate for other projects was 49.71%. Delays can be due to one or more reasons, including problems with financing and paying for work done [21],[18], Poor contract management, changes in site conditions, material shortages, design changes, and weather conditions, among others. as an example, Yogeswaran et al. [22] examined 67 civil engineering projects in Hong Kong and found that at least 15-20% of the time exceeded was due to bad weather.

1.1.3.2 Cost Overrun

Cost is an important consideration throughout the project lifecycle. Unfortunately, most of the projects failed to get project done at the estimated cost. In addition to time overrun, cost overruns are also a severe problem in the construction sector. This is a significant problem in both developed and developing countries. The trend is most acute in developing countries, where these excesses sometimes exceed 100% of the expected cost [23]. A study by Omoregie & Radford [15], [24] says that the average minimum cost escalation rate for projects in Nigeria was 14 percent. Another study in Slovenia of 92 traffic structures built showed that 51% of contracted construction projects experienced price overruns [25]. While in Uganda, the north bypass project in Kampala experienced a cost overrun of more than 100% of the contract price.

Zujo et al [26] indicated that in Croatia, 81% of the 333 projects analyzed were experiencing price overruns, while in Bosnia and Herzegovina, a study of 177 structural projects found that the contracted price was not reached in 41.23% of the projects. In the UK construction sector, it has been found that nearly one-third of clients complain that their projects are generally over budget [22][27]. One comprehensive research conducted by Flyvbjerg [23][28] Regarding cost overruns in the global construction industry, 9 out of 10 projects were found to have exceeded costs. Typical excesses range from 50 to 100%.

1.1.3.3 Other Related Issues

Of course, the construction industry is fragmented and complex where it is site-specific, unique manufacturing, and resource-and software-driven. The industry has always faced serious and chronic problems such as overtime, cost overruns, waste generation, negative environmental impacts, and excessive consumption of resources [12].

1.1.3.4 Construction Waste

Waste is another major problem in construction projects. Waste directly impacts productivity, material loss, and project completion time, resulting in a significant loss of revenue. Forsberg et al. [29] claimed that the amount of waste contributes around 30-35% to the production cost of the project. The number of building materials wasted on the site is relatively high and corresponds to 9% of the weight of the materials purchased [36]. They studied the material waste generated on a Dutch construction project and found that the average waste per house was 6,860 kg, which consisted of 4,480 kg of construction debris and 2,380 kg of other types of solid waste.

1.1.3.5 Excessive Resource Consumption

The built environment has significant effects on resources accounting for one-sixth of the world's freshwater withdrawals, a quarter of timber harvests, and two-fifths of materials and energy flows. Facilities also have impact zones outside their immediate site, affecting community watersheds, air quality, and transportation patterns [30]. Buildings constructed without due consideration to energy, environmental impact, and conservation of natural resources will result in harmful waste that affects our environmental integrity [31].

1.1.3.6 Threat to Environment

The built environment is the least environmentally friendly human activity because it consumes many natural resources and pollutants. The environmental impacts of the AEC industry are significant and easily recognizable [30]. Most people do not take environmental protection seriously on construction sites. They assume the construction site is just a temporary arrangement that will last between two and three years. The AEC Industry is one of the primary sources of air pollutants in urban areas [32]. The emission of carbon dioxide from buildings has contributed to global warming and the change in extreme weather conditions worldwide. Timber harvesting leads to the loss of natural forests. Other impacts of building a new building include mining to provide aggregate, cement production, waste in water, and the extensive use of toxic chemicals in the materials [12].

1.1.3.7 Mitigation measures for these issues

Once the situation in the construction sector has been briefly presented, it is time to consider how to find a solution to the mentioned problems. This review will present risk management practices, the impact of manufacturing, ICT, and innovative concepts such as Integrated Project Delivery (IPD) and lean construction. Finally, the concepts of Building Information Modelling (BIM) and 4D technology should be developed, first separately and finally as a group to deliver the 4D/5D BIM environment, which is the focus of this study.

1.1.4 Project Management practices

According to Nwachukwu and Nzotta [33], Poor construction project performance is regressive in most developing economies. It can be attributed to the misuse of project management best practices, project performance metrics, and critical success factors that make up the multiple factors affecting construction projects. By extension, this includes a poor understanding of the relationships between these multiple entities that may not seem obvious. Also, Chen et al. [34] pointed out that most of these variables are interrelated and influence each other, making it necessary to understand the dynamics of these relationships for effective management, resource allocation, and control.

To properly define the success of a project, a set of criteria or principles is necessary to act as criteria that guide or govern the success of the project. These criteria are referred to as project success criteria or project performance metrics. According to Atkinson [35], The most traditional criterion for determining project success is the "iron triangle" that defines project success in terms of cost, time, and performance quality. This standards framework has proven limited because it does not focus on a wide range of project stakeholders [36]. It only provides a measure of the result of the project that relates to the efficiency of the project. Another way to determine project success is measuring success concerning cost per unit, construction and delivery speed, program and cost growth, and other quality metrics [37]. Other areas to expect project success include safety, health, participant satisfaction, environmental performance [38] , and project implementation in relation to time, cost, quality, and safety. [39], Design, modification, rework, safety, time, and cost reports [40], and a good understanding of customer needs resulting in customer satisfaction [41].

The project management institute (PMI) defines project management in their project management guide [42] "project management is the application of knowledge, skills, tools, and techniques to project activities to meet the expectation of project stakeholders." To achieve this, a good understanding of the dynamics of project management practices is required by project management personnel. The world is dynamic and driven by technology, hence the need for project managers to be up to date on contemporary issues in project management. Developments in management science have developed the concept of project management into a complete system of knowledge [38] Which makes it essential for effective project management especially in the construction sector [43].

1.1.4.1 Delay Mitigations

The society we live in is experiencing an increase in the allocation of responsibility. This increase is also evident in the construction sector [44]. Between 1973 and 1980, there was a 100% increase in housing-related lawsuits [45]. It is well known that in construction disputes, delays are most often the cause [46]. In the past, delays in completing construction projects were accepted in the construction industry. Today, with limited customer budgets, delays can become a critical cost component. As a result, construction delays often end in building compensation claims (a recent study by Bordoli and Baldwin [47] found that 52% of construction projects in the UK end in compensation claims of some kind).

Construction delays occur for various reasons and can be caused by any participant involved in a construction project. Delays must be correctly classified when trying to mitigate their effects or attribute responsibility. This is because the techniques used vary according to the delay's circumstances. Generally, there are two main types of delays. Here they are:

- Excusable.
- Not Excusable.

Unexplained delays can be classified as "compensable" or "non-compensable." It is also helpful to identify "critical" and "non-critical" delays. Time-based construction complaints can have a disastrous effect on construction projects. A quick examination of the preceding claims indicates particularly severe financial consequences on the claimant's part, and it is also known that the claims destroy the profitability of the entire business for the customer [45]. For these reasons, effective control systems must be used to avoid or minimize the effects of the resulting delays and disputes before a full claim status is reached.

Control systems that should be used to avoid or mitigate time-based complaints are already widely used by project managers in the construction industry. The central control system used by project managers is the construction program. Regardless of the form they take, construction schedules are a vital part of managing the construction process. They provide the general planning, monitoring, and control mechanism by which the project team can ensure the achievement of the client's goal. The significance of construction programs is of particular importance when applied to the need to measure the impact of construction delays [48].

1.1.4.2 Earned Value Management (EVM)

Earned value management is used for monitoring and control of projects. EVM is a project management methodology used in projects to see how our projects are progressing according to the plan created prior to the implementation of the project [49], [50]. The main input elements are planned value (PV), realized value (EV), actual cost (AC), and budget to be completed (BAC). From the essential elements/inputs, variances, performance indicators, and forecasting indicators in timing and costs can be found. Therefore, once the EVM data has been analyzed, it is possible to know whether a project is on schedule, late or late [51], [52]. Primavera P6® can perform Earned Value Analysis calculations for the projects. Primavera is a project and portfolio management software that provides project schedule, cost planning, and control [53].

1.1.4.3 Claims & Disputes Management

Construction complaints and disputes are increasing and have become a burden on the construction sector [54]. Even with a more expert understanding of the construction contract and a more reasonable risk distribution system, complaints will continue to pose problems if handled inadequately in practice [55]. It is crucial that contractors file complaints according to the contract's steps, provide details on additional costs and time, and provide satisfactory evidence. In addition, project owners must follow a comprehensive procedure for monitoring and handling complaints submitted by contractors.

Complaint management is the process of hiring and coordinating resources to advance a complaint from identification and analysis to preparation and submission before initiating negotiation and settlement [56]. The main objective of the claims management process is to solve some problems efficiently and effectively. Avoiding litigation and arbitration in settlement of complaints is a good practice that successful contractors should consider [57].

Understanding the causes of construction complaints is the first step to avoiding them. According to the contractors, “post-tender design changes” are the main reason for the claims. The second reason is “the project was executed in inappropriately short periods with insufficient on-site investigations, design work, tenders and procurement documentation,” The third was due to “inadequate definition and / or determination of the exact scope of the contract.” Both owners and contractors must do their best to ensure proper administration and management of the project, including proper and adequate staffing and coordination of the project and trade. It is crucial that each entity understands its duties and obligations under the contract and can fulfill them as stipulated in the contract [58].

1.1.4.4 Lean Construction

According to the National Standards Institute's Lean Network and Technology Manufacturing Expansion Partnership, Lean is a systematic approach to waste minimization, constantly improving and maintaining production rate according to customer needs [59]. Many examples are used to develop the concept of lean application in practical work, whether in the manufacturing or construction industry, such as Toyota production system, Ford production, soft Japanese construction, etc. The purpose of lean manufacturing is to design and manufacture the product according to customer requirements and support the improvement of the efficiency of the production system [60]. According to the [61], Lean Manufacturing is a multi-standard collaborative approach to maximize benefits or produce minimum waste. Lean construction is an innovation in the construction industry because it is different from the typical traditional approach. When there is a change in a particular provision, there is always a withdrawal from its use as an innovation [62]. Following are the leading measures taken into consideration for the Lean approach:

- Waste minimization.
- Just-in-time approach.
- Value based approach.
- Continuous improvement.
- Quality Management System.
- Agility towards required change.

1.1.5 Industrial Revolution 4.0 (ICT)

New technologies are developing very rapidly. We live in an era of change [63], not measured in years, but in days or even hours as the digital revolution advances all aspects of life forward at an even faster pace [64] . For example, the development time of Industry 1.0 lasted several centuries; The development from phase 1.0 to phase 2.0 took nearly 100 years. It took 70 years to transit to Industry 3.0, and 30-40 years after the third revolution, the German federal government introduced Industry 4.0 in 2011 [65], [66]. It is expected that version 5.0 will be adopted soon [67]. Japan is already planning to develop "Society 5.0" by taking full advantage of technological innovations, such as the Internet of Things (IoT), artificial intelligence (AI), and big data of the fourth industrial revolution [90]. The construction sector has also benefited from this development, giving rise to Building 4.0 [68]. The construction industry has also taken advantage of this development, giving the term Construction 4.0 [69]. Therefore, construction could transform into a technology-driven industry by adopting ideas and technologies of Industry 4.0 [70].

Industry 4.0 is a phase of the industrial revolution associated with digital technologies. Hamelink [71] as cited from [72] described digital technologies as advanced information and communication technologies that allow information to be acquired, stored, processed, visualized, communicated, combined, and collaborated. There are stunning examples of modern digital technologies: cloud storage, augmented reality, virtual reality, digital twin, artificial intelligence, electronic, physical systems, big data, blockchain, laser scanners, robotics and automation, sensors, IoT, actuators, sensors, etc. for that [69] . A study by Perrier et al. shows that existing 4.0 tools are mainly used to improve, locate, and simulate actions. At the same time, technologies can have different applications and can be associated with different project management processes at different stages of the project life cycle. This agrees with Universal 4.0 Technologies [73].

Construction 4.0 is a new concept, but it gets much attention, so many researchers have defined it. A literature review revealed that definitions are vague and mainly adopt broader concepts than Industry 4.0, a precursor to Building 4.0 [69]. Before the emergence of the term Construction 4.0, researchers attempted to define the concept of Industry 4.0 from a construction perspective. Oesterreich and Teuteberg describe it as a diverse set of interdisciplinary technologies that digitize, automate, and integrate the building process along the value chain [70]. One of the proposed classifications, which has been developed to characterize the concept of Building 4.0, is based on two pillars: digitization of the construction sector and industrialization of building processes [69],[74].

There is a void between Industry 4.0 and the construction industry, and it will continue to grow if there is low technology adoption and a lack of innovative processes in construction [66]. More competent resources are required for modern construction, but smart construction is still developing [75]. Going digital is necessary to develop the construction industry for increasing its productivity [72].

Construction 4.0 is a traditional building that has been updated with technological innovations and a new way of perceiving and understanding the building in light of innovation and increased productivity [69] [76]. For example, the technologies adopted by the construction sector by Industry 4.0 are the Internet of Things, simulation, autonomous systems, robotics, augmented reality, additive manufacturing, and big data. The technology that the manufacturer has not adopted is cyber security. On the other hand, there are specific applications only for construction, namely Building Information Modelling (BIM), 3D Building Printing, or Building Component Modules. Therefore, the construction sector has also adapted the concept of Industry 4.0 within the sector [66].

BIM is one of the widely researched smart systems [77]. Oesterreich and Teuteberg recognized that Building Information Modelling (BIM) is considered one of the most important technologies in construction and plays a crucial role in digitizing the building environment [70]. BIM saves time, costs, and sustainable planning, reduces waste, and improves project performance. Contractors can leverage the digital data provided by implementing BIM early in the project. In the construction phase, the compatible use of BIM technology and digital processing provides advanced management, well-organized project formation, and accurate information distribution [104]– [106].

The adoption of Industry 4.0 technologies can bring economic benefits to improve efficiency, productivity, quality, and collaboration, help improve sustainability and safety and restore the bad image of the construction sector. However, to achieve these benefits, companies must contend with higher implementation costs, process and organizational changes, or a growing need for data security [70]. Meanwhile, the application of emerging information technology for the development of intelligent building systems requires improving the work efficiency of staff, improving construction efficiency, obtaining, and updating information promptly and simple, better management of smart construction sites, optimal allocation of machinery and material resources, and better exchange of information from multiple sources [75].

Alaloul et al. 2020 [81] conducted a comprehensive analysis to identify the main problems delaying the implementation of IR 4.0 related technologies in the construction sector and the opportunities that have been realized in the long term. Then a questionnaire was conducted, in which the collected data were analyzed. This study shows that the critical factors influencing the success of the implementation are social and technical. The study was conducted applying the principles of the Six Sigma Quality Initiative, DMAIC. DMAIC (Define, Measure, Analyze, Improve, and Control) is a data-driven development process to enhance strategic business plans using a development framework for improvements, not just Six Sigma. The conditions of each phase are identified and reviewed frequently before moving on to the next phase as the best results are obtained with this methodology when the application process is flexible to meet requests by eliminating unnecessary procedures even if the framework is considered rigid. The key factors affecting the successful implementation of IR 4.0 in the construction sector were identified and linked to the analyzed data. Survey questionnaires were distributed to various construction companies to obtain the views of construction professionals. The questionnaires were distributed via e-mail, and hard copies produced 100 of 160 valid responses and were statistically evaluated. Figure 4 presents a profile of the respondents. From table 1, 53% of the interviewees are not aware of the application of IR 4.0 technology in the construction sector, while 34% are revealed in some part of their work experience. However, only 13% of the remaining respondents are unsure of the technology used listed as IR 4.0 related technology. Distribution of the defendant's status within their companies. 32% of respondents held executive positions, 33% were engineers, and 6% were surveyors. The remaining 29% of the respondents were people in other jobs.

Table 1
Respondents' profile.

S. No.	Variable	Category	Frequency	Percentage (%)
1	Exposure to IR 4.0 Technology	Yes	34	34
		No	13	13
		Maybe	53	53
2	Age Group	20–29	23	23
		30–39	19	19
		40–49	26	26
		>50	32	32
3	Years of Experience	<5 years	24	24
		5–10 years	8	8
		11–15 years	15	15
		>15 years	53	53
4	Position in the Company	Project Director/Manager	32	32
		Design Engineer	9	9
		Project Site Engineer	24	24
		Quantity Surveyor	6	6
		Others	29	29
5	Company Profile	Developer	15	15
		Consultant	13	13
		Contractor	41	41
		Client	11	11
		Others	20	20

Figure 4 -Respondents Profile of the survey [78]

The scaling process of the DMAIC architecture was validated by defining techniques and concepts related to IR 4.0. 47% of participants were exposed to IR 4.0 related technologies. The most common technologies used are social media and Building Information Modelling (BIM), as shown in Figure 5.

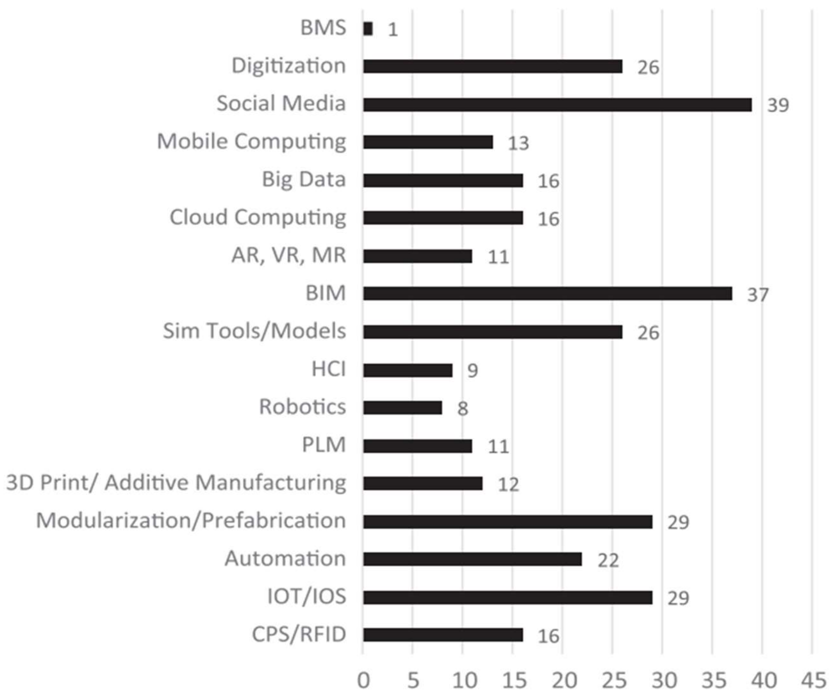


Figure 5 - Industry 4.0 related technologies & concepts. [78]

1.1.6 Building Information Modelling (BIM)

1.1.6.1 BIM impacts and outcomes

The BIM Industry Working Group [82] indicates substantial organizational impacts through BIM implementation for all stages of the construction process. Arayici et al. [83] indicate that stakeholder collaboration widens the organization's boundaries, thereby improving the performance of the project organization during the design and construction process. This collaboration is further supported by Kymmell [84] and BSI [85]. However, other effects highlighted by Howard and Björk [86] demonstrates the need to implement BIM to modify business processes beyond the simple promotion technique. Implementation of BIM can affect all processes in the project organization and, therefore, cannot be treated in isolation as a software tool. Hence it can be defined as an associated process rather than a simple technology, and both approaches require that BIM be managed holistically. Holzer [87] concludes that BIM is a more accurate working method. Through progression, BIM will reduce waste (materials, resources & cost) through improved designs and construction processes [88]. Nawari [89] attributes one of the successes of BIM to creating more sustainable communities. Another critical aspect leading to improved accuracy, design, and construction is 3D visualization as identified by BIM hub [90] and Bentley [91]. However, for a successful implementation of BIM operations, all construction team members need the security of the internal and external confidential data of the BIM model. The BIM model can be part of an external network [117]. However, this can lead to legal problems. The construction contract needs to address legal issues to reduce this significant risk [92]– [94]. The cost of implementing BIM in terms of resources and training is a significant obstacle in the construction sector [95]– [100]. Despite the high cost of implementation, BIM will ultimately be driven by clients [95], [97]. Horeetal.[101] suggests that if adoption becomes a requirement, the government should support training to facilitate implementation. The size of organizations implementing BIM is an essential factor because it is easier to implement BIM within the customer or on the supply side than SMEs [83] ; however, it may be out of reach of some SMEs due to its cost [102]. This study ranked the various aspects of BIM adoption in order of importance [103] .

1.1.6.2 BIM application across the project lifecycle

The project can be seen differently depending on its theory/contexts of the system [104]. For instance, [105] project is “a temporary effort made to create a unique product, service, or result.” Temporary refers to the characteristic of a project that has a beginning and an end. On the other hand, unique means that the project involves doing something that has not been done before. There may be a similar project to the previous one, but there are unique projects in terms of resources, business environment, etc. [106]. The project life cycle consists of four phases: Initiation, Planning/Design, Execution, Control, and Closing. Each stage of the project life cycle is a critical factor that will determine the project's success.

Eadie et al. 2013 [103] The project life cycle is defined as including project initiation, feasibility, design, construction, delivery, operation, maintenance, and final demolition. BIM is cited as being functional and provides benefits at these stages. However, the frequency of use by organizations at each stage of the project lifecycle is omitted from the literature.

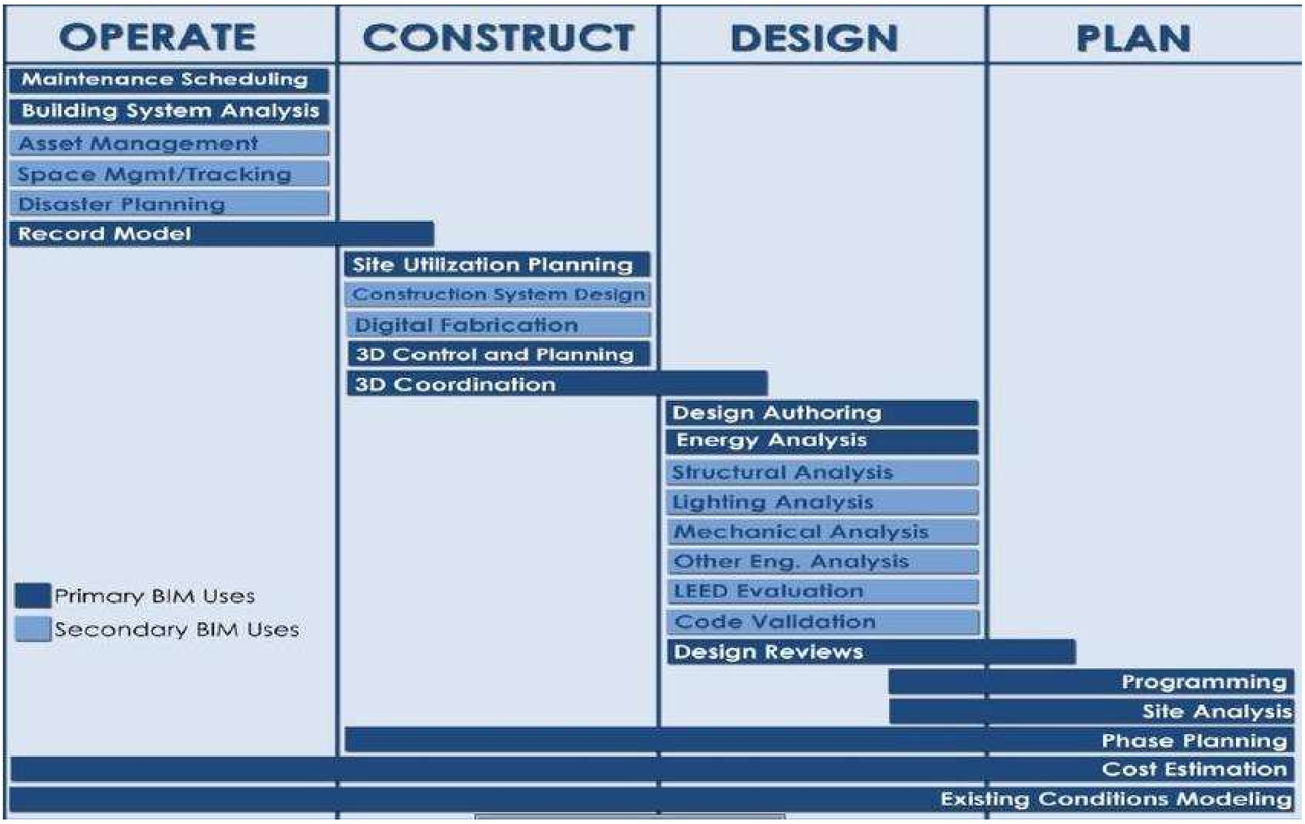


Figure 6 - BIM Uses Throughout a Building Lifecycle [107]

1.1.6.3 BIM Maturity Levels

The maturity model is designed to ensure that expected skill levels, support criteria and guidance notes (not shown in this graph) are clearly articulated and relate to each other and how they can be applied to projects and contracts in the industry[108] .

The purpose of defining levels 0 through 3 is to categorize the types of technical and collaborative work to allow a brief description and understanding of the processes, tools, and techniques that will be used. In essence, it is an attempt to demystify the term “BIM” by defining it in a clear and transparent way to the supply chain and allowing the customer to understand precisely what the supply chain has to offer [108]. Producing this maturity indicator recognizes that different construction clients have their own offering. Organizations currently have varying levels of experience with their BIM approaches, and it is a systematic progression of “learning” over a period [108].

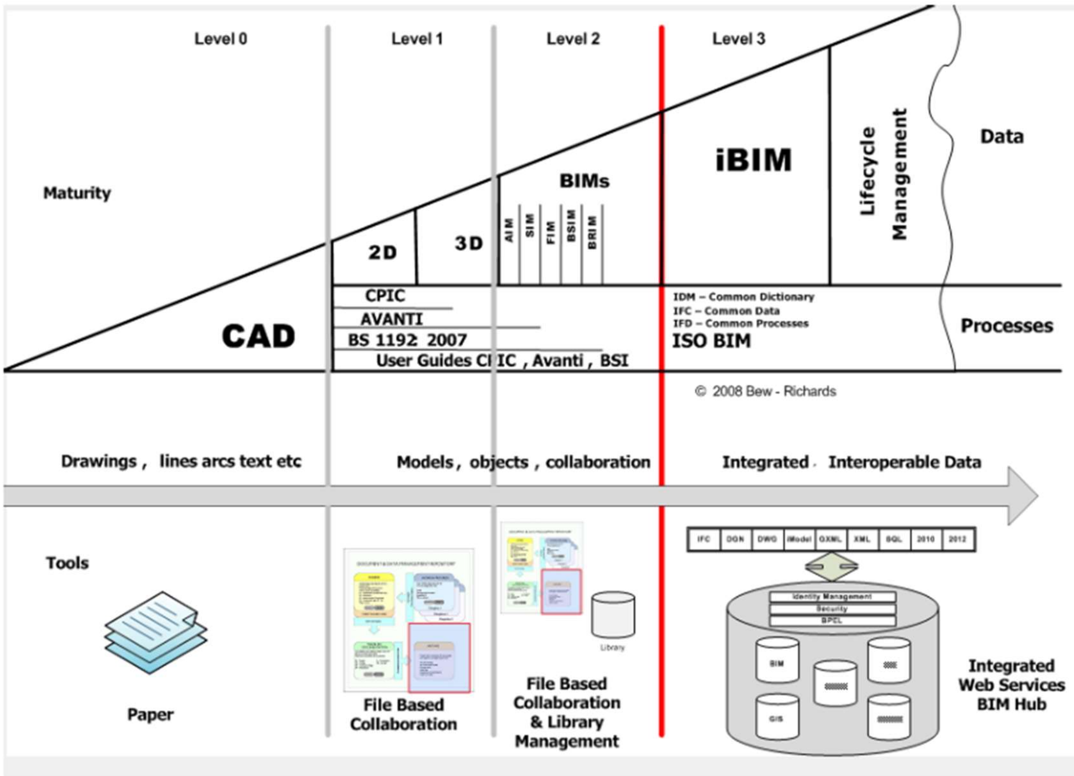


Figure 7 - BIM maturity levels [108]

Level Definitions

Level 0: Unmanaged CAD in 2D, with paper (or electronic paper) as the most likely data exchange mechanism.

Level 1: CAD managed in 2D, or 3D format using BS1192: 2007 with a collaboration tool that provides a shared data environment and possibly some standard data structures and formats. Business data is managed by independent financial management and cost management packages without integration.

Level 2: Managed 3D environment saved in separately organized "BIM" tools with accompanying data. A management system manages commercial data. An integration based on proprietary interfaces or dedicated middleware can be considered "pBIM" (proprietary). The approach may utilize 4D programmed data and 5D cost elements, and operational feed systems.

Level 3: Open process and data integration enabled by "web services" compliant with the emerging IFC / IFD standards, managed by a collaborative model server. It could be regarded as iBIM or integrated BIM potentially employing concurrent engineering processes.

Secondly, the concept of Level of Development Specification (LOD) is a reference that allows professionals in the architecture and construction sector (AEC) to define and express the content and reliability of BIM in the different phases of the design with a high level of clarity. And construction process [109]. It allows authors to specify what is reliable in their models and allows downstream users to clearly understand the usability and limitations of the models they receive [109]. According to the figure, the data-level descriptions define the minimum specific content requirements and related authorized uses of each element of the model in five detailed incremental levels of completeness. In LOD100 and LOD200, the model element is represented by non-detailed geometry [110]. In the LOD300, a model element is graphed as a specific system, object, or assembly in terms of quantity, size, shape, position, and orientation [110]. On the LOD400, the model element contains more details, manufacturing, assembly, and installation information [110]. Finally, the LOD500 element is a validated representation of shape, position, quantity, and orientation [110].

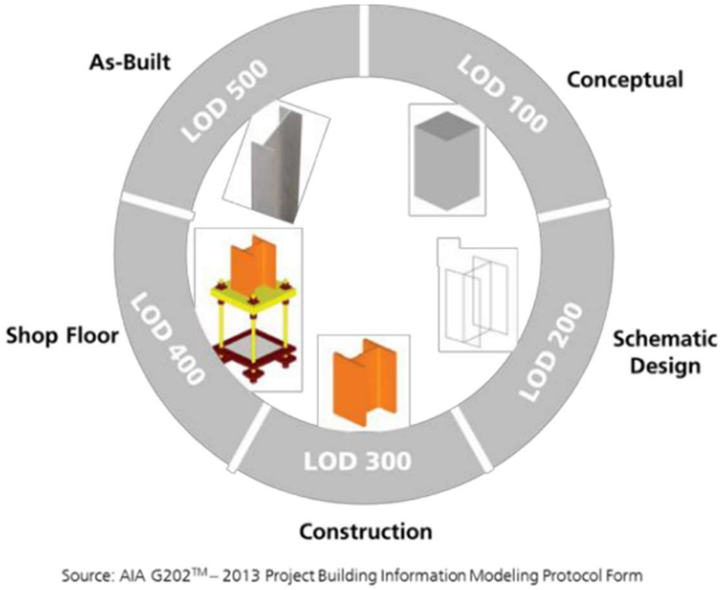


Figure 8 – Project Building Information Modelling Protocol Form [110]

Aside from maturity and LOD levels, introducing additional functionality into the BIM methodology leads to what are generally known as BIM dimensions that indicate areas of potential implementation. Far from being just a 3D modelling tool, BIM is rather a multidimensional approach (nD) that integrates many business functions into the information management and retention process [111]. This is achieved in part by integrating graphical and non-graphical data. In this way 4D, 5D, 6D ..., nD take place next to the BIM acronym: 4D BIM for time management, 5D BIM for cost management, etc.

Finally, to represent the hierarchy, applications can also be inserted in: (1) BIM environment, (2) BIM platforms and (3) BIM tools [112]. The first refers to the integration of different BIM platforms and tools within an organization to improve data management and other business functions in systems such as BIM servers. The second is primarily concerned with design applications where the original data model is created. The output from BIM platforms is usually exported to BIM tools, which are the third type of application where specific tasks can be performed.

1.1.6.4 BIM Implementation Around the World

BIM is by no means the same all over the world. There are specific countries where this concept was introduced a few years ago and many more are just starting to join. Furthermore, "the level of awareness, knowledge and interest within countries varies from discipline to discipline and from client to client" [113] . Another fact is that not all companies implement BIM with the same level of maturity, especially in those countries at an early stage of adoption of this methodology [114].

There are some countries like the United States, Canada, Australia, Singapore, United Kingdom and Nordic countries (Finland, Denmark, Norway, and Sweden) with notable levels of BIM implementation. Good evidence of this are the numerous standardization guidelines available on the Internet, as well as the publication of reports to reflect the current situation in these countries [114].

According to a 2012 Smart Market report, the overall adoption of BIM by the North American construction industry (United States and Canada) increased from 28% in 2007 to 71% in 2012. Looking at the pro's numbers, another interesting fact that reflects this relationship is that the contractors outperformed the architects, which is a clear sign of realizing the benefits on their part. Engineers are the group with the lowest score but the highest growth since 2009. Moreover, as mentioned in the previous pages, the size of the companies is also important: 91% of large companies have adopted BIM in North America versus only 49% of small businesses 'Figure 2.13'. The adoption level of BIM is also important, i.e., the number of projects in which it has been used "Fig. 2.14 ". Owners are the leaders in the lightweight user group, but this fact is set to change by 2014. As for hiring 4D BIM contractors, the report notes that although it has already been adopted by some large companies, it is still in the development phase initial phases [115].

Another recent UK national BIM report revealed the status of implementation by 2013 based on a comprehensive survey. There is still talk of "awareness", which means that the use of BIM is not as widespread as in the United States. Only 6% of respondents were unfamiliar with BIM in the UK, but only 39% knew and used BIM and the remaining 54% were aware of it. In addition, the term CAD has a large presence in the report because a significant proportion of companies have not yet adopted BIM, as well as the fact that many of them continue to confuse it with 3D. In fact, even though the use of 3D (non-BIM) is on the rise, among all the operators in the sector who took part in the survey, 25% admitted that they still use only 2D technology. Professionals were asked about their confidence in BIM skills and only 35% of respondents were confident in this, while 40% were not and the remaining 25% were somewhere in between [116].

The UK case is particularly interesting in Europe as by 2016 it will be mandatory that all public projects have been completed with the implementation of BIM at least at "Level 2" [117]. This is a clear signal of the measures taken by governments and the importance of introducing new policies for countries to adopt BIM models.

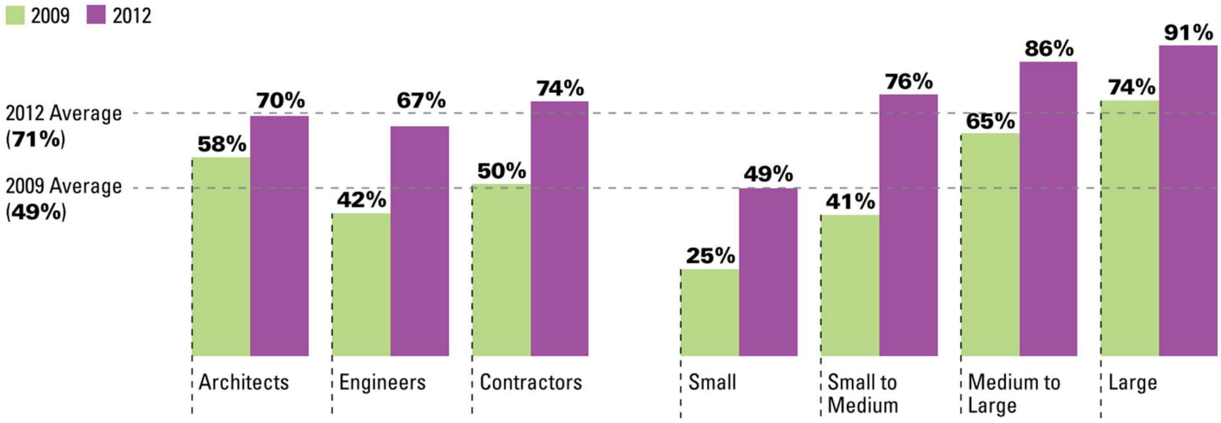


Figure 9 - Comparison between 2009 and 2012 BIM implementation in North America by player and firm size [115].

1.1.6.5 Interoperability

With a focus on BIM systems, there have been major attempts to develop standards to create interoperability between these systems to make them compatible with each other. This means that for a model to be compatible with models generated by other software tools, it is necessary that they all be translatable into a file format so that all object information can be transmitted correctly [118]. In general, interoperability issues in BIM projects are mostly resolved in a standardized file exchange format, Industry Foundation Classes (IFC), first identified in 1996 by the International Association for Interoperability (IAI) and developed by buildSMART International [119]. As explained on the buildSMART website, the definition of IFC is "In general, the IFC, or 'Industry Foundation Categories', is a standardized numerical description of the built environment, including civilian buildings and infrastructure. It is an open international standard (ISO 16739-1: 2018) is intended to be vendor independent, or neutral, and usable on a wide variety of devices, software platforms, and interfaces for many different use cases" [120]. IFC indicates 'how' information should be one of the general and universally accepted standards (ISO/PAS 16739:2005) for information exchange in the AEC sector [119]. IFC uses the ISO-STEP EXPRESS language to recognize its models. Objects defined in the IFC data model that allow "smart" information exchange are included in BIM [118].

1.1.6.6 BIM Design Platforms

The BIM working methodology requires the adoption of design software platforms. Some of these applications available so far are listed in Table 1 classified by company:

COMPANY	BIM PLATFORM	LOGO
Autodesk	Revit (Architecture, Structures, MEP) *Last Version: Revit 2014*	
Graphisoft	ArchiCAD *Last Version: ArchiCAD17*	
Bentley	Bentley Architecture *Last Version: Bentley Architecture V8i*	
Nemetschek	Allplan Architecture *Last Version: Allplan Architecture 2013*	
Gehry Technologies	Digital Project *Last Version: Digital Project V1, R5*	
Tekla	Tekla Structures* *Last Version: Tekla Structures 19*	

*Only for the creation of structural BIM models

Table 1 - Main BIM design platforms and last versions available in the market [119]

1.1.7 4D BIM

1.1.7.1 Definition

4D modelling combines a 3D model with time (via a schedule). These models combine building elements and building activities to visualize building processes over time; 3D objects are related to specific activities, which can appear or disappear at specific times according to the schedule. Elements of a permanent building to be constructed appear during the construction period and remain throughout the remainder of the planning. Temporary objects such as construction supports appear only for a specified duration, and then disappear [121].

The visualization provided by the 3D BIM was not enough to achieve faster delivery [122][123]. Indeed, many other dimensions need to be added for BIM to fulfil its potential. These activities, include sustainability, asset management, accessibility, safety management, energy saving, acoustic among others [124], These activities linked with 3D BIM model led to some n-dimensional extensions, recently proposed in the literature [125].

1.1.7.2 Objective of 4D models

"While it's possible to create an image of a building in your mind, to see it take shape on screen, in sequence, creates much more effective shared understanding with the entire delivery team" [126]. CPM planning has been the accepted method of choice for construction project planning since the 1950s, but CPM has drawbacks resulting from inability to deal with dominant constraints, difficulty in assessing and communicating interconnection activities and insufficient work planning attitudes [127]. Traditionally, plans for the stages were communicated through 2D snapshots showing each stage. This requires the auditors to imagine, in their minds, the activities that will take place at a particular time and place in the project. Many stakeholders cannot see the whole big picture based solely on a Gantt chart. The Gantt chart (used to show CPM planning) only presents the sequence of events, not physical objects, which can be difficult to verify and evaluate [128]. The general purpose of 4D models is to visually inform interested parties of the building plan, scope of work, project affected areas, and/or tenant movements on renovation projects. 4D models provide a way to visually display an animated process to describe the construction phase and plan [121].

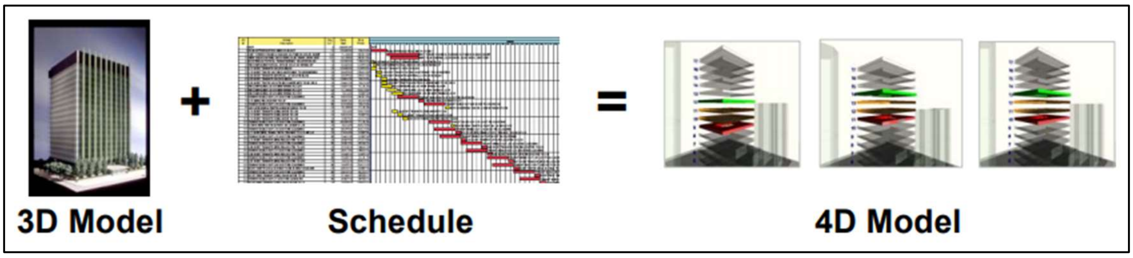


Figure 10 – 4D Models link 3D components with activities in phasing schedule [121]

1.1.7.3 4D models in the project lifecycle

4D models can be used throughout the project lifecycle [121]. Although many industry cases have been documented regarding the use of 4D models throughout the project lifecycle, it can be beneficial to use 4D models in three specific phases:

Pre-design:

4D models were used for strategic project planning during the feasibility stage. For instance, the model can be used to define different timing sequences and oscillating space configurations or to improve a build program. These models allow different alternatives to be compared with a detailed evaluation at a relatively low cost to the team and owner.

Design Development:

4D models can be used to improve the buildability of a project and to determine the benefits of different construction processes. These templates can be used to improve the build schedule, timing, and/or sequencing of tenants.

GC Selection/Construction Bidding:

4D models can also be requested in a Request for Proposals (RFP) to show the contractor's ability and direction in carrying out the work. If the job is complex, 4D models can be used to understand the tenant stages and/or the sequence of construction activities during the rendering. If contractors better understand space and constraints, bids may be more accurate.

Construction:

4D models of temporal aspects can be used to coordinate construction and review buildability. This includes understanding where and how processes operate over a period and understanding site traffic and flow processes. On-site, these templates can be used for bi-weekly reviews of work progress and for comparing established programs against those planned for management and claims purposes.

1.1.7.4 Findings and Literature in 4D BIM

Advanced 4D BIM is now widely used and its growing adoption is attributed to the general acceptance that 4D is about planning in general. This was confirmed by [129] where a comprehensive investigation was conducted to investigate the use of 4D BIM. Where the relationship of BIM 4D with planning is a consensus. This means that most of the professionals already understand when they talk about 4D. However, most publications have developed specific activities embedded in 4D without associating them with a specific dimension. The journal article dealing with 4D BIM was published by Hu et al. [130] who used 4D safety analysis for scaffolding management. So, the word "security" was soon associated with four-dimensional planning. Additionally, several authors have discussed the use of 4D BIM for security management. Safety plans can be virtually reviewed before actual on-site implementation and problems can be anticipated using simulations [131],[132],[133],[119]. Indeed, between 2010 and 2011, some authors linked 4D BIM to safety planning [134],[135]. Bansal [136] correlates the table with GIS and explores the use of 4D GIS in construction safety planning. This is supported by the systematic review by Martínez Ayers et al.[137] BIM's treatment of safety management in the construction sector. They highlighted the benefits of using BIM to identify potential risks in the fourth dimension of BIM.

Then [138] was the author who addressed the benefit obtained using 4D BIM then followed by [139],[140]. Since then, 4D BIM has brought many benefits to the construction industry, including avoiding direct and indirect costs due to inefficient scheduling and updating problems [138], facilitating the management of changes that occur during the construction phase [141], management errors associated with the construction phase and for better control and scaling Project progress [141],[142],[143]. The subsequent development of 4D was suggested by Kiviniemi et al.[144].

Over the past decade, authors have started using 4D (Time and Planning) BIM to solve various problems. Indeed, as Al-Azhar recalled, one of the main problems of construction is planning [145]. This author reports the result of a survey conducted in 2007 among professionals. The goal was to verify the key areas where BIM successfully contributes. The survey showed that project planning was the primary area where BIM was being used successfully and where the company really wanted to use it. No wonder planning is rapidly becoming the fourth dimension, by consensus. As 4D is developing in different directions, other authors have begun to associate 3D with cost, called 5D. Some authors have explored the possibility of associating BIM elements with cost data and automatically tabulating the data. This is possible thanks to the close interrelation that once existed between costs and programs. Indeed, they share common data such as costs, resources, and budgeted quantities [146]. Fifth dimensional BIM was demonstrated with Popov et al. It has increased significantly since 2012 [147].

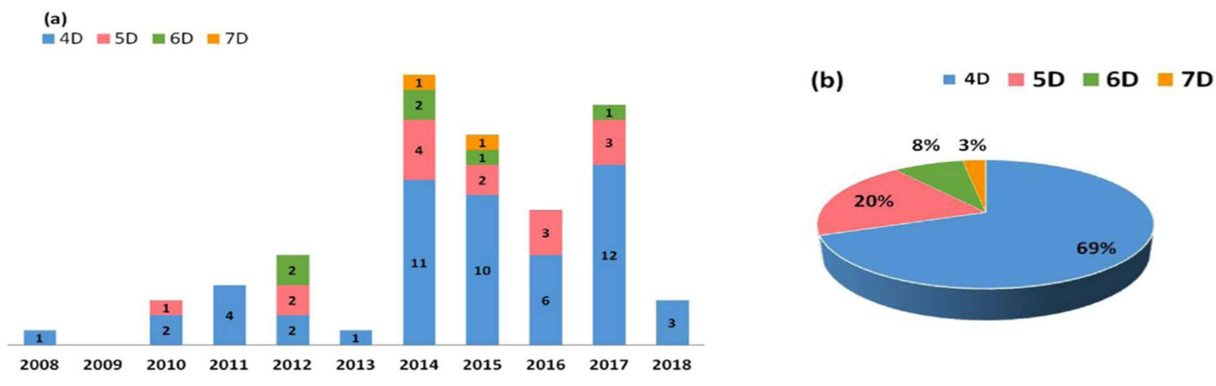


Figure 11 - Publications related to BIM dimensions, through Scopus and keywords (a) by year, (b) in percentage of the total number of papers of (a).[129]

1.1.7.5 Utilities of 4D models

The review of existing literature on 4D BIM application development, indicates that it can be expected that many functions will be covered by modern 4D technology. The true value of 4D planning is a topic of debate among professionals, with the client many times the only beneficiary of all this, not the planners [114]. However, as stated by [148], it may be appropriate to deduce the usefulness and function of using 4D BIM in:

1.1.7.5.1 Scheduling

Timing in construction is intended to clearly define how projects are grouped with specific activities and a sequencing logic that defines durations and directs the overall progress flow of the site. The integration of the tables into '4D' BIM have been formulated as well as the 'Model Simulation' and 'Sequence Animation' studies. The sample planning information can be used in many ways. BIM planning continues to create a higher level of project visibility and has proven to be an effective way to visually communicate with a team how the project is put together.

1.1.7.5.2 Constructability

Buildability is a project management technique that reviews construction logic from start to finish during the pre-construction phase to identify potential roadblocks, constraints, and problems. The use of BIM when building spatial coordination has been a catalyst for the rapid adoption of BIM in the construction industry. In an interesting advance, the value of using models to coordinate system and facility planning has been transformative in the way the construction industry now approaches system conflict resolution. Previously, spatial coordination problems were addressed via optical scales by individual reviewers. Now, the models are examined in collaborative 3D environments to better understand and then solve the problems (Fig. 12).

Figure 12 – model coordination review meeting [148]

1.1.7.5.3 Analyzing Data in BIM

The ability to analyze a large amount of data available in BIM or collected through the design and construction process creates a wide range of possibilities. All systems have now been developed with a focus on collecting this data and making it more relevant during design and construction. Some of these tool’s focus on tasks such as equipment management, security, inventory monitoring, problem management, document accessibility reporting, and several other solutions that aim to simplify, automate, and simplify the work that takes place in the field.

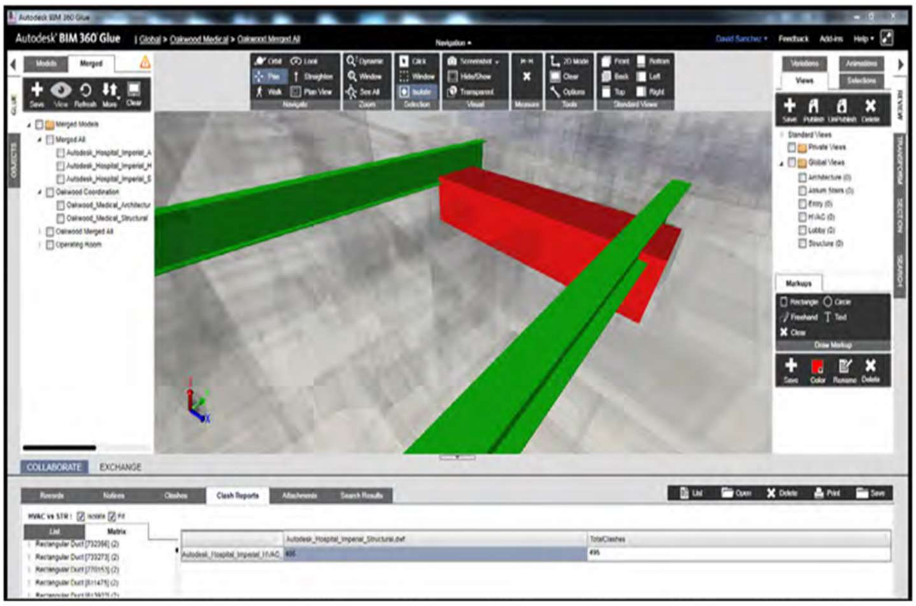


IMAGE COURTESY OF AUTODESK

Figure 13 - AUTODESK BIM 360 GLUE

1.1.7.5.4 Coordinating Construction

Sequencing, security, logistics, material storage, delivery, quality control, equipment management, and reporting, along with a host of other coordination activities, make up a manager's day.

1.1.7.5.5 Controlling Schedules

During construction, various BIM tools and mobile devices can help monitor planning progress. For many contractors, the gold standard for project scheduling controls is Critical Path Method (CPM) planning. A large amount of data indicates that this type of planning method is largely ineffective in building. For many contractors, the gold standard for project scheduling controls is Critical Path Method (CPM) planning. A large amount of data indicates that this type of planning method is largely ineffective in building.

1.1.7.5.6 Other Utilities

- **Change Management.**
- **Material Management.**
- **Tracking Equipment.**
- **Project Close Out.**

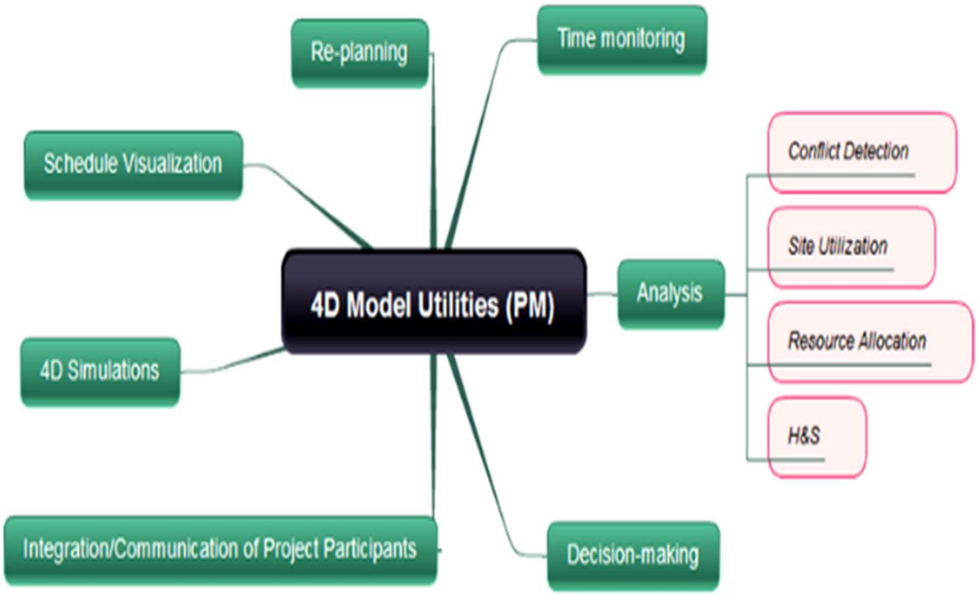


Figure 14 - Assessment of 4D BIM applications for project management functions [114]

1.1.7.6 4D BIM Tools

There are several aspects to consider when selecting a 4D BIM tool. This section should explain the requirements for the different model building methods and the software available [114].

Requirements for 4D BIM tools Although the uses of 4D BIM have already been explained, the performance varies from one application to another. As a tool that is to be used by contractors, 4D-capable BIM applications must meet several requirements, some of which are listed below [119]:

-Import capabilities.

- Export/Output capabilities.

- Merge and update options for the BIM model.

-Data reorganization.

- Temporary elements and equipment.

- Animation.

- Automatic linking.

With these working methodologies entering the construction arena, the 4D BIM application market has gradually grown, and various software has been developed. The following Table 2 presents a list of various commercial applications available to date for 4D BIM purposes:

COMPANY	4D BIM TOOL	LOGO
Autodesk	Navisworks* *Last Version: Navisworks 2014*	AUTODESK NAVISWORKS
Synchro Ltd.	Synchro Professional *Last Version: Synchro Professional 4.7.2*	Synchro
Vico Software	Virtual Office 4D Manager *Last Version: ---*	VICO SOFTWARE Integrating Construction
Tekla	Tekla Structures** *Last Version: Tekla Structures 19*	TEKLA Structures
Bentley	Bentley Navigator *Last Version: Bentley Navigator V8i*	Bentley
Innovaya	Visual Simulation *Last Version: ---*	innovaya
Gehry Technologies	Digital Project Extensions *Last Version: V1, R5*	Gehry Technologies

*2 different versions: Manage & Simulate
**Only for dealing with structural BIM models

Table 2 - Main BIM tools and last versions available in the market [119]

1.1.8 5D BIM

1.1.8.1 Definition

The estimate derived from BIM (also known as 5D) has long been considered the “golden goose” of BIM in the pre-construction phase of the project. Conceptually, the BIM-derived estimate uses the database underlying the building information model to correlate these model components directly to unit cost or cost aggregation recipes to produce an estimate [148].

The appreciation of BIM has grown exponentially in terms of complexity and ease of use since the first iterations of the software. The tools are now beginning to make the BIM estimation process smoother by allowing you to combine related “non-model” data such as 2D PDFs and CAD drawings for use in the start-up process [148].

The industry now has a more solid understanding of how to accomplish model-based estimation, and many best practices are available from vendors, user groups, and industry associations to help address model-based vs. placeholder or hypothesis estimation. Model-based estimation still requires significant investments to create cost databases and processes used to estimate and update information derived from BIM. However, many companies see efficiencies in modernization and accuracy [148].

1.1.8.2 Development of 5D BIM

The development of 5D (cost) capabilities is evolving and major project cost management companies are starting to realize competitive advantages by adopting a "new age" approach to cost management [149]. A major indication for using this technology occurred in 2008 in the United States. When, The Association for the Advancement of International Cost Engineering (AACE), the American Society of Professional Evaluators (ASPE), the US Army Corps of Engineers, the General Services Administration (GSA) and the National Institute of Building Sciences (NIBS) formed an agreement to work together to solve cost engineering issues for the facilities industry as part of the SMART Alliance. The aim was to develop systems and protocols for collaboration and coordination of cost engineering and estimation throughout the project life cycle. "The consortium continues to adjust to, and coordinate with ever-changing standards, so that the process of extracting and processing the 5D (cost) information from the BIM model is clearly defined, especially as the design evolves" [150].

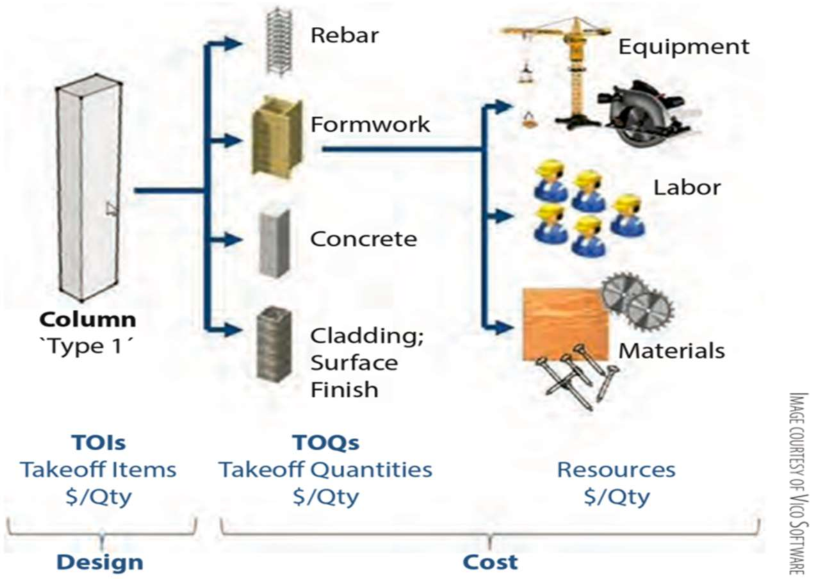


Figure 15 - 5D data flow [148]

1.1.8.3 Controlling Cost

Understanding project costs and cash flows is the lifeblood of a project. Data from BIM can be a valuable source of information from the design model to better inform estimates, reduce assumptions, and create better dialogue at the start of a project. But how do we bring the ability to control costs into the field? Traditional approaches have involved the use of multiple spreadsheets, detailed budget allocations, and usually a methodology for determining the percentage of composite work [148].

As noted above, the trend of collaboration and real-time input industry continues towards cost control and input transformation as the ability to generate reports from the field begins to predominate over office input. In addition, preliminary estimates derived from BIM generated for a project are put to construction as scope budgets are established. Some teams are finding ways to continue linking cost data as build continues, validating billing rates with custom scope charts built into tools like Navisworks [148]. Another method is to use estimation platforms such as Vico and laser scanning to check the cost of the work performed against visual verification in the field (Fig. 1.20) [148].

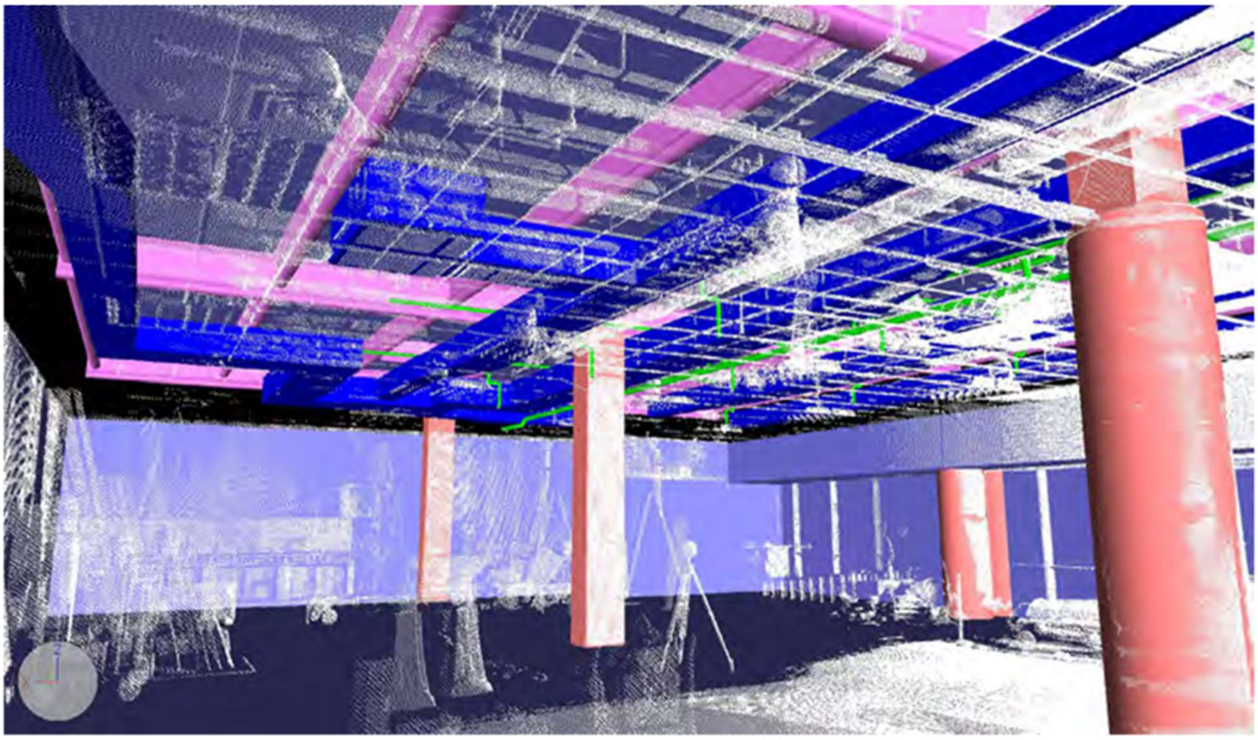


Figure 16 - Laser scan and BIM overlay[148]

CHAPTER TWO

2.1 Description of the Case Study

2.1.1 Introduction

Extending the futuristic metro network by 200 km, innovating its 68 stations designed with today's greatest architects, with its 140 km2 urban influence on the Greater Paris territory and with the ambition of its artistic and cultural approach along its route, the Grand Paris Express is the largest A civil development project in Europe. Its implementation will help create 2 million passengers every day, a new way to experience one's transport time and on a larger scale in one's own lands.

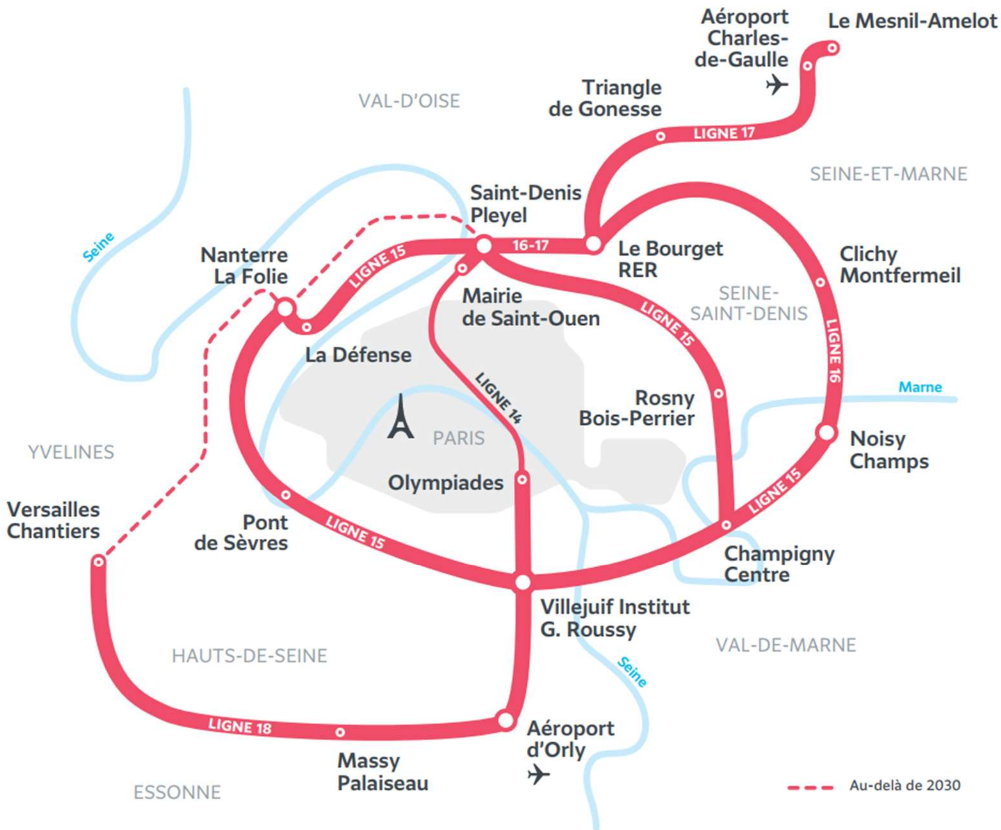


Figure 17 - Map of the underground Network Connecting the City of Paris

2.1.2 The Greater Paris Society (La Société Du Grand Paris)

The public body created by the State for the dissemination and financing of the Grand Paris Express, the SGP is responsible for the design of the project in all its dimensions: a schematic diagram of all lines, infrastructure projects, purchase of railway carriages, installation of areas, etc. Thus, today the Société du Grand Paris guarantees the construction and development of stations, including the interconnection with existing transport lines.

2.1.3 Sevran Beaudottes Station

Sevran Beaudottes station is a driving force of urban renewal, redesigning a central location on Salvador Allende Street, with a pedestrian and cycle layout. A real link between the Sifran districts, this space will allow easier service between the different modes of transport and the numerous shops and services that will be set up at the train station.

Sevran Beaudottes station on line 16 of the new underground erected in the north of the city, near the Beau Sevran shopping center. Directly interconnected with RER B, it enhances the service to the region with the entire network. About 21,000 people reside within a kilometer radius around the station, where approximately 45,000 trips a day will be made in 2025.

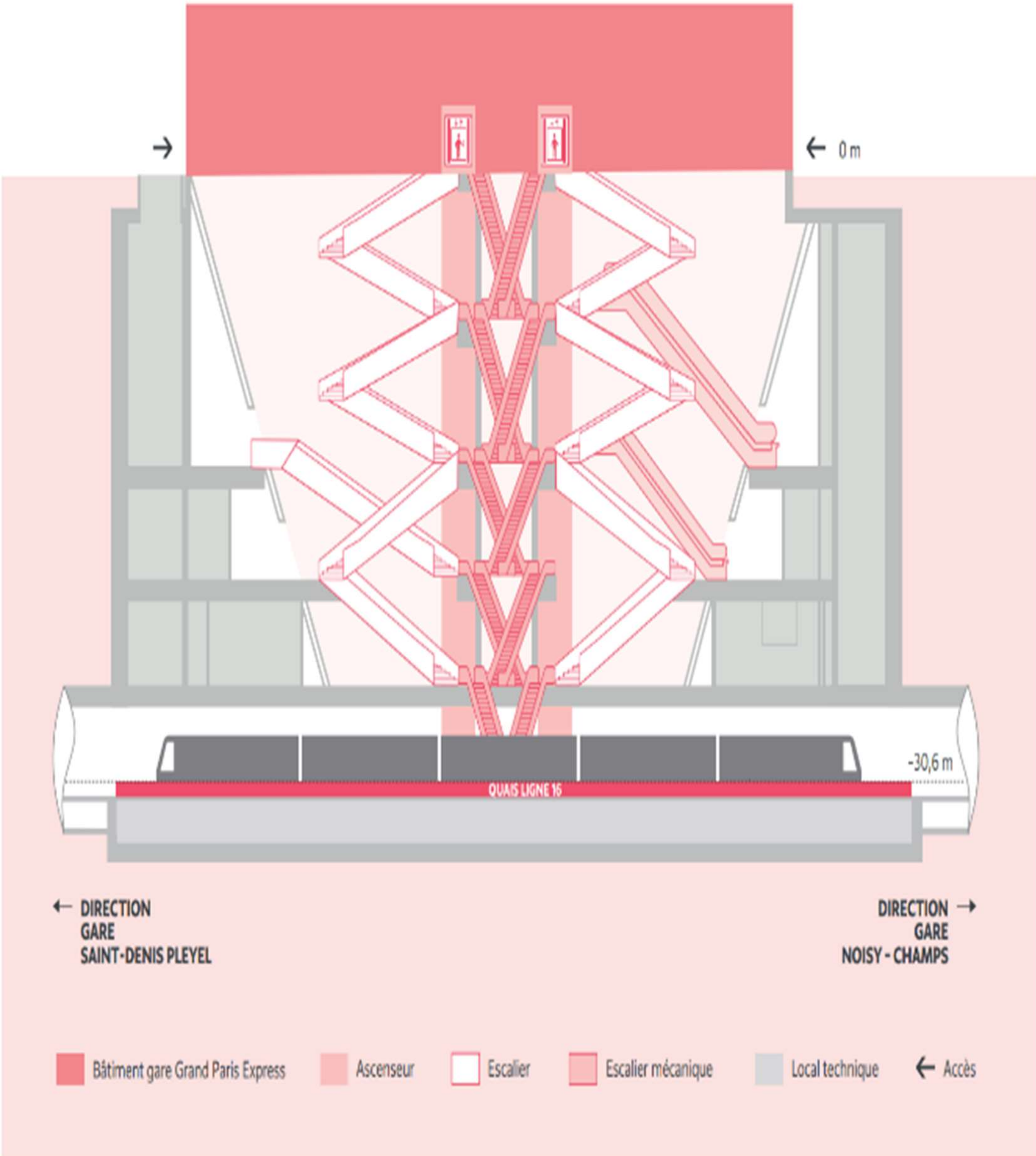


Figure 18 - Sevran Beaudottes Station Section View

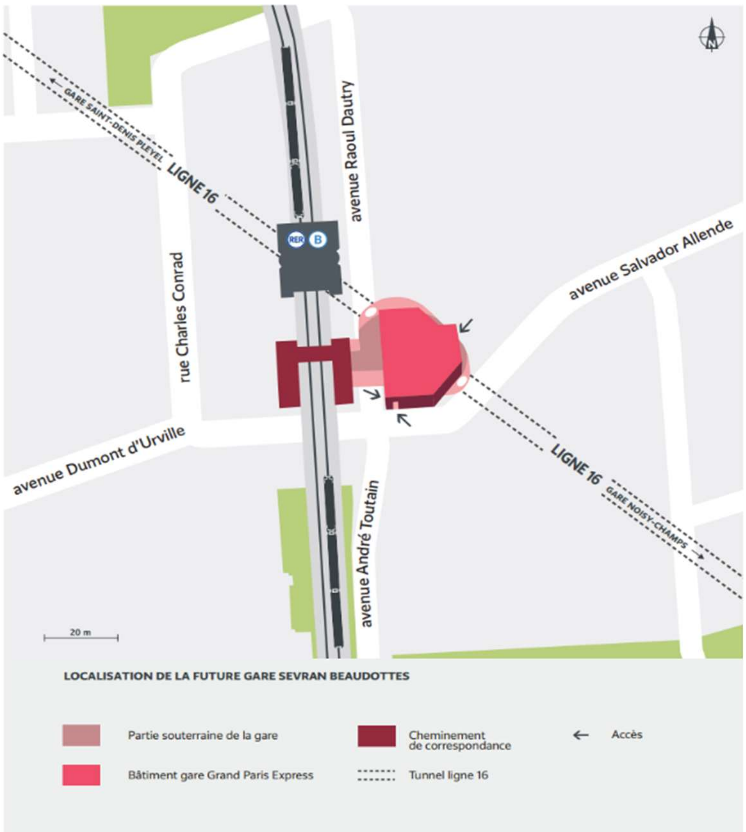


Figure 19 - Plan view of Station showing intersection with Line 16 underground network

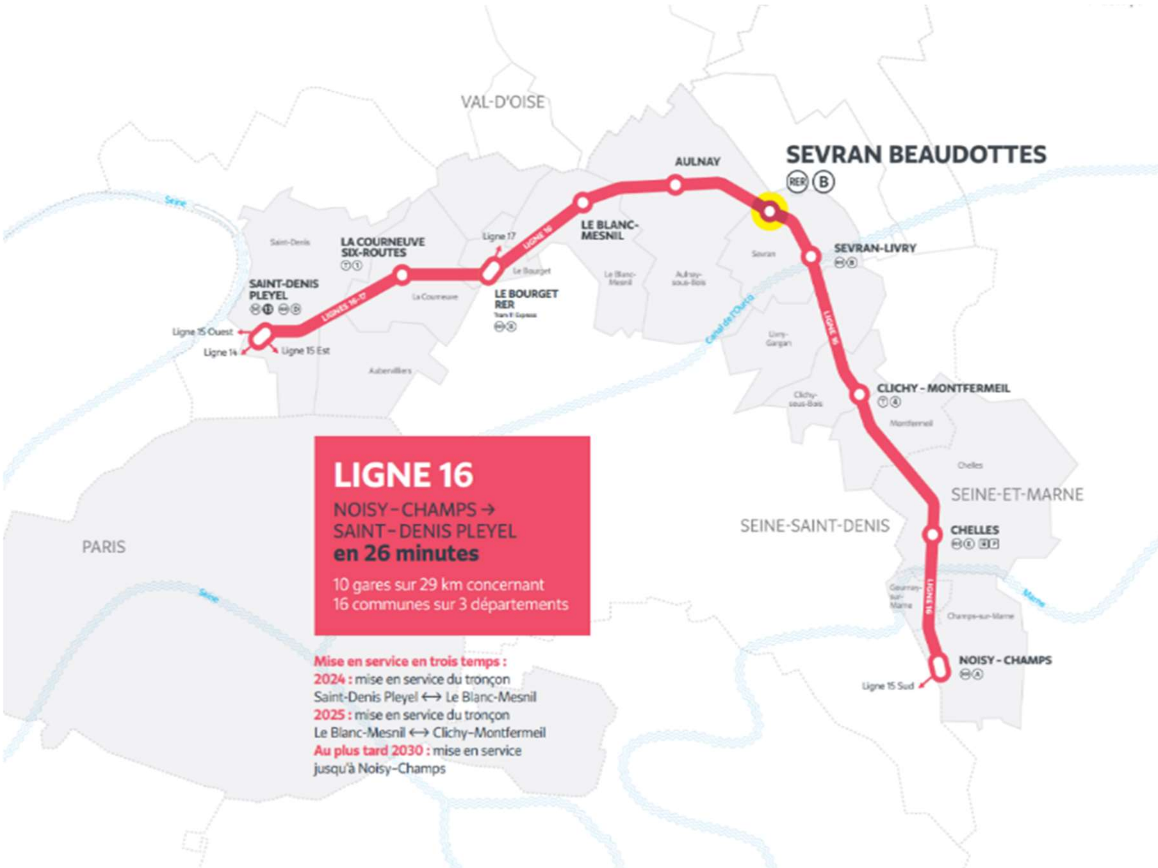


Figure 18 - Underground Network of Line 16

2.1.4 Information about the Model

The Revit BIM model provided contains linked projects of Architectural, Structural, Contest & plumbing links models.

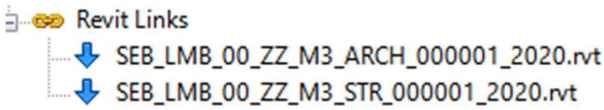


Figure 19 - Revit Model Links

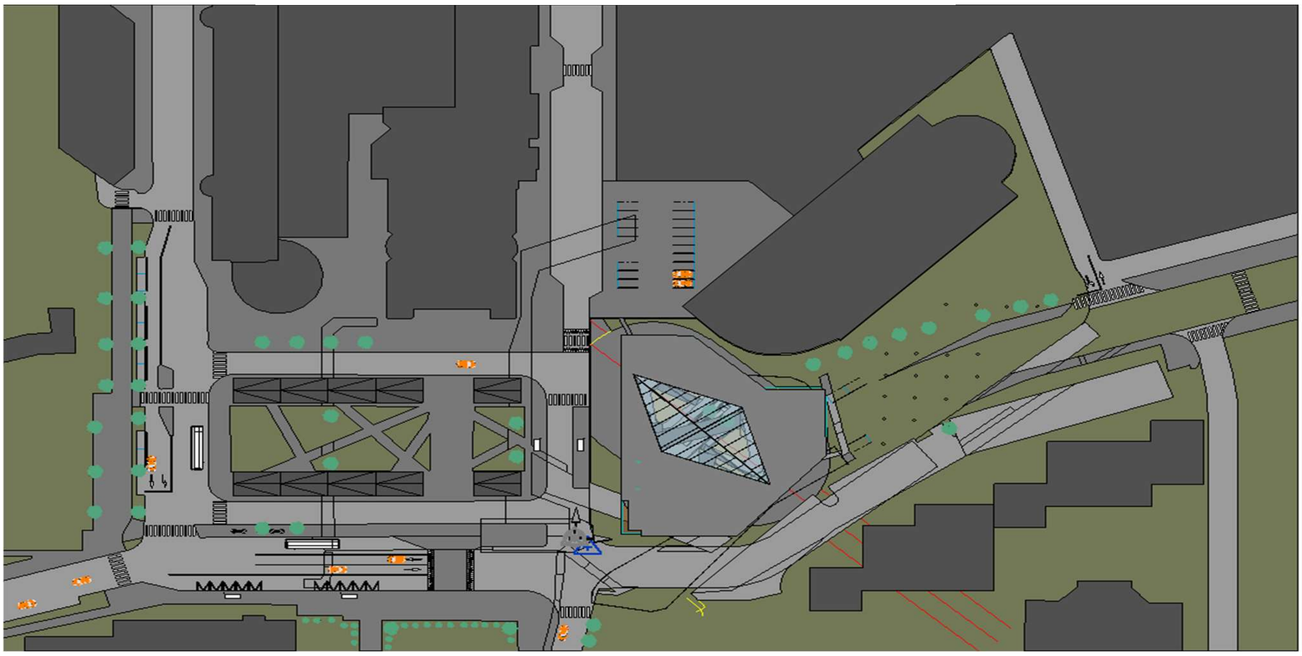


Figure 20 - Revit Model Plan View

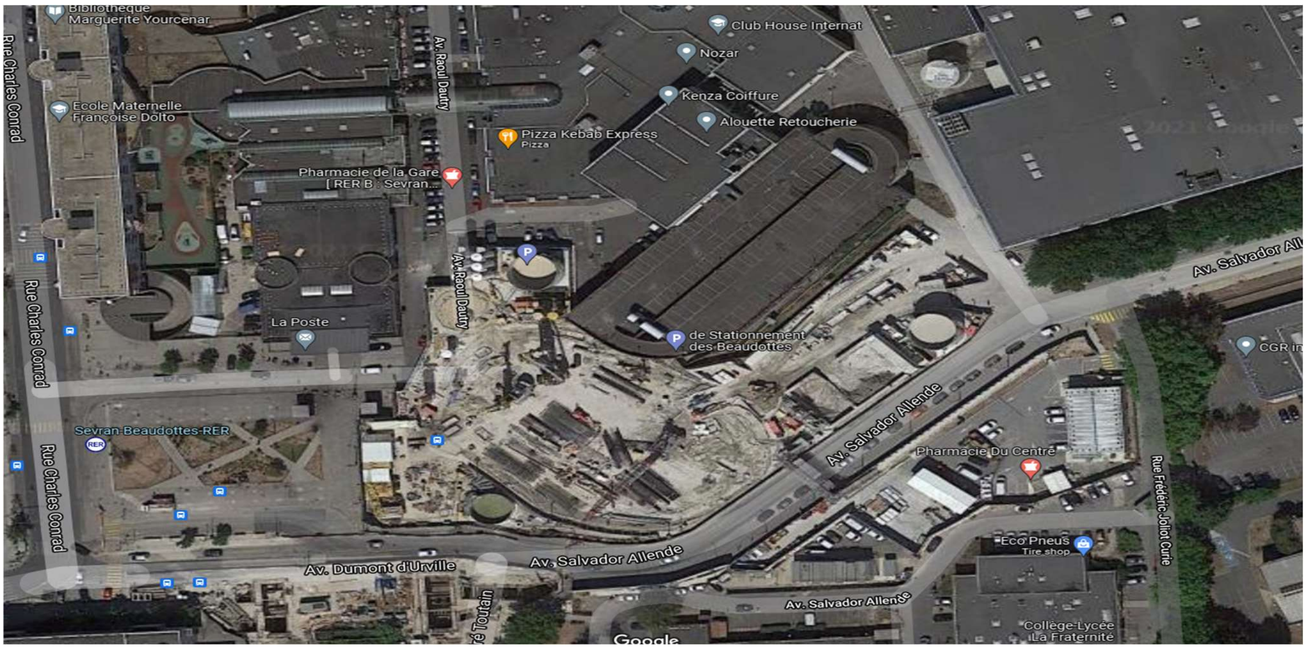


Figure 21 - Real View of the Station on Google Maps

2.1.5 Preparatory Works Schedule

For this thesis, it is essential to test simulated preparations and collisions with real traffic. The preparatory work program includes 17 plumbing and electrical works under Salvador Allende Street. In addition to the location and operation of the old station, which coincides with the current construction works of the new station. Time is the most crucial factor in the preparatory stages for introducing large infrastructures in a highly urbanized context. The duration of this phase is relevant for road users and affects the entire community adjacent to the project area. Detailed planning is required due to the complexity and social impact of a project. A high level of coordination between all professionals involved is essential for the best phasing plan. Hence the need to obtain high information is necessary to coordinate and manage such a complex building phase for the sole purpose of avoiding critical workflow errors, which is the type of time conflict that occurs when two objects on a construction site are designed to collide or overlap during assembly. All of this must be managed and planned along the fourth dimension, allowing two "objects" to be in the same place but at different times. The work will be to obtain a feasible and optimal construction phase plan, evaluating the potential risks of spatial and temporal collisions. In a dynamic perspective, keep track of times and costs simply by changing a few variables. This provided an advantage of the feasibility of the method.

Mainly the phases are explained as follows:

Nome attività	Duration	Start	Finish	Predecessors	Work	Cost	Fixed Cost
SEB_Deviazione DEA	518.88 d	Thu 01/11/18	Tue 27/10/20		5,488 h	###########	450,000.00 €
Fase 1	30 d	Thu 01/11/18	Wed 12/12/18		240 h	132,000.00 €	0.00 €
Fase 2	30 d	Thu 13/12/18	Wed 23/01/19	2	240 h	132,000.00 €	0.00 €
Fase 3	30 d	Thu 24/01/19	Wed 06/03/19	5	240 h	132,000.00 €	0.00 €
Fase 3.1	3 d	Thu 07/03/19	Mon 11/03/19	8	24 h	13,200.00 €	0.00 €
Fase 3.2	21 d	Tue 12/03/19	Tue 09/04/19	11	168 h	92,400.00 €	0.00 €
Fase 3.3	14 d	Thu 11/04/19	Wed 01/05/19	14	112 h	61,600.00 €	0.00 €
Fase 4	30 d	Wed 01/05/19	Wed 12/06/19	17	240 h	132,000.00 €	0.00 €
Fase 5.1	70 d	Wed 12/06/19	Wed 18/09/19	20	560 h	308,000.00 €	0.00 €
Fase 5.2	14 d	Wed 18/09/19	Tue 08/10/19	23	224 h	95,200.00 €	0.00 €
Fase 5.3	30 d	Tue 08/10/19	Tue 19/11/19	26	480 h	204,000.00 €	0.00 €
Fase 6.1	14 d	Tue 19/11/19	Mon 09/12/19	29	224 h	95,200.00 €	0.00 €
Fase 6.2	21 d	Mon 09/12/19	Tue 07/01/20	32	336 h	142,800.00 €	0.00 €
Fase 7.1	60 d	Tue 07/01/20	Tue 31/03/20	35	960 h	408,000.00 €	0.00 €
Fase 7.2	30 d	Tue 31/03/20	Tue 12/05/20	38	480 h	204,000.00 €	0.00 €
Fase 8	60 d	Tue 12/05/20	Tue 04/08/20	41	480 h	264,000.00 €	0.00 €
Fase 9.1	30 d	Tue 04/08/20	Tue 15/09/20	44	240 h	132,000.00 €	0.00 €
Fase 9.2	30 d	Tue 15/09/20	Tue 27/10/20	47	240 h	132,000.00 €	0.00 €

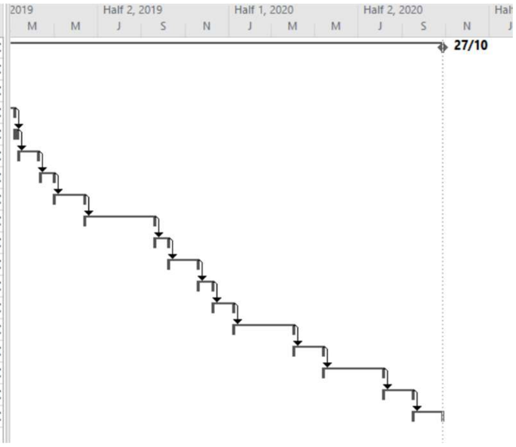


Figure 22 - Preparatory Works Schedule

CHAPTER THREE

3.1 Methodology

The methodology uses a constraint-based system on 4D modeling, and it is presented to define the possible sequences in which the underground piping and electrical work to produce a new road can be built or demolished. The result of this step is a scheduling plan that satisfies a set of predefined constraints and does not create space-time conflicts. Furthermore, detect clashes between the simulated activities and elements on the federated model.

3.1.1 Proposed 4D BIM Workflow Patterns

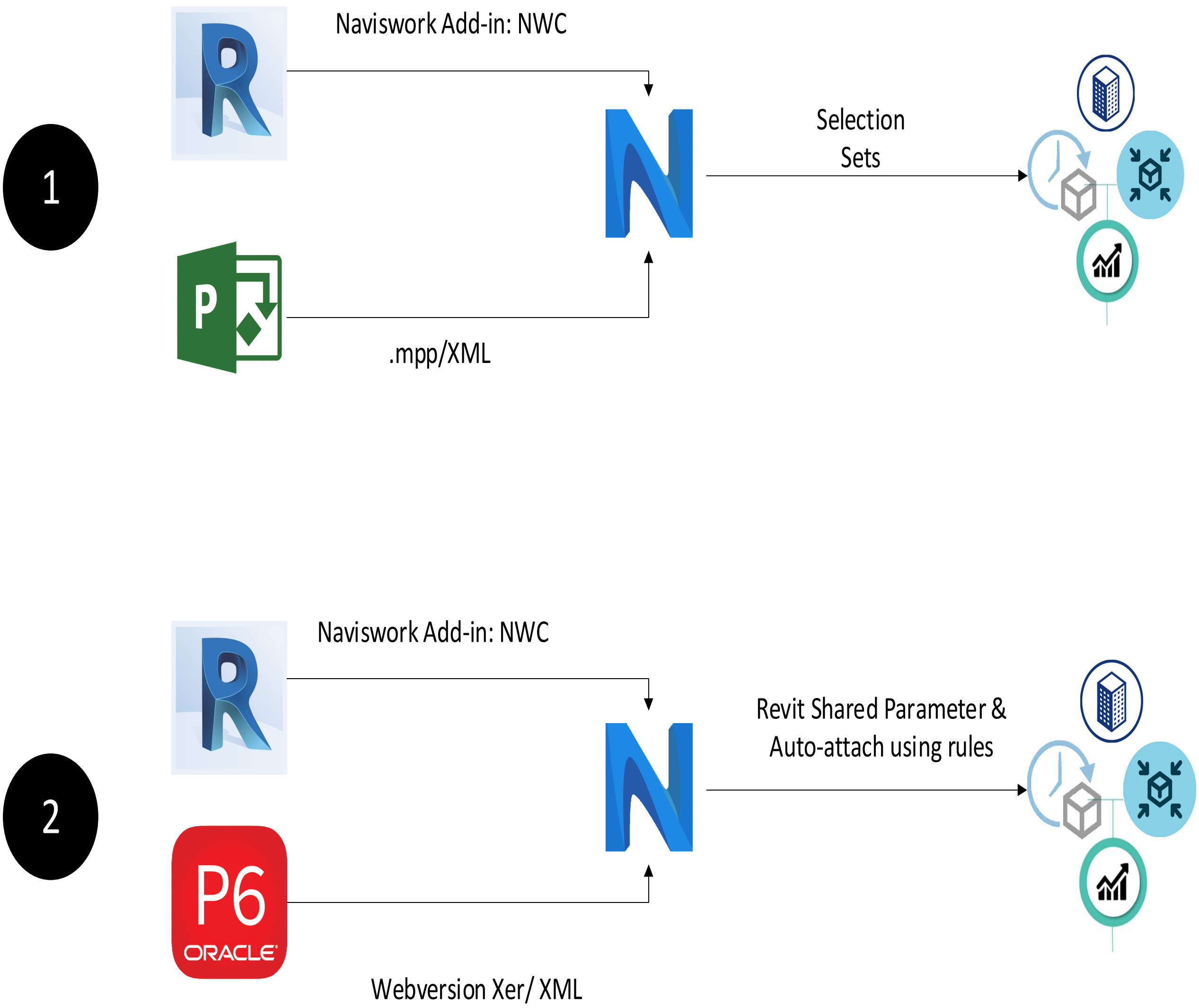


Figure 23 - 4D BIM Workflow Patterns

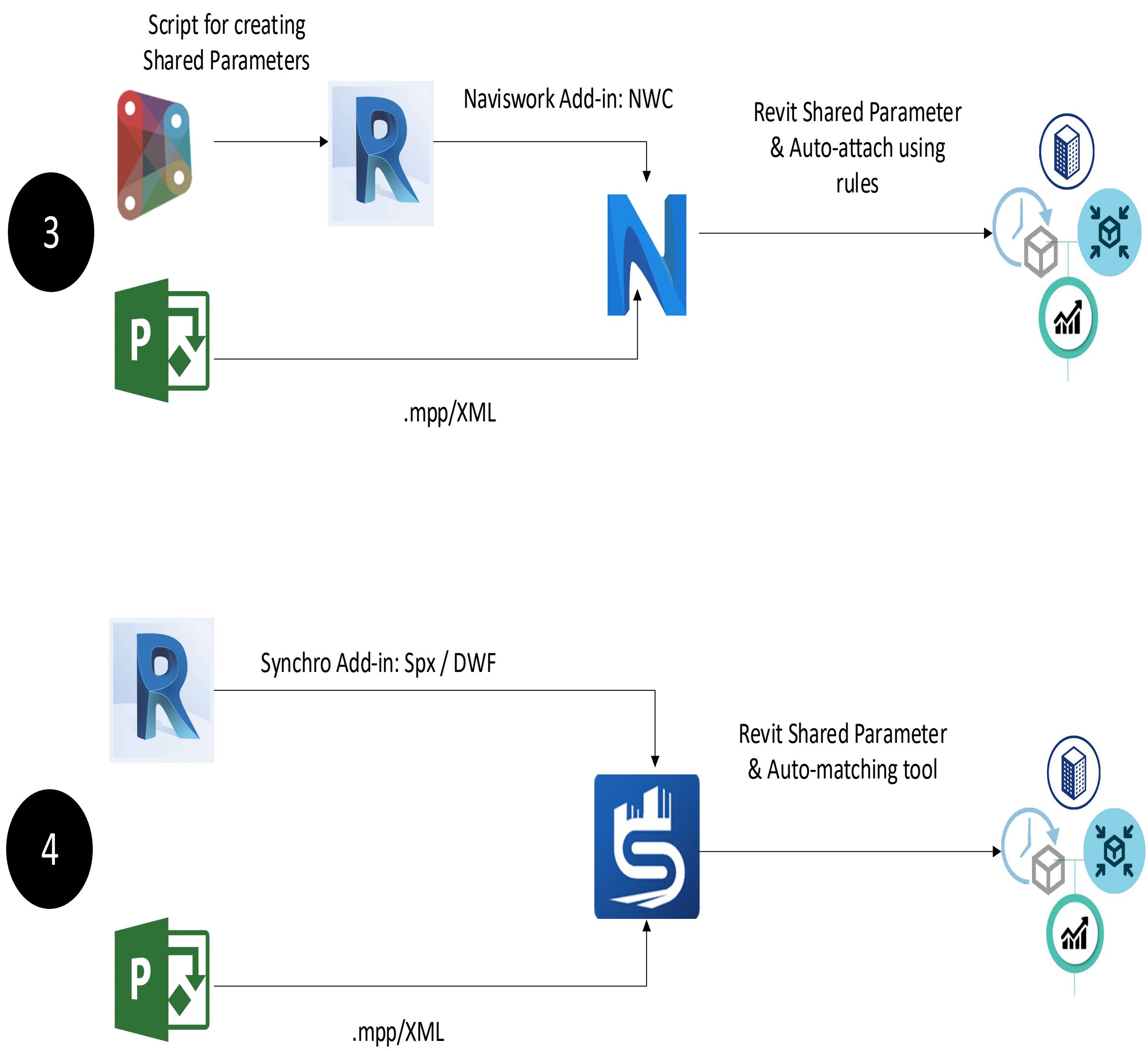


Figure 24 - 4D BIM Workflow Patterns

3.1.2 Definition of the BIM software used

In each workflow there are different groups of software has been used:

Design Software: is a software package used to design and develop a BIM model. Such as Autodesk Revit®.

Project Schedule Management Software (PSMS): software packages used for sequencing and creating schedules for construction project management such as Oracle Primavera P6® and Microsoft Project®.

Simulation, Coordination, and Project Control Software (SCPC): software packages used for construction project management and model reviews. Project managers, consultants, planning engineers, and suppliers use these software packages. Among them, Navisworks® 2020, (Autodesk®, CA, United States), Synchro Pro®2021(6.3.2.0, Bentley®, PA, United States) have similar functions, like 4D scheduling and construction project management, plus the capability of reading and checking IFC models.

3.1.3 Model Shared Parameters

3.1.3.1 Revit®

Autodesk Revit® s building information modeling software for users from the AEC industry. The software allows users to design buildings, structures, and components in 3D and annotate the model by creating Elements. 2D - Access building information from the building model database. Revit® can provide tools for planning and monitoring the various phases of a project's life cycle, from concept to construction and subsequent maintenance and demolition [151].

For 4D modeling and coordination, Revit® can involve the standard parameters of the project. These parameters are definitions of parameters that can be added to families or projects. Standard parameter definitions are stored in a file independent of any family file or Revit® project; hence it allows the file to be used by different families or projects [152].

3.1.3.1.1 Creation of a Shared Parameter

On Revit, a parameter with the name "simulation" under a particular parameter group is added. As predefined project parameters are information containers related to a 3D object or multiple objects, The project parameter can be shown on the list of project parameters. It can be modified as per the user wants:

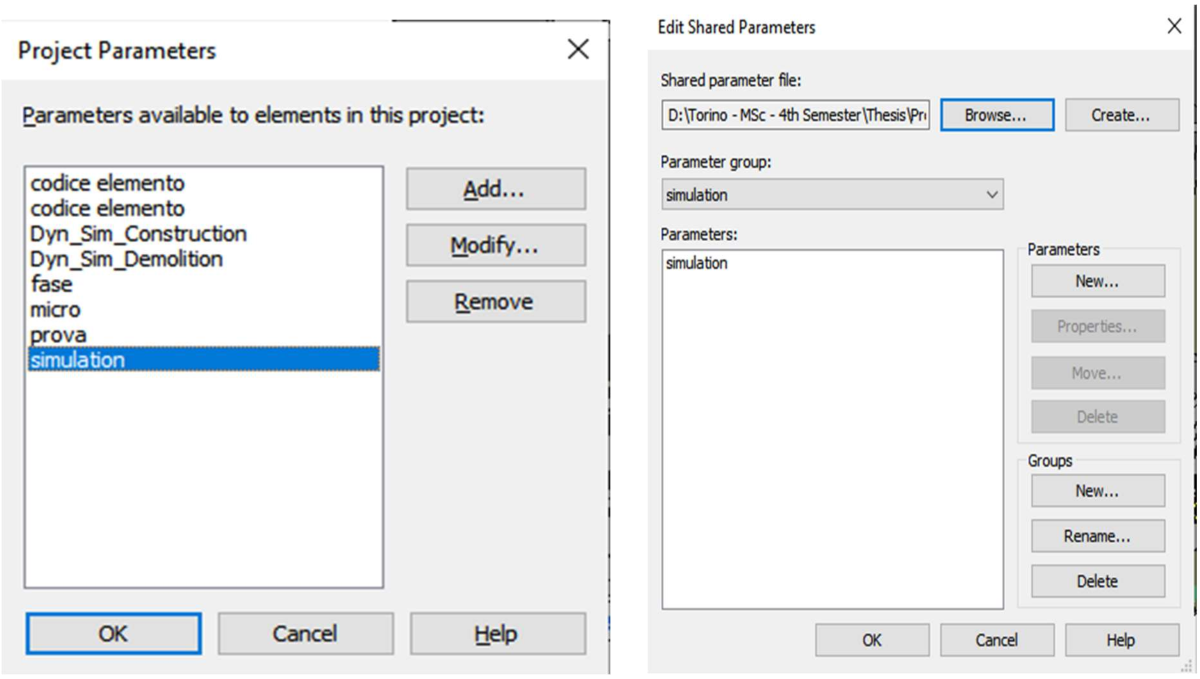


Figure 25 - Creation of a Shared Parameter in Revit

The properties of the shared parameter should be aligned with which elements want to be associated with this parameter. For example, the properties represent which discipline the parameter should be related to the type of model categories the parameter can represent. More information is shown in fig.28.

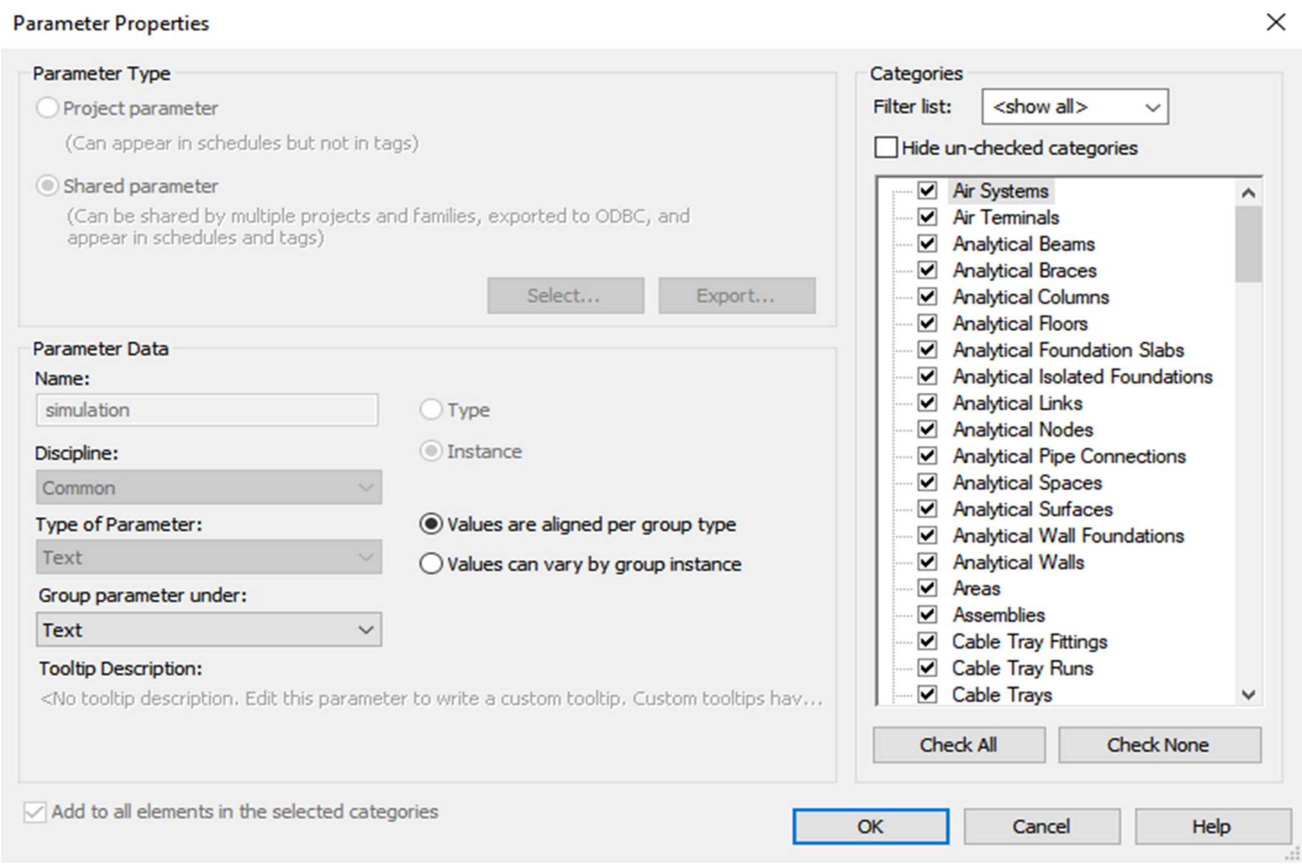


Figure 26 - Parameter Properties in Revit

After applying the parameter on some elements, the element properties will be updated with the corresponding shared parameter, as can be seen in the following figure:

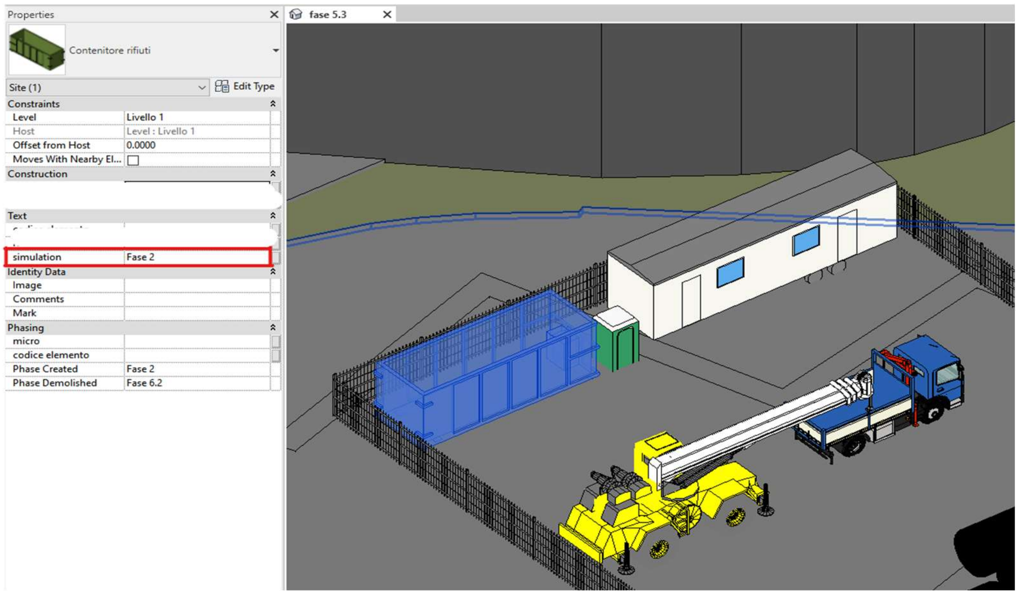


Figure 27 - Simulation Parameter Appearance on Element Properties

3.1.3.2 Dynamo®

Dynamo® is a visual programming interface that allows customization of the building information workflow. Dynamo® is an open-source visual programming platform for designers. It installs as part of Revit®. To start a new script, install two packages from the server called DataShapes® and PracticalBIM®. The script will depend on the category of items to simulate. If the project has a detailed WBS, this process is straightforward. If your project has built phases, these phases can be used to generate the simulation parameter. A copy of the script can be found in the Appendices at the end of this document.

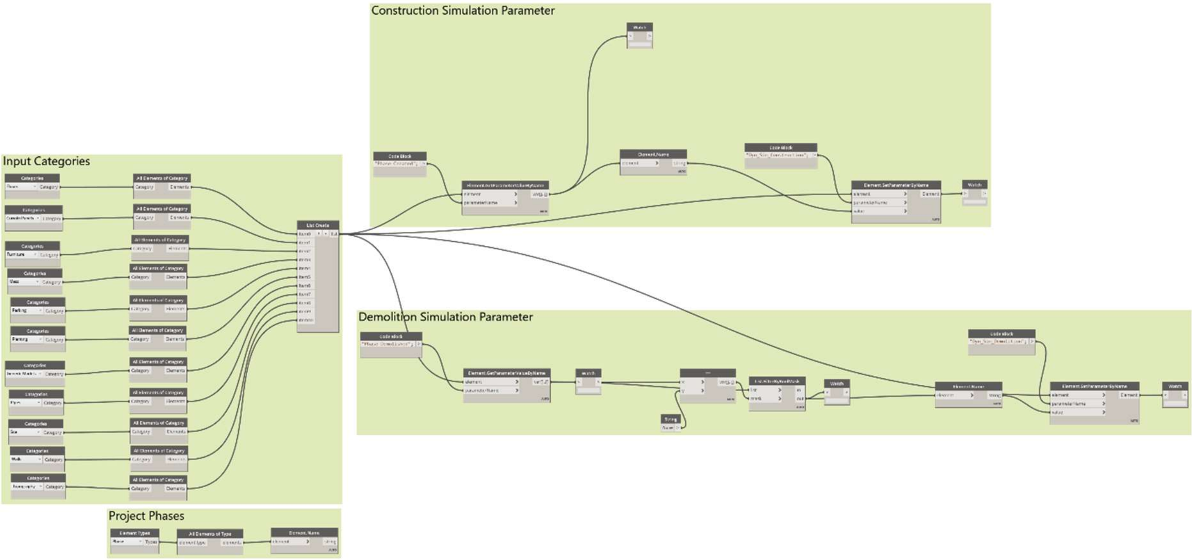


Figure 28 - Dynamo Script for Simulation Parameter Production

The results of this automation process, within seconds after running the script, the simulation parameter generated can be seen on the project properties tab on Revit®. In the thesis case, there are two simulation parameters because there are two appearances profiles one stand for Construction and one for demolishing activities, As follows:

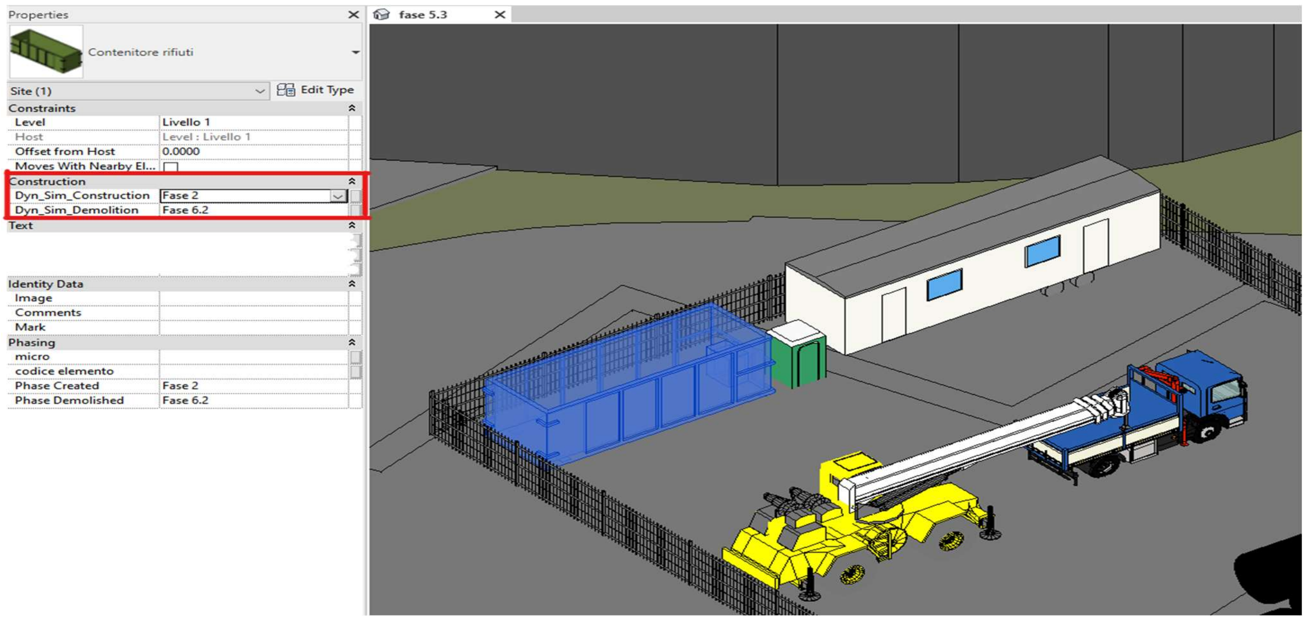


Figure 29 - Dynamo Simulation Parameter appearance on element properties

3.1.4 Model Export to SCPC Software

3.1.4.1 Navisworks®

Navisworks® is a 3D design and review package for the Microsoft Windows operating system. Navisworks® is primarily used in the construction industry to integrate 3D design packages (such as Autodesk Revit, AutoCAD, MicroStation) and allows users to open and combine 3D models; browse around them in real-time; and review the model using a range of tools, including commentary, redline, point of view, and measurement. Navisworks® has many Plugins that support adding interference detection, 4D time simulation, realistic rendering, and PDF-like publishing. Navisworks® Simulate and Manage support many designs file formats. Popular supported formats include Navisworks® -. nwd, nwf, nwc. AutoCAD® drawing - .dwg, .dxf (up to AutoCAD® 2018). MicroStation® (SE, J, V8, XM) -. dgn, prp and prw (up to version 7 and v8). 3D Studio Max® - .3ds, prj (up to 3ds Max 2018). ACI SAT -. sat, sat (all ASM SAT, up to ASM SAT v7). DWF -. dwf and. dwfx (all versions). IFC - .ifc (IFC2X_PLATFORM, IFC2X_FINAL, IFC2X2_FINAL, IFC2X3, IFC4) [153].

Autodesk Revit® can export .nwc files using the Navisworks® extension found in the Add-ons bar. A Navisworks® settings window appears, which helps you manage the features required for the export process and is also helpful with other data.

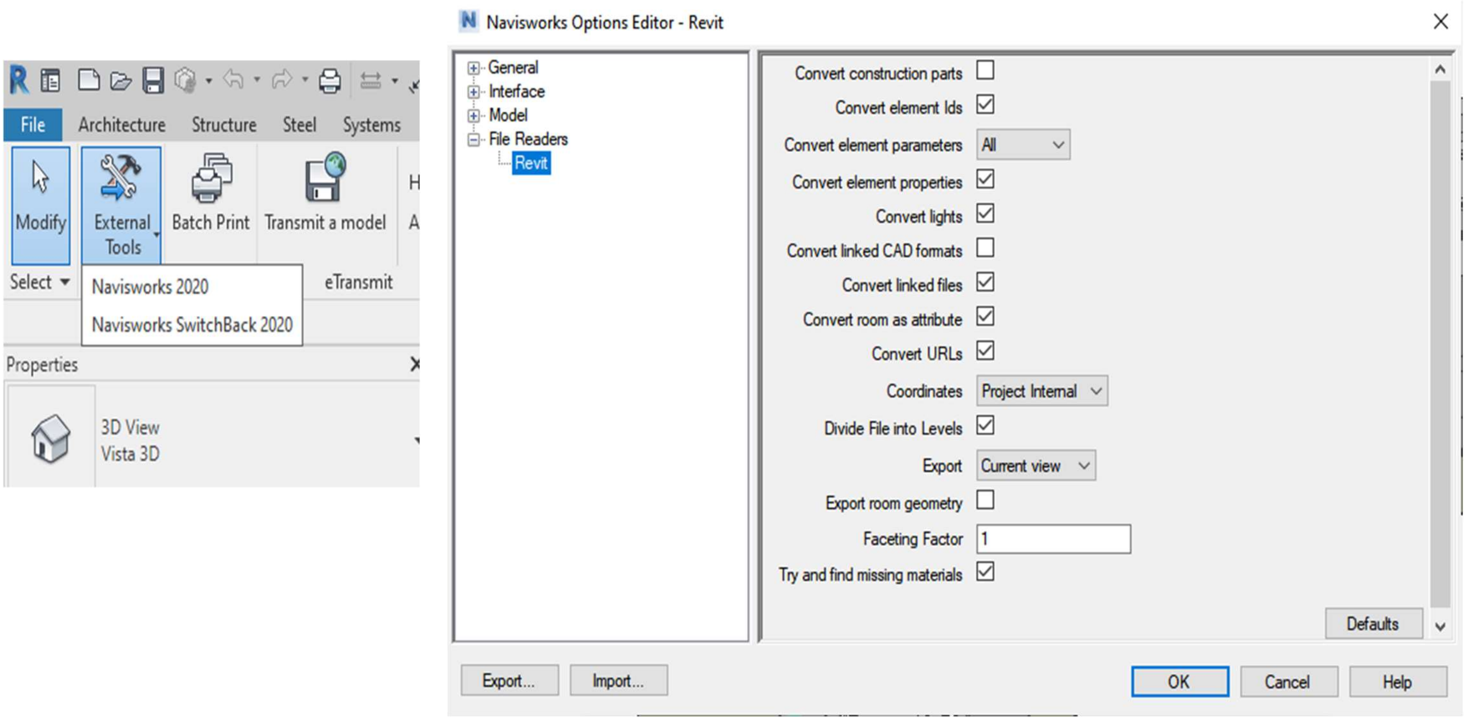


Figure 30 - Navisworks Revit Plug-in & Export Options

3.1.4.2 Synchro Pro®

Synchro 4D Pro® is an advanced tool for planning, scheduling, and managing construction projects in a 4D environment. Planning and planning are essential for safe, efficient, and high-quality construction. While using 4D, the computer becomes a functional area where sequences, safety, special reports, and more can be continuously viewed and discussed before and for the project's duration. Because Synchro Pro® connects 3D resources (human, material, equipment, space) with related table activities, making changes and comparing baselines with alternatives is quick and easy. Sequencing and "what if" scenario testing is highly efficient and engaging. Communications are crystal clear, as it is possible to see every process step. Collaborative knowledge sharing creates unique innovations and methods that create a competitive advantage. Synchro Pro® integrates with Oracle® Primavera and other planning software but is a standalone CPM planning tool that does not rely on importing schedules from legacy software. The ability to view the plan while maintaining its integrity allows project delivery performance to exceed current performance standards consistently and reliably, quickly, and excitingly. The Synchro Pro® Plug-in for Revit® exports models directly from Revit® to. SPX format for data exchange [154].

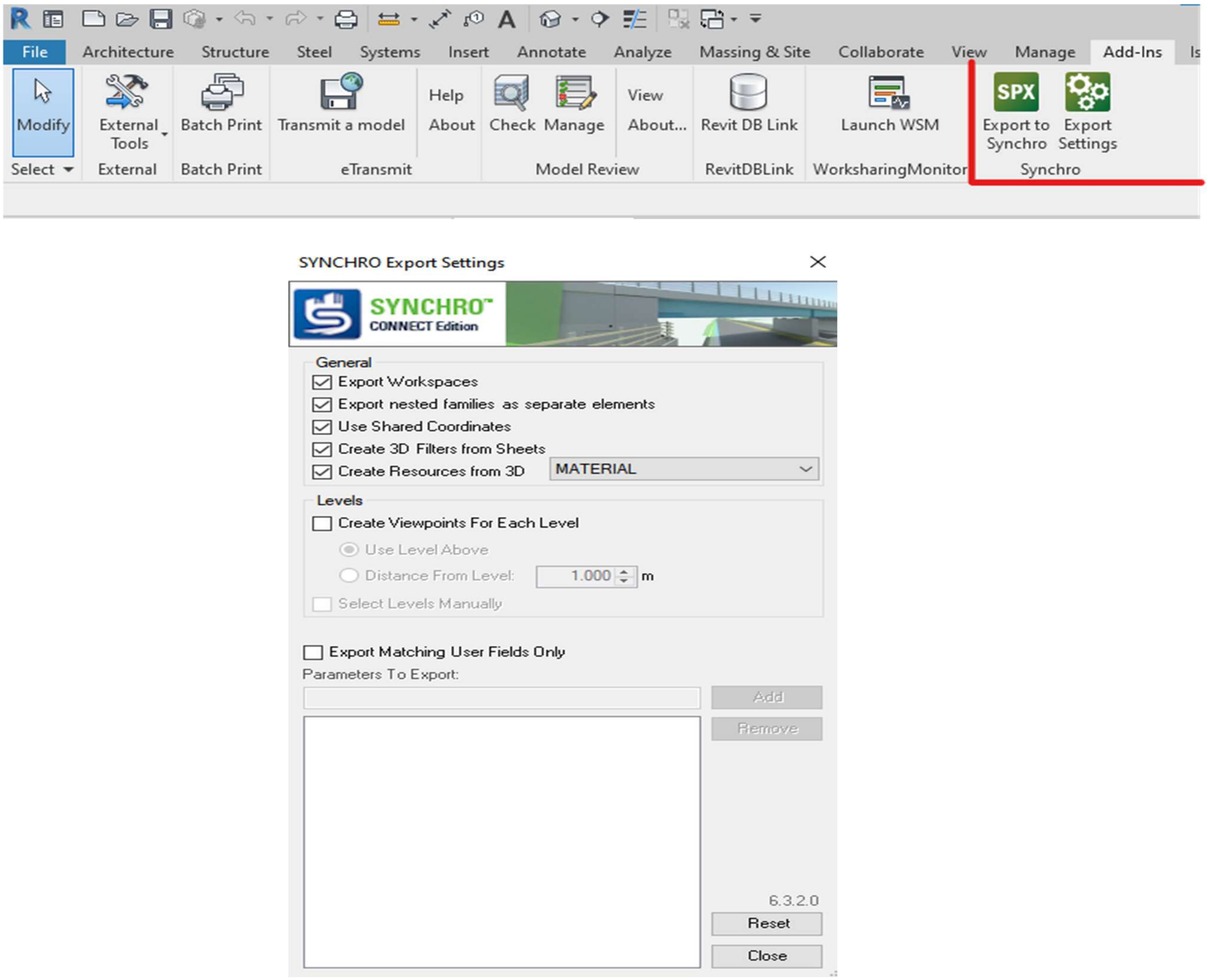


Figure 31 - Synchro Pro Revit Plug-in & Export Options

Synchro Pro® export/import settings allow the Revit model to be exported into direct. Spx synchro project files. The user can choose to export particular project parameters or the whole project parameters.

However, in general Synchro Pro® accept a wide range of file formats for 3D projects. Including Autodesk® drawings files .dwg, and Design Web Format. DWF etc. …

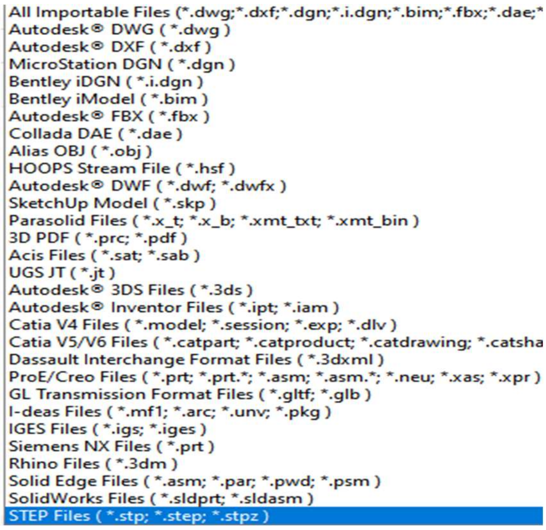


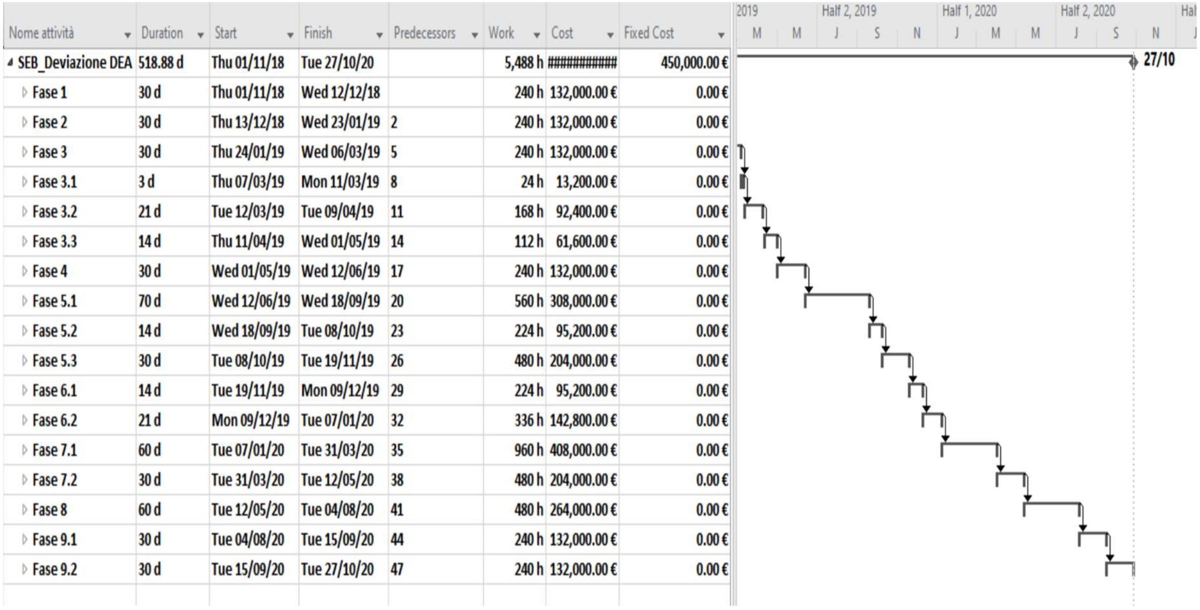
Figure 32 - File Formats for 3D Objects accepted by Synchro Pro

3.1.5 Project Schedule Management Software (PSMS) and Export

3.1.5.1 Microsoft Project®

Microsoft Project® is a project management program package designed and sold by Microsoft®. It is designed to assist the project manager in setting a schedule, allocating resources to tasks, monitoring progress, managing the budget, and analyzing workloads. The Microsoft Project file format is .mpp. The table can be exported with the .xml file extension, an Extensible Markup Language (XML) file, which are plain text files that use custom tags to describe the structure and other properties of the document. The project can also be exported as a. CSV file, a comma-separated values file used by spreadsheet programs such as Microsoft Excel.

The planning is charged with the resources and costs presented on the 4D federation model. The preliminary work schedule is, as mentioned earlier, a 17-stage schedule which is expected to take approximately 520 working days. A copy of the Gantt chart can be found in the appendices at the end of this document.



Nome attività	Duration	Start	Finish	Predecessors	Work	Cost	Fixed Cost
SEB_Deviazione DEA	518.88 d	Thu 01/11/18	Tue 27/10/20		5,488 h	###########	450,000.00 €
Fase 1	30 d	Thu 01/11/18	Wed 12/12/18		240 h	132,000.00 €	0.00 €
Fase 2	30 d	Thu 13/12/18	Wed 23/01/19	2	240 h	132,000.00 €	0.00 €
Fase 3	30 d	Thu 24/01/19	Wed 06/03/19	5	240 h	132,000.00 €	0.00 €
Fase 3.1	3 d	Thu 07/03/19	Mon 11/03/19	8	24 h	13,200.00 €	0.00 €
Fase 3.2	21 d	Tue 12/03/19	Tue 09/04/19	11	168 h	92,400.00 €	0.00 €
Fase 3.3	14 d	Thu 11/04/19	Wed 01/05/19	14	112 h	61,600.00 €	0.00 €
Fase 4	30 d	Wed 01/05/19	Wed 12/06/19	17	240 h	132,000.00 €	0.00 €
Fase 5.1	70 d	Wed 12/06/19	Wed 18/09/19	20	560 h	308,000.00 €	0.00 €
Fase 5.2	14 d	Wed 18/09/19	Tue 08/10/19	23	224 h	95,200.00 €	0.00 €
Fase 5.3	30 d	Tue 08/10/19	Tue 19/11/19	26	480 h	204,000.00 €	0.00 €
Fase 6.1	14 d	Tue 19/11/19	Mon 09/12/19	29	224 h	95,200.00 €	0.00 €
Fase 6.2	21 d	Mon 09/12/19	Tue 07/01/20	32	336 h	142,800.00 €	0.00 €
Fase 7.1	60 d	Tue 07/01/20	Tue 31/03/20	35	960 h	408,000.00 €	0.00 €
Fase 7.2	30 d	Tue 31/03/20	Tue 12/05/20	38	480 h	204,000.00 €	0.00 €
Fase 8	60 d	Tue 12/05/20	Tue 04/08/20	41	480 h	264,000.00 €	0.00 €
Fase 9.1	30 d	Tue 04/08/20	Tue 15/09/20	44	240 h	132,000.00 €	0.00 €
Fase 9.2	30 d	Tue 15/09/20	Tue 27/10/20	47	240 h	132,000.00 €	0.00 €

Figure 33 - MS Project Gantt Chart

3.1.5.2 Primavera P6®

Primavera® is a software for business project management. It includes project management, planning, risk analysis, resource management, collaboration, and control capabilities and integrates with other business software such as Oracle and SAP ERP systems [155].

Oracle Ownership Orchestration (XER) supports all project information, resources, and roles produced using the P6 Professional® or P6 EPPM® tool of project management tools. Primavera PM XER file format allows export data between P6 Professional version 5.0 or later for use in P6 Professional. Contractor XER format is supported for importing data from Contractor 4.0 and later to PM and exporting data to Contractor 5.0 or 6.1 and later.

Primavera XML P6 format allows to share of basic and project information between P6 Professional or P6 EPPM databases. XLS files allow sharing information with other spreadsheet applications. The MPX format allows you to share information with Microsoft Project and integrate with other third-party tools. The Microsoft Project XML format allows sharing information with Microsoft Project 2007, 2010, and 2013. The file format specified during import or export determines the type of information that can be shared [155].

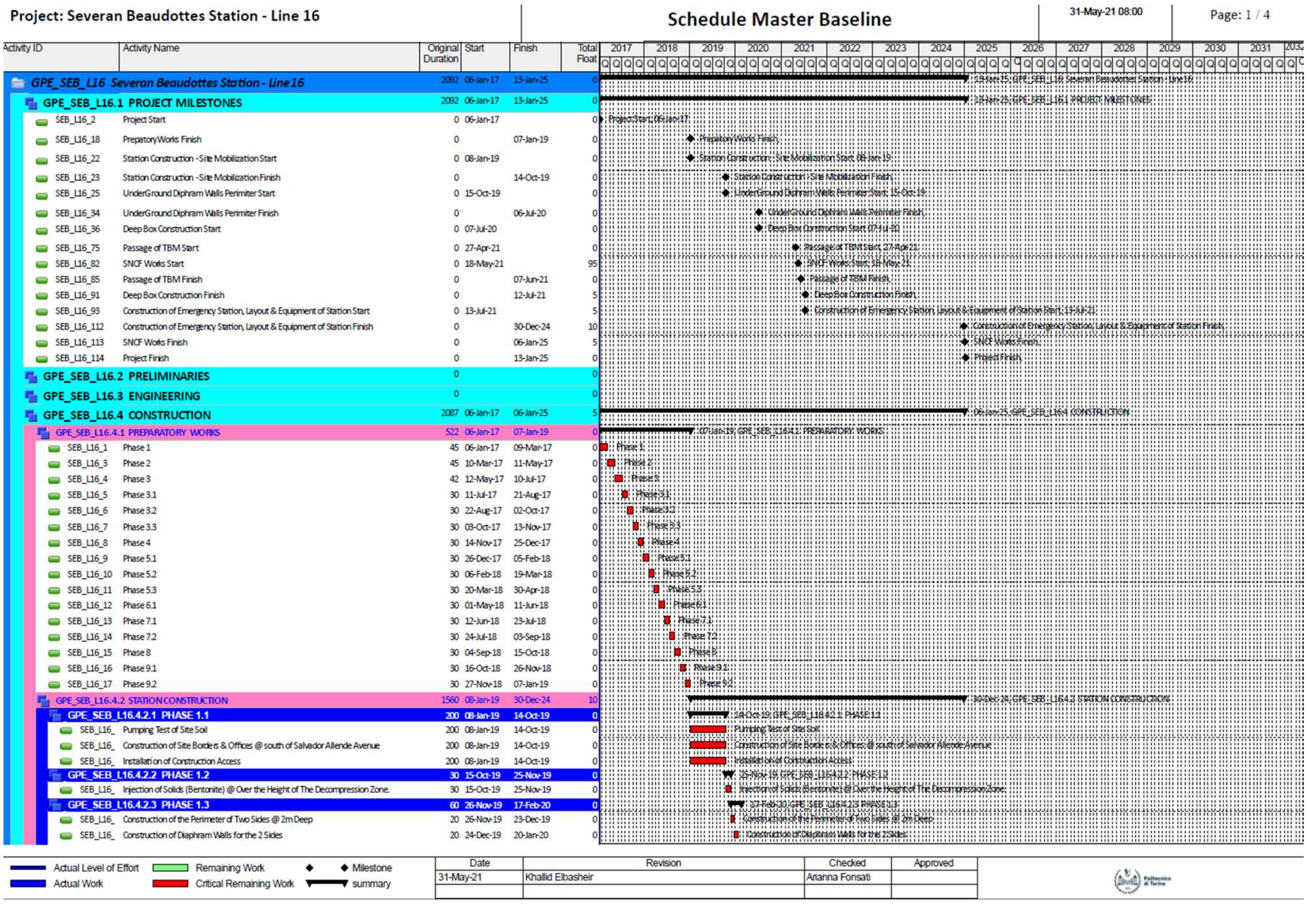


Figure 34 - Primavera P6 Gantt Chart

3.1.6 SCPC Software for Simulation Creation

3.1.6.1 Navisworks®

As mentioned before, Navisworks® is a powerful software for 4D simulations for construction projects. The production of project 4D simulation is done through the Timeliner tool on Navisworks®, a tool that integrates the schedule activities and 3D objects. The process starts by appending the Navisworks® cache files .nwc that was recently exported from Revit®. If another linked model exists or annex structures need to be added, a careful check on location and coordinates should be done. On the Timeliner tool, the schedule should be added using the available formats for Navisworks®, which are Microsoft Project® .mpp, XML formats. Then building hierarchy should be done. The schedule and Gantt chart will appear on the Timeliner tool under the Tasks ribbon. The final process is to attach these tasks to 3D objects on the model. For these operations, there are several methods. Such as Selection and Search Sets and Auto-attach using Rules. In this Thesis, both methods have been explored.

3.1.6.1.1 Selection & Search Sets

Selection and search sets can be added, moved, deleted, and organized into folders. It is possible to update the search and selection combinations. The current selection can be changed in the view of the scene or the current search criteria, and the group's contents can be changed to reflect this. Scene elements and selection trees can be dragged into the group's window to create new selection groups. search sets can be imported from an XML file to use with the model [156].

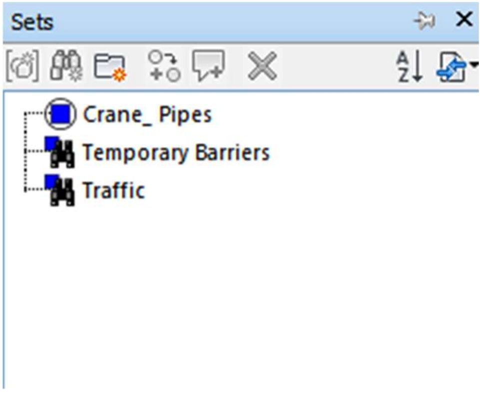


Figure 35 - Navisowrks Sets Dialogue

3.1.6.1.2 Auto-Attach using Rules

It can take a long time to attach tasks manually. If this is the case, it is possible to instantly apply pre-defined and custom rules to attach tasks to objects in the model. It is good practice to use task names that correspond to the selection tree layers or create search and selection groups that correspond to the task names.

3.1.6.1.3 Predefined Rules

Items By Task Name This rule is chosen to connect each geometric component of the show to each action with the indistinguishable title within the wanted column. The default is to utilize the name column.

Selection Sets by Task Name this rule is chosen to join each Selection and Search Set within the demonstrate to each assignment with the indistinguishable title within the wanted column. The default is to utilize the name column.

Layers By Task Name this rule is chosen to connect each layer within the show to each errand with an indistinguishable title within the wanted column. The default is to utilize the Name column.

Attach Items to Task by Category/Property This rule is chosen to join each thing within the show with the characterized property to each errand with the same title within the indicated column. The default is to utilize the Name column; in any case, and to characterize the values [157].

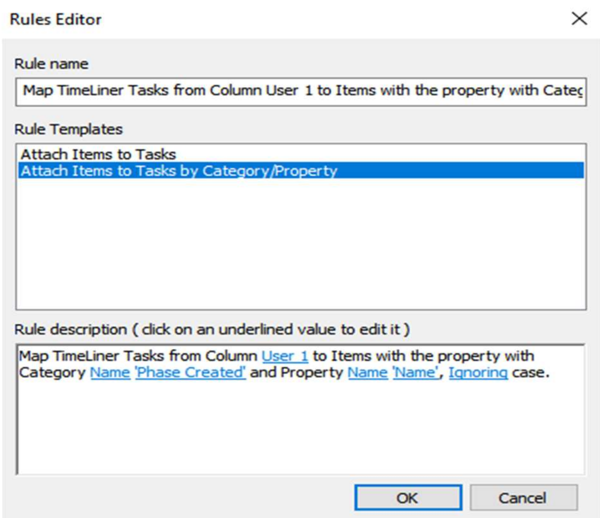


Figure 36 - Navisworks Auto attach using rules editor

3.1.6.2 Synchro Pro®

In addition to Navisworks® as a major software on construction management, also Synchro Pro® plays an important role in the industry due to its powerful features that lead to strong project control and project monitoring. , Synchro Pro® for the function of Construction Simulation has the same features as Navisworks®. The desired Model 3D view can be exported as a Synchro® Project file format thanks to Synchro-pro Plugin. spx. other export methods are mentioned above.

Firstly, the unique feature in Synchro Pro® is that to have a simulation of a 3D object, a 3D resource must be created to enable simulation and attachment to different activities. However, this process leads to a large project file if the model is substantially large and has a lot of elements and families. Concurrently, the project schedule can be imported to Synchro Pro® using many formats. Specifically, Synchro Pro® works perfectly with Asta® Power Project files, and Stand-Alone version of Primavera P6® through its connection to the SQL database, and of course Microsoft Project® .mpp files.

The Assigning methods of 3D resources to schedule tasks are many, but the fastest way is to assign by using Resources to Tasks Auto-matching. In this tool, a rule is made whereby it is used to differentiate and align 3D resources with tasks according to Resources User Fields, corresponding to original Revit® Parameters and Schedule user fields corresponding to a user-field on the schedule file that correlates or match precisely with the Revit Parameters.

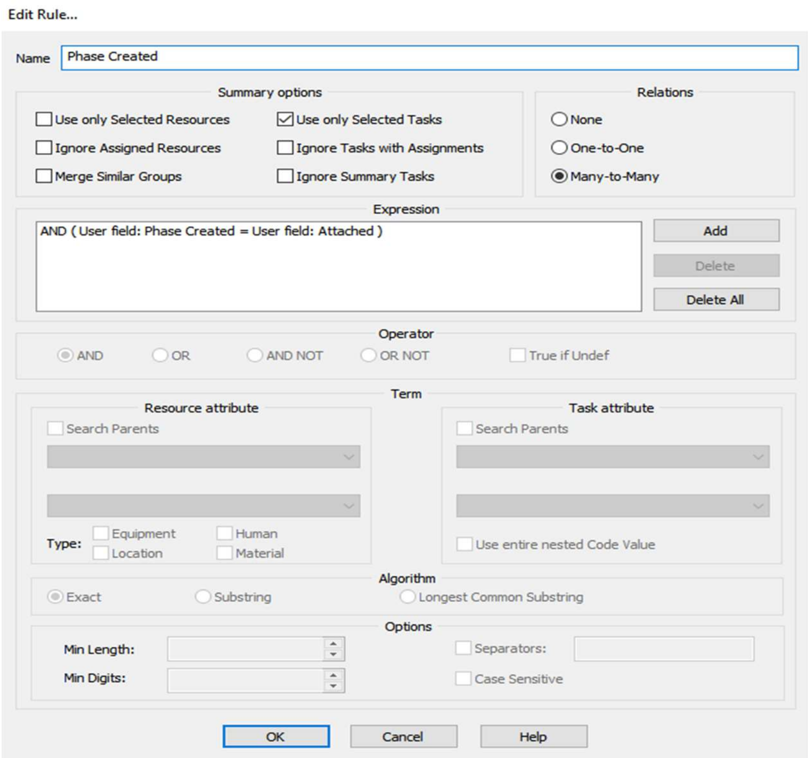


Figure 37 - Synchro Pro rules editor for resources to task assignment

3.1.7 SCPC Software for Clash Detection Test

3.1.7.1 Navisworks

The Clash Detective tool allows the user to search the overall design model, identifying interdisciplinary clashes early in the design process or during construction. This feature is only available to Autodesk Navisworks® Manage users. A set of many tests have been performed on the model. These tests are considered dynamic test because it is conducted between traffic and preparatory works elements in animations of the Timeliner.

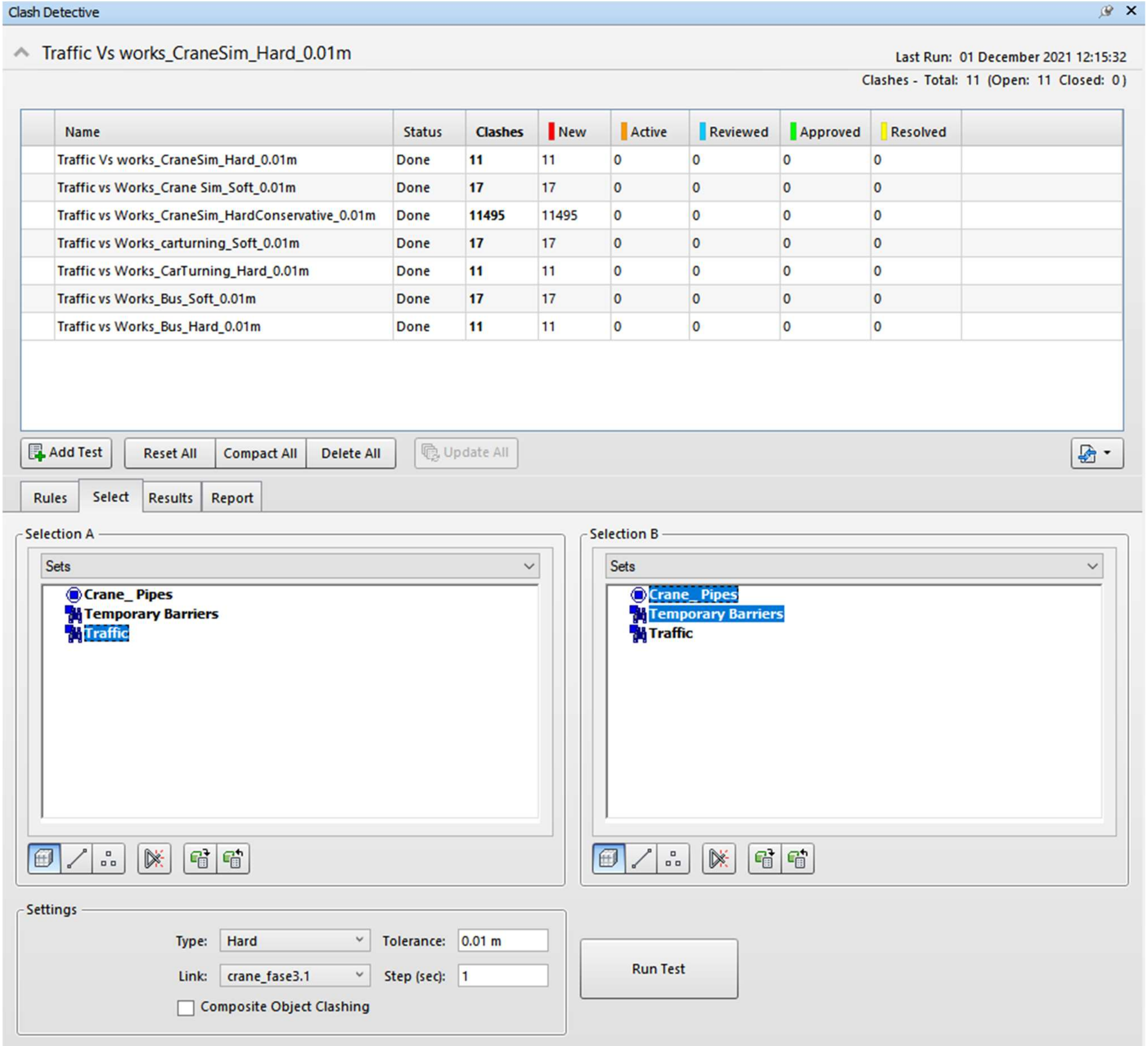


Figure 38 - Navisworks Clash Detective Tool

3.1.7.1.1 Time-Based Soft Clashing

Time-based soft clash combines the functions of TimeLiner, Animator, and Clash Detective. Project templates can include the representation of temporary elements, such as working beams, ships, cranes, fixtures, etc. If static objects are to be used, it is needed to add them to the TimeLiner project and schedule them to appear and disappear in specific locations within a specified period. In addition, it can create dynamic animation scenes so that objects move around the project site, change their size, etc. Once created, these scenes should be linked to the tasks in the TimeLiner project schedule. The appearance or disappearance of fixed objects can prevent moving objects on the site. A gradual time-based commitment setting allows for automated verification throughout the project's life. When a simple time-based clash session is triggered, in each step of the TimeLiner sequence, the Clash Detective is used to check if a clash has occurred. In that case, the date of the engagement will be recorded with the event that caused the clash [158].

Figure 39 - a result of Clash Detection report

3.1.7.2 Synchro Pro®

Clash detection allows verifying the interactions between elements in the model and sharing these problems with other project participants. This ensures that different engineering disciplines can work together, and that construction can occur without coordination problems. Engagement detection is divided into two stages. The primary step is to choose what to test. The moment arranged is the introduction of the comes about after the work has been handled. In Synchro Pro®, the Clash Detection tool allows to detect Dynamic Clash, which means that tests are performed during the simulation of the project. Know the potential encounters that emerge during the simulation of the project. This brings the great advantage of 4D simulation to verify safety during construction resource optimization through virtual working procedures.

For this research, a detection test is conducted between the traffic, which includes any vehicle in the model buildings, against the second object, which are the temporary works performed on the simulation mentioned above. For instance:

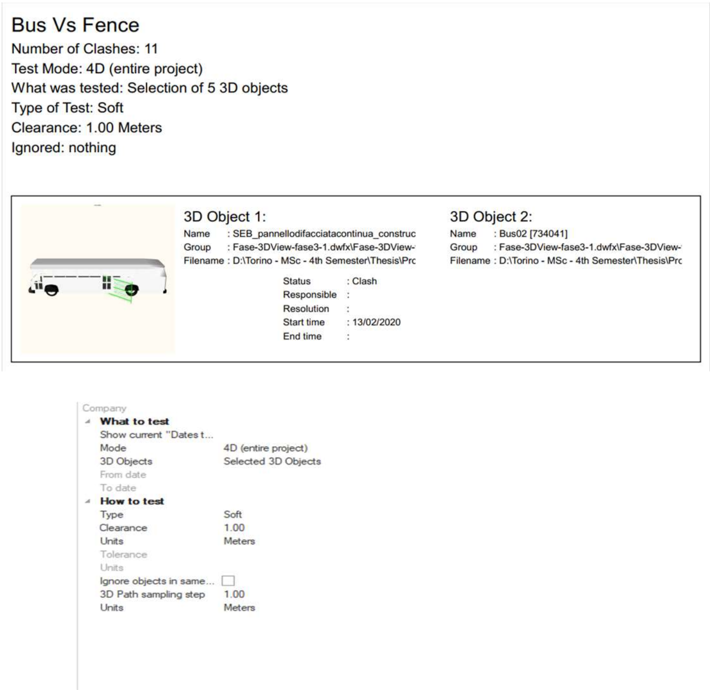


Figure 40 - Synchro Pro Dynamic Clash detection test tool and results

CHAPTER FOUR

4.1 Results

4.1.1 The 4D simulation comparison

The presence of 4D digital environments contributes to creating construction processes that reduce waste of materials, time, and effort and generate the most significant possible economic value in fulfilling customer demands. Moreover, improving interoperability would also improve the quality of project implementation for a construction company.

The case study review shows that BIM technology brings many advanced construction management capabilities for project scheduling, cost estimating, and even project control by contractors. In concrete terms, the project manager will have access to flexible construction schedules methodologies that can be stored in a database to be available for the automatic generation of the construction schedules in other similar projects. These robust workflows allow the project manager to control the project and achieve maximum efficiency of the process, which in the end, results in lower costs, improves safety risks mitigation, and a shorter execution period, which benefits all stakeholders and the industry.

Figure 41 - Navisworks Simulation Video

Figure 42 - Synchro Pro Simulation Video

4D Simulation Comparisons		
Program	**Navisworks®**	**Synchro Pro®**
Video Compression & Resolution	Microsoft Video 1, Compression quality 80%, width:1920, Height; 1080, Frame per seconds (FPS): 24, Anti-Aliasing: 2x.	Xvid MPEG-4 Codec width:1920, Height; 1080, Frame per seconds (FPS): 24, Anti-Aliasing: 2x.
Video length	2 minutes	2 minutes
Details Appearance on Video	Tasks as per Timeliner, cost Cash-Flow as per Timeliner, and legend of appearance profiles.	Tasks but rigid as just a picture, legend of appearance profiles, Gantt Chart but rigid as a picture, and 3D resources List.
Processing Time	60 minutes*	30 minutes*

* The processing time is fundamentally based on the computer's capabilities of the author.

Table 3 - 4D Simulation Results Comparison

4.1.2 The clash detection results comparison

Navisworks® and Synchro Pro® enable interference detection validation precise interference checking and are an essential step in identifying and resolving problems while still in the design stage. This avoids wasting time and additional costs to be incurred in detecting critical issues on an open construction site.

Within the case study beneath examination, the location of dynamic engagement was an instrument of crucial significance. A preliminary analysis of the interaction between traffic brief and metropolitan works was carried out. This made it conceivable to highlight all the underground structures captured by the unearthing and draw up an arrangement to arrange the deviations. Navisworks® empowers obstructions discovery approval exact impedances checking and is a fundamental step in recognizing and resolving problems whereas still within the plan arrange. This maintains a strategic distance from sitting around idly and extra costs to be brought about in recognizing fundamental issues on an open development location.

The differences between the two workflows appear in the animations considered, although both programs can test opposing objects through the animation timeline. However, Navisworks® provides a specific ability to test conflicting objects in certain animations. Conversely, Synchro Pro® only allows testing of conflicting objects in a snapshot of focus time (e.g., 4D Simulation).

Dynamic Clash Detection Comparisons			
Program	**Test Characteristics**	**Time Based Soft Clashing**	**Time Based Hard Clashing**
Navisworks®	Object 1: Traffic Object 2: Temporary Works Tolerance: 0.01 m Animation: TimeLiner Animations	Clearance: 0.01 m Average Number of clashes: **17**	Tolerance: 0.01 m Average Number of Clashes: **11**
Synchro Pro®	Object 1: Traffic Object 2: Temporary Works Tolerance: 0.01 m Animation: 4D Simulations	Clearance: 0.01 m Average Number of clashes: **11**	Tolerance: 0.01 m Average Number of clashes: **4**

Table 4 - Dynamic Clash Detection Results Comparison

It can be clear that the additional specifics of Navisworks provide a more significant number of clashes due to dynamic testing clashes in detailed animations of the simulation, whereas Synchro Pro provides testing throughout the 4D simulation or a snapshot of focus time, hence the smaller number of clashes.

4.1.3 AHP method

The analytic hierarchy process (AHP) [159], The Analytical Hierarchy Process may be an organized method for organizing and analyzing complex choices based on science and psychology. Created by Thomas L. Saaty within the 1970s, Saaty collaborated with Ernest Forman to create the Master Choice program in 1983, and AHP has experienced broad investigation and refinement ever since. It represents a rigorous approach to determining the weights of decision criteria. Each participant compares the relative importance of each pair of elements using a specially designed questionnaire. The experiences of individual experts are used to estimate the relative amounts of factors through pairwise comparisons.

Decision-making situations that an AHP can be applied to include:

- Choice - choosing an alternative from a given set of alternatives, usually when multiple decision criteria are involved.
- Sort - Sort several alternatives from most to least desirable.
- Prioritizing: determining the comparative advantage of members of a group of alternatives, rather than selecting one or simply rating them
- Allocate resources: Allocate resources from a range of alternatives
- Benchmarking - compare the processes in your organization with those of other leading organizations.
- Quality management - managing the multidimensional aspects of quality and quality improvement.
- Conflict Resolution - Resolving disagreements between parties with seemingly incompatible goals or positions.

As can be seen within the material that takes after [159], The use of AHP involves the mathematical synthesis of different judgments on the decision problem in question. It is not uncommon for such judgments to come across dozens or even hundreds. Although calculations can be done manually or with a calculator, it is common to use one of several computerized methods to enter and synthesize judgments. The simpler ones involve standard spreadsheet software, while the more complex ones use ad hoc software, often enhanced by special hardware to obtain judgments from decision-makers gathered in the conference room.

The procedure for using AHP is summarized as follows:

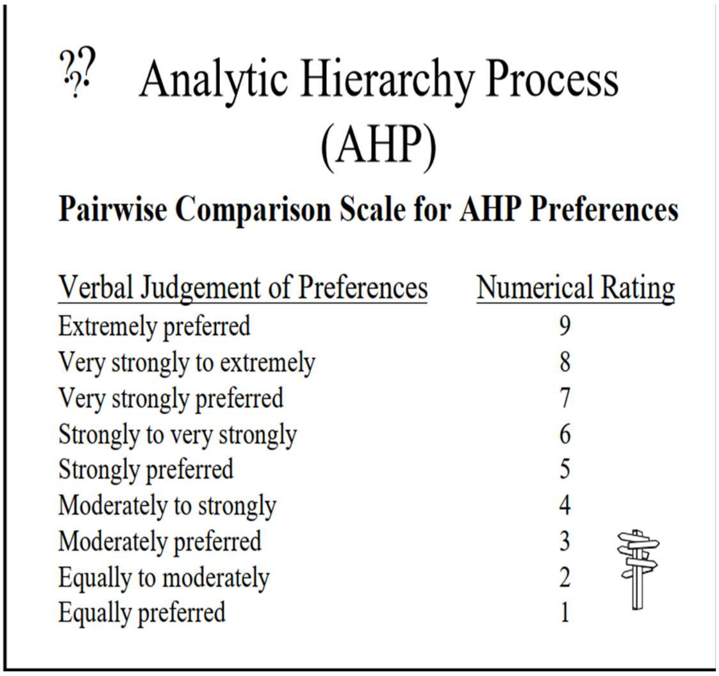
- Modeling the problem in the form of a hierarchy containing the goal of the decision, the alternatives to achieve it, and the criteria for evaluating the alternatives.
- They prioritized among the hierarchy elements by formulating a series of judgments based on binary comparisons of the elements. For example, investors might say they prefer location over price and price over timing when comparing potential commercial property purchases.
- Aggregate these provisions to produce a set of general priorities for a hierarchy. This will combine investors' judgments about the location, price, and timing of properties A, B, C, and D into the overall priorities of each property.
- Check the consistency of sentences.

Make a final decision based on the results of this process.

4.1.4 AHP Criteria

The decision-making process of the optimum workflow through the AHP method requires the selection of criteria upon which the ranking is made. For the case study, different criteria have been chosen, for example, the time in minutes required to perform each task of the workflow, and this results in sub-criteria such as Revit exporting time, Task Assignment Time, Shared Parameter, Rendering & animation time, and dynamic clash detection time. The other criteria include No. of formats for Import/Export, Cost of the BIM Platform, Information Modelling Share, and customization.

4.1.4.1 Step 1: Pairwise Comparison


Analytic Hierarchy Process (AHP)

Pairwise Comparison Scale for AHP Preferences

Verbal Judgement of Preferences	Numerical Rating
Extremely preferred	9
Very strongly to extremely	8
Very strongly preferred	7
Strongly to very strongly	6
Strongly preferred	5
Moderately to strongly	4
Moderately preferred	3
Equally to moderately	2
Equally preferred	1

Figure 43 - Rating of AHP preferences

4.1.4.1.1 Pairwise comparison matrix (for each attribute)

Time				
	Option 1	**Option 2**	**Option 3**	**Option 4**
Option 1	1.00	0.11	0.11	0.11
Option 2	9.00	1.00	0.33	0.33
Option 3	9.00	3.00	1.00	0.50
Option 4	9.00	3.00	2.00	1.00
	28.00	7.11	3.44	1.94

Table 5 - Time criteria pairwise matrix

No. of Formats for Import/Export				
	Option 1	Option 2	Option 3	Option 4
Option 1	1.00	0.50	0.50	0.20
Option 2	2.00	1.00	1.00	0.20
Option 3	2.00	1.00	1.00	0.20
Option 4	5.00	5.00	5.00	1.00
	10.00	7.50	7.50	1.60

Table 6 - Import/Export Formats criteria pairwise matrix

Cost				
	Option 1	Option 2	Option 3	Option 4
Option 1	1.00	4.00	1.00	2.00
Option 2	0.25	1.00	0.25	1.00
Option 3	1.00	4.00	1.00	3.00
Option 4	0.50	1.00	0.33	1.00
	2.75	10.00	2.58	7.00

Table 7 - Cost of BIM platform criteria pairwise matrix

Information Modelling Share				
	Option 1	Option 2	Option 3	Option 4
Option 1	1.00	0.11	0.11	0.11
Option 2	9.00	1.00	1.00	1.00
Option 3	9.00	1.00	1.00	1.00
Option 4	9.00	1.00	1.00	1.00
	28.00	3.11	3.11	3.11

Table 8 - Information Sharing criteria pairwise matrix

Customization				
	Option 1	Option 2	Option 3	Option 4
Option 1	1.00	0.50	0.50	0.20
Option 2	2.00	1.00	1.00	0.20
Option 3	2.00	1.00	1.00	0.20
Option 4	5.00	5.00	5.00	1.00
	10.00	7.50	7.50	1.60

Table 9 - Customization criteria pairwise matrix

4.1.4.1.2 Pairwise comparison matrix (for the criteria)

Criteria					
	Time	Number of Formats for Import/Export	Cost	Information Modelling Share	Customization
Time	1	0.5	0.17	0.5	0.5
Number of Formats for Import/Export	2	1	0.17	1	1
Cost	6	6	1.00	6	6
Information Modelling Share	2	1	0.17	1	1
Customization	2	1	0.17	1	1
	13	9.5	1.67	9.5	9.5

Table 10 - Criteria pairwise matrix

4.1.4.2 Step 2: Synthesize judgments:

4.1.4.2.1 Normalized pairwise comparison matrix and relative priorities

Normalized Pairwise Matrices					
Time					
	Option 1	**Option 2**	**Option 3**	**Option 4**	**Relative Priorities**
Option 1	0.04	0.02	0.03	0.06	0.04
Option 2	0.32	0.14	0.10	0.17	0.18
Option 3	0.32	0.42	0.29	0.26	0.32
Option 4	0.32	0.42	0.58	0.51	0.46
					1.00

Table 11 - Time Normailized pairwise matrix

No. of Formats for Import/Export					
	Option 1	**Option 2**	**Option 3**	**Option 4**	**Relative Priorities**
Option 1	0.10	0.07	0.07	0.13	0.09
Option 2	0.20	0.13	0.13	0.13	0.15
Option 3	0.20	0.13	0.13	0.13	0.15
Option 4	0.50	0.67	0.67	0.63	0.61
					1.00

Table 12 - Import/Export Normalized pairwise matrix

Cost					
	Option 1	**Option 2**	**Option 3**	**Option 4**	**Relative Priorities**
Option 1	0.36	0.40	0.39	0.29	0.36
Option 2	0.09	0.10	0.10	0.14	0.11
Option 3	0.36	0.40	0.39	0.43	0.39
Option 4	0.18	0.10	0.13	0.14	0.14
					1.00

Table 13 - Cost of BIM Platform Normalized pairwise matrix

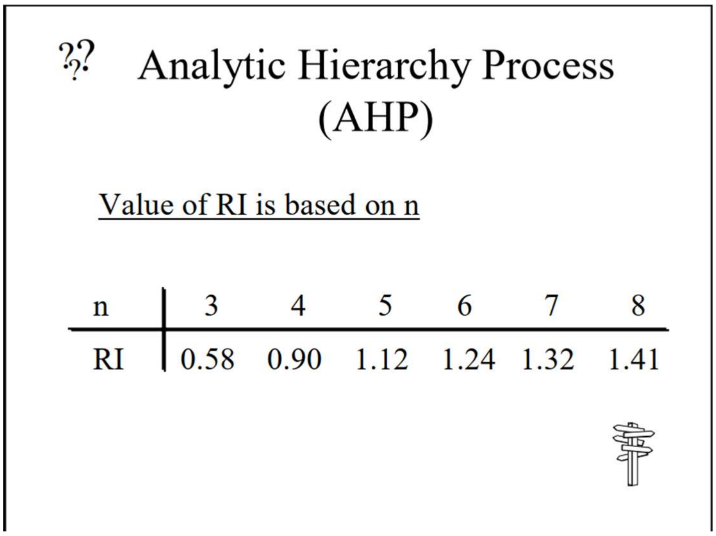
Information Modelling Share					
	Option 1	**Option 2**	**Option 3**	**Option 4**	**Relative Priorities**
Option 1	0.04	0.04	0.04	0.04	0.04
Option 2	0.32	0.32	0.32	0.32	0.32
Option 3	0.32	0.32	0.32	0.32	0.32
Option 4	0.32	0.32	0.32	0.32	0.32
					1.00

Table 14 - Information Share Normalized pairwise matrix

Customization					
	Option 1	**Option 2**	**Option 3**	**Option 4**	**Relative Priorities**
Option 1	0.10	0.07	0.07	0.13	0.09
Option 2	0.20	0.13	0.13	0.13	0.15
Option 3	0.20	0.13	0.13	0.13	0.15
Option 4	0.50	0.67	0.67	0.63	0.61
					1.00

Table 15 - Customization Normailized pairwise matrix

4.1.4.2.2 Consistency Check:



Time									
multiply pairwise with relative priorities				**weighted sum**	**divide sum with priorities**	**average λ**	**CI**	**CR**	
0.04	0.02	0.04	0.05	0.14	4.05	4.221	0.074	0.082	**Consistent**
0.32	0.18	0.11	0.15	0.76	4.16				
0.32	0.55	0.32	0.23	1.42	4.39				
0.32	0.55	0.65	0.46	1.97	4.29				

Table 16 - Time Criteria Consistency Check

No. of Formats for Import/Export									
multiply pairwise with relative priorities				**weighted sum**	**divide sum with priorities**	**average λ**	**CI**	**CR**	
0.09	0.07	0.07	0.12	0.36	4.02	4.061	0.020	0.023	**Consistent**
0.18	0.15	0.15	0.12	0.60	4.04				
0.18	0.15	0.15	0.12	0.60	4.04				
0.45	0.74	0.74	0.61	2.54	4.14				

Table 17 - Import/Export Formats Criteria Consistency Check

Cost									
multiply pairwise with relative priorities				**weighted sum**	**divide sum with priorities**	**average λ**	**CI**	**CR**	
0.36	0.43	0.39	0.28	1.46	4.07	4.046	0.015	0.017	**Consistent**
0.09	0.11	0.10	0.14	0.43	4.04				
0.36	0.43	0.39	0.42	1.60	4.05				
0.18	0.11	0.13	0.14	0.56	4.03				

Table 18 - Cost of BIM Platform Criteria Consistency Check

Information Modelling Share									
multiply pairwise with relative priorities				**weighted sum**	**divide sum with priorities**	**average λ**	**CI**	**CR**	
0.04	0.04	0.04	0.04	0.14	4.00	4.000	0.000	0.000	**Consistent**
0.32	0.32	0.32	0.32	1.29	4.00				
0.32	0.32	0.32	0.32	1.29	4.00				
0.32	0.32	0.32	0.32	1.29	4.00				

Table 19 - Information Sharing Criteria Consistency Check

Customization									
multiply pairwise with relative priorities				**weighted sum**	**divide sum with priorities**	**average λ**	**CI**	**CR**	
0.09	0.07	0.07	0.12	0.36	4.02	4.061	0.020	0.023	**Consistent**
0.18	0.15	0.15	0.12	0.60	4.04				
0.18	0.15	0.15	0.12	0.60	4.04				
0.45	0.74	0.74	0.61	2.54	4.14				

Table 20 - Customization Criteria Consistency Check

4.1.5 AHP results

Final Overall Priorities (Ranks)		
Option	**Priority**	**Rank**
Workflow 3	0.325	1
Workflow 4	0.289	2
Workflow 1	0.239	3
Workflow 2	0.146	4

Table 21 - Final Ranking of Workflow Patterns

4.1.6 AHP Results Documentation:

Benefiting from the great advantage of Autodesk Revit in customization and plug-in creations. The result of this research study has been documented in a Revit Add-in that summarizes the methodological approach for each workflow based on this thesis study.

4.1.7 Assessment Tool Add-in

The Assessment Tool represents the selection process of each of the workflows conducted on this thesis. As a result of the user selection, printed documentation of the workflow pattern will be visualized, indicating the processes and steps required to complete 4D BIM results.

4.1.7.1 Revit API

. NET provides a rich and powerful API that can automate repetitive tasks, extend core Revit functions in simulation, conceptual design, build and build management, and more. The Revit .NET API allows programming in any .NET compatible language, including VB.NET, C#, and C++/CLI. The SDK provides comprehensive .NET code examples and documentation to help you develop using the Revit API [160].

4.1.7.2 Visual Studio Community: Coding with C#

Microsoft Visual Studio is a coordinates improvement environment (IDE) from Microsoft. It is utilized to create computer programs and websites, web applications, web services, and mobile applications. Visual Studio uses Microsoft software development platforms such as Windows API, Windows Forms, Windows Presentation Foundation, Windows Store, and Microsoft Silverlight. It can deliver both local and overseen code.

API stands for Application Programming Interface - how a software programmer can communicate with a software product. For example, the Revit API allows programmers to work with Revit and defines the functions that a software programmer can use within Revit. How Revit API allows you to write Revit application instructions one by one.

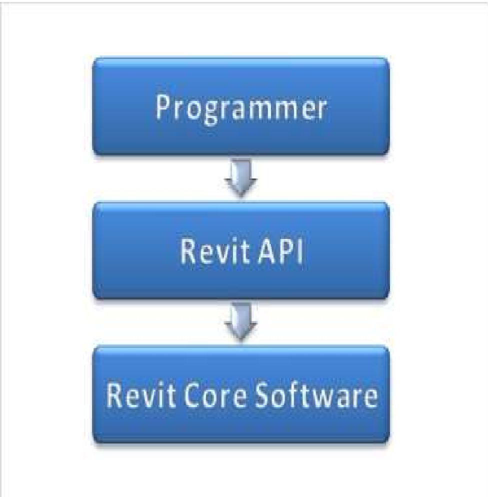


Figure 44 - Revit API framework

A software plug-in A type of software unit (or file) that adds functionality to a software product, typically in the form of a command that automates a task or customization of the product's behavior. When we talk about a Revit plug-in and hear the term add-on used for this product, we mean the unit containing the code that uses the Revit API. Revit loads these plug-ins and uses them to adjust their behavior under certain conditions, such as when the plug-in user executes a specific command [161].

Using a Revit add-in template provided by **Jeremy Tammik** [162], Who is The Building Coder and 3D Web Coder. A prolific author passionate about collaboration and sharing works with Forge's partner development team on Autodesk APIs. The module provides quick communication between Visual Studio and the Revit API, making it easier for the developer to devote himself to writing the code for the add-in.

The add-in could be presented with the following flow-chart:

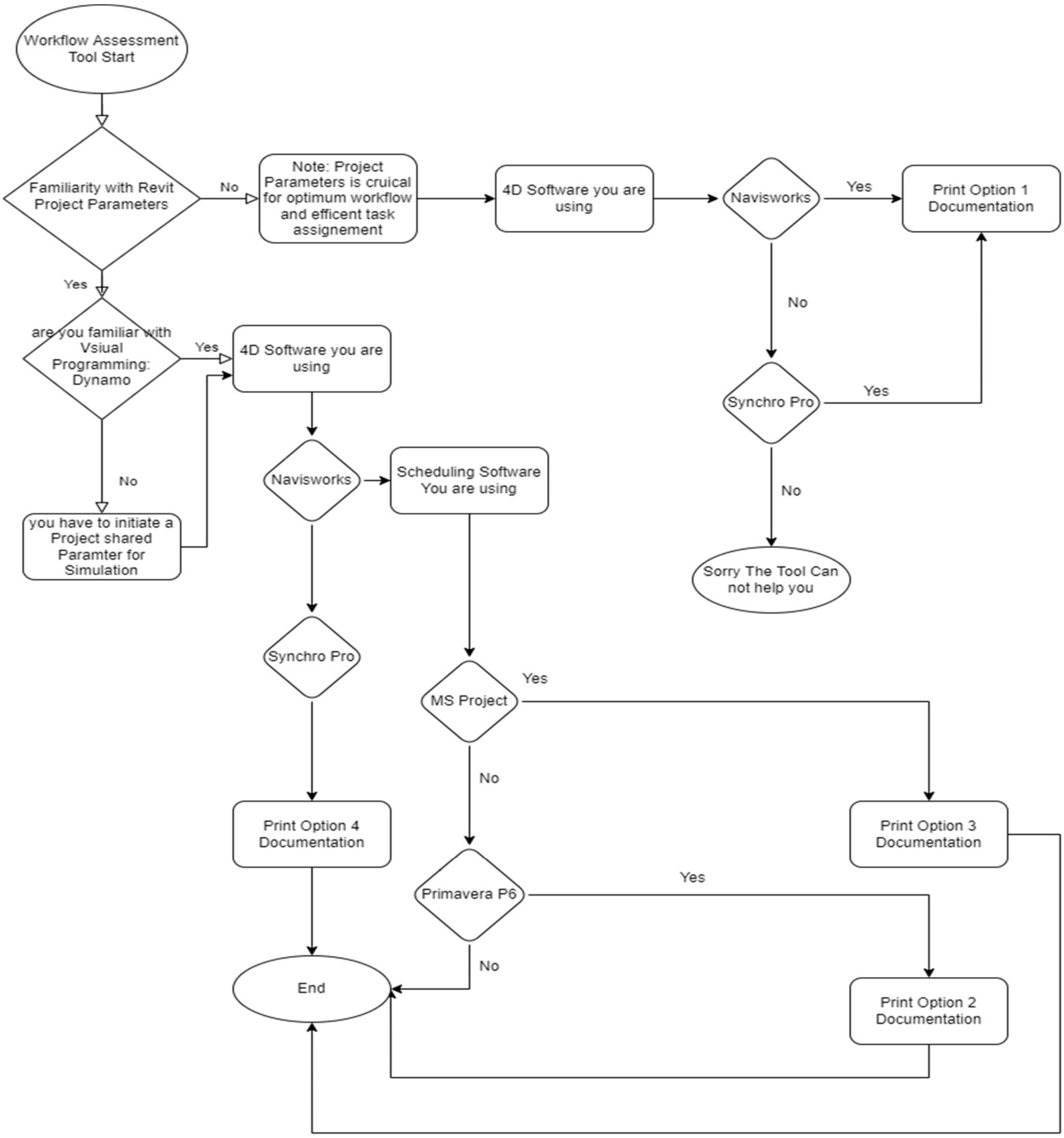


Figure 45 - Assessment Tool Plugin Flow-Chart

The following images represent the add-in function once the code is started:

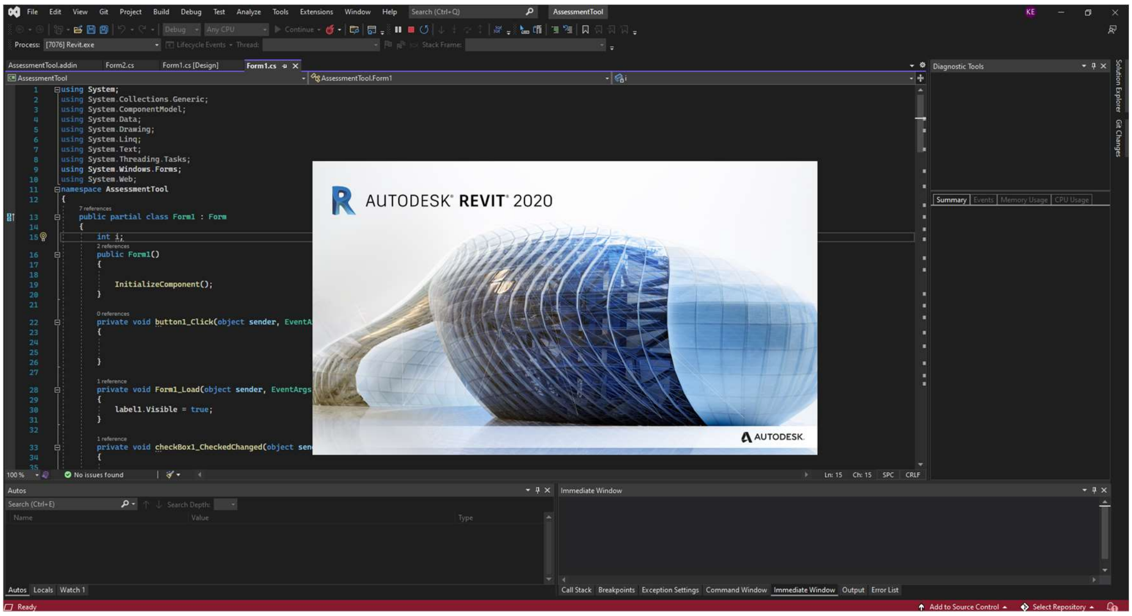


Figure 46 - Visual Studio after running the Plugin code

Visual Studio will communicate with Revit API to force open the software.

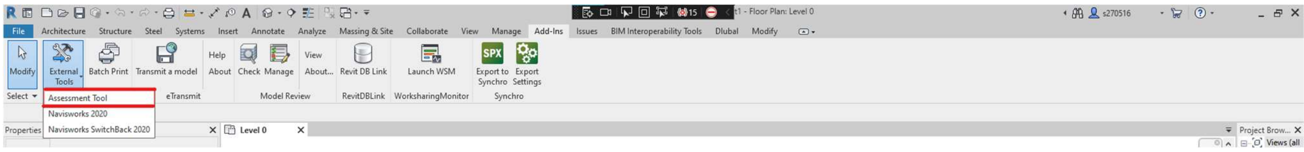


Figure 47 - Plugin location on Revit

Under the Add-in Ribbon in Revit, on External Tools, the Assessment Tool Add-in can be seen as part of the add-ins.

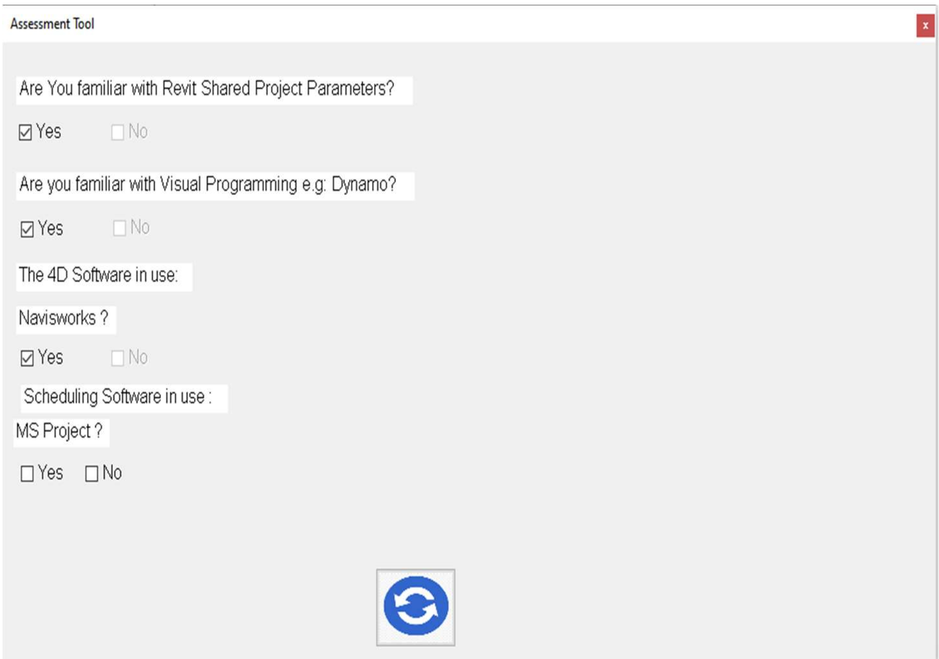
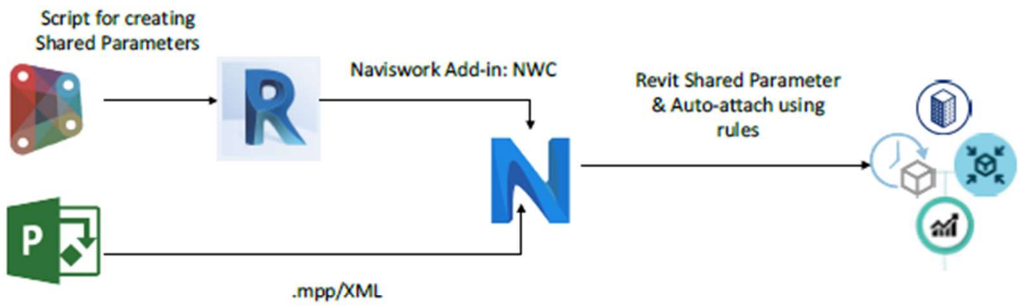


Figure 48 - Details of the Assessment Tool

"This Documentation is based on the research thesis conducted by Khalid Elbasheir, a M.Sc. student at Politecnico di Torino, under the supervision of Prof. Anna Osello & Arch. Arianna Fonsati."

Documentation of 4D BIM - Workflow Pattern

Option 3:



1. In Revit, create a Shared parameter that corresponds to Simulation tasks available in your schedule. Using Dynamo, this process is fast and do not take much time.
2. In Dynamo, start a new script, you would need to install two packages from the server named DataShapes and PracticalBIM, now, your script would depend on what element category you want to simulate, if the project has a detailed WBS this process is clear. If project has construction phases, you can use these phases to create your simulation parameter. If not, you have to use Slabs and ground levels to automate the simulation parameter. The dynamo scripting is very customisable according to your case.
3. Export the desired model in NWC (Navisworks Cache) format, it is advised to use the Existing Navisworks Plugin in Revit.
4. In Navisworks, Append the Model, all geometry and properties associated with the model should be appended if the export process is well done, If another linked model existed or there are annex structures needs to be added, a careful check on location and coordinates should be done.
5. On the Timeliner tool, add your Microsoft project schedule .mpp format or XML format. Then rebuild task hierarchy.
6. Now, using auto-assignment rules tool available in TimeLiner, attach your shared Parameter with corresponding task ID or WBS code.
7. Play the animation.

"According to the Research Thesis conducted in Politecnico di Torino, this method achieved a Score of 0.3254 on the AHP (Analytical Hierarchy Process) method scale, and it is ranked on number 1 out of 4 workflow patterns."

Figure 49 - Documentation of the workflow pattern chosen based on the assessment tool

CHAPTER FIVE

5.1 Conclusions & Recommendations

4D Automation Simulation is a productive tool for the planning process. It can reduce uncertainty about construction processes, increase the visibility of construction workflows, and support the detection of potential conflicts and safety risks on a construction site.

However, due to the high degree of dependency on workflows, slight errors in any part of the workflow affects the entire process and results. The results of this Thesis showed that using visual programming applications such as **Dynamo®** may reduce these errors to a great extent while saving production time.

The results showed that the construction planning process could be automated to a large extent. The proposed workflow patterns can achieve significant savings in time and cost. It was observed that the efficiency of workflow patterns depends on:

- The BIM platform used.
- The time required by the BIM practitioner to complete the 4D BIM simulation.
- Interoperability and information sharing.

4D modelling can end up essential back since 3D assets (human assets, equipment, spaces, and materials) are connected to arranged exercises, permitting simpler administration of development groupings and any varieties. The result could be a more productive, solid, and secure work preparation, which adjusts well with all stages of comprehensive management, sparing time and money. A master designer and company specialist can take advantage of all levels of control 4D can accomplish, connecting personability and aptitudes to ICT capabilities, computing control, data sharing, versatile modalities, and expanded reality applications. However, it is fundamental to keep in mind that in case, on the one hand, innovative development permits modern quality measures to become to, on the other hand, it is fundamental not to disregard that those who utilize these assets are experts within the development segment with involvement and total preparing.

In future research, it is recommended to include testing the proposed workflow patterns on different-functions construction projects inefficiency and practical applicability. In addition, it includes assessing the 4D/5D federated models with updated schedules from the as-built site during the project's life cycle to monitor and control the project. Lastly, it is advisable to examine the assessment tool Plug-in developed during this research through testing by BIM and Non-BIM practitioners to develop a valuable overview of the workflow pattern efficiency.

The author would like to point out that this research highlights the efficiency of BIM workflows that can occur in real applications when dealing with different BIM tools and is not focused on assessing any quality of a particular or all BIM software used during the research.

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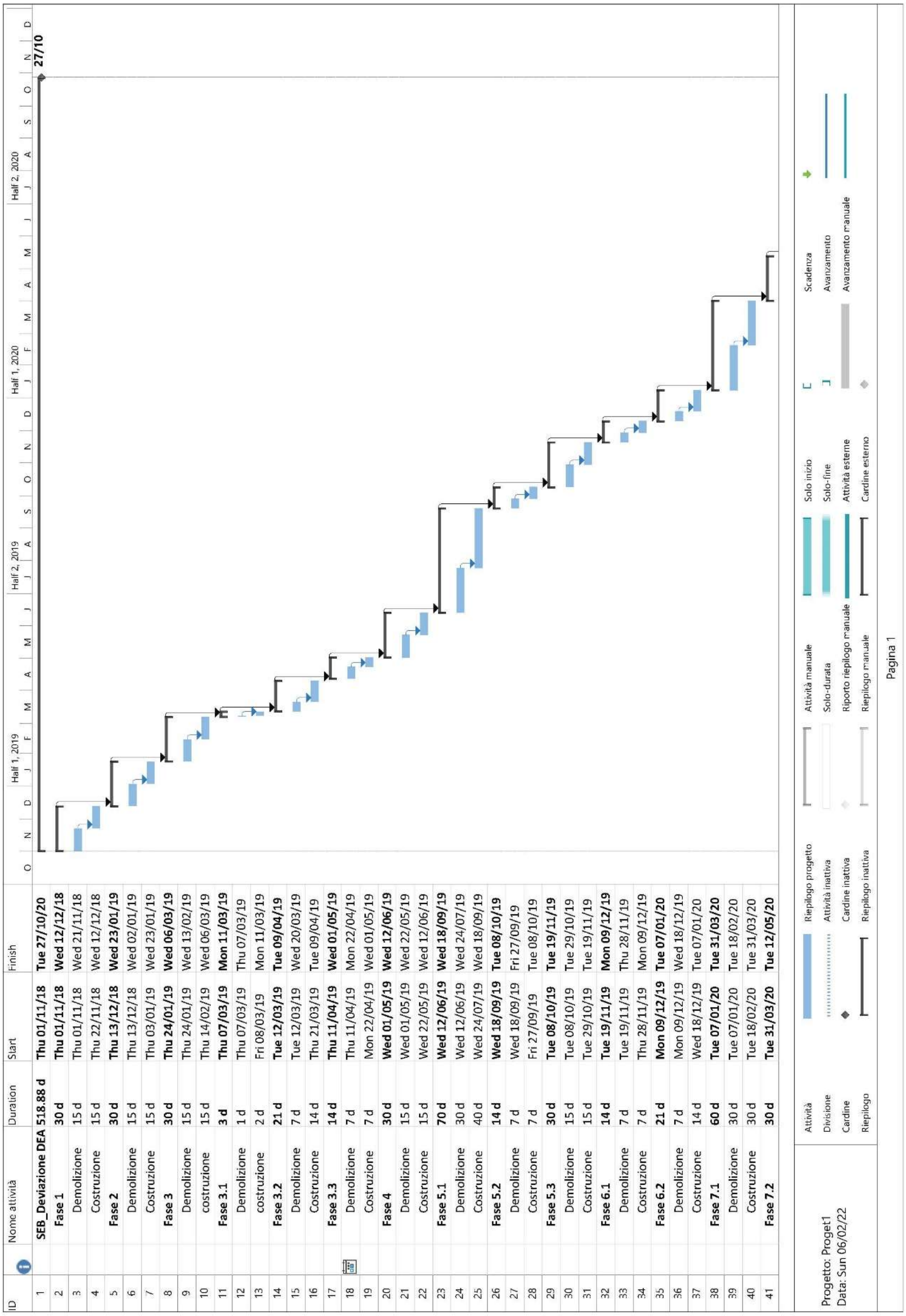
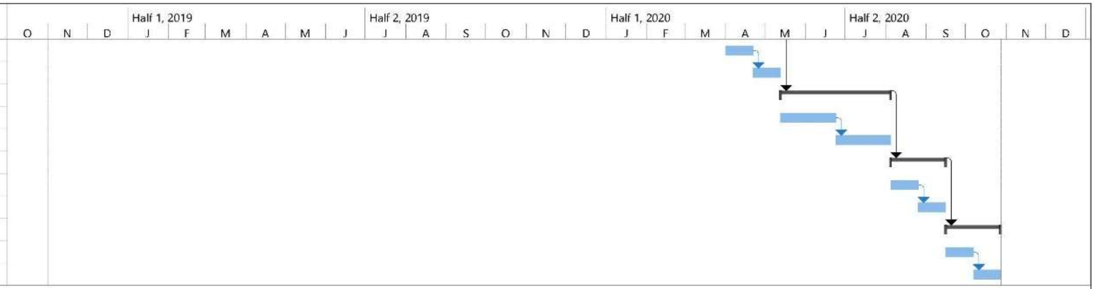
APPENDICES

MS Project Gantt Chart

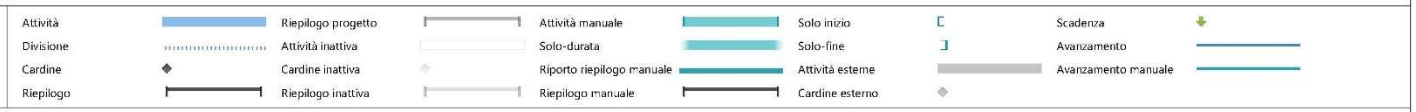


ID	Nome attività	Duration	Start	Finish
1	**SEB_Deviazione DEA**	**518.88 d**	**Thu 01/11/18**	**Tue 27/10/20**
2	**Fase 1**	**30 d**	**Thu 01/11/18**	**Wed 12/12/18**
3	Demolizione	15 d	Thu 01/11/18	Wed 21/11/18
4	Costruzione	15 d	Thu 22/11/18	Wed 12/12/18
5	**Fase 2**	**30 d**	**Thu 13/12/18**	**Wed 23/01/19**
6	Demolizione	15 d	Thu 13/12/18	Wed 02/01/19
7	Costruzione	15 d	Thu 03/01/19	Wed 23/01/19
8	**Fase 3**	**30 d**	**Thu 24/01/19**	**Wed 06/03/19**
9	Demolizione	15 d	Thu 24/01/19	Wed 13/02/19
10	costruzione	15 d	Thu 14/02/19	Wed 06/03/19
11	**Fase 3.1**	**3 d**	**Thu 07/03/19**	**Mon 11/03/19**
12	Demolizione	1 d	Thu 07/03/19	Thu 07/03/19
13	costruzione	2 d	Fri 08/03/19	Mon 11/03/19
14	**Fase 3.2**	**21 d**	**Tue 12/03/19**	**Tue 09/04/19**
15	Demolizione	7 d	Tue 12/03/19	Wed 20/03/19
16	Costruzione	14 d	Thu 21/03/19	Tue 09/04/19
17	**Fase 3.3**	**14 d**	**Thu 11/04/19**	**Wed 01/05/19**
18	Demolizione	7 d	Thu 11/04/19	Mon 22/04/19
19	Costruzione	7 d	Mon 22/04/19	Wed 01/05/19
20	**Fase 4**	**30 d**	**Wed 01/05/19**	**Wed 12/06/19**
21	Demolizione	15 d	Wed 01/05/19	Wed 22/05/19
22	Costruzione	15 d	Wed 22/05/19	Wed 12/06/19
23	**Fase 5.1**	**70 d**	**Wed 12/06/19**	**Wed 18/09/19**
24	Demolizione	30 d	Wed 12/06/19	Wed 24/07/19
25	Costruzione	40 d	Wed 24/07/19	Wed 18/09/19
26	**Fase 5.2**	**14 d**	**Wed 18/09/19**	**Tue 08/10/19**
27	Demolizione	7 d	Wed 18/09/19	Fri 27/09/19
28	Costruzione	7 d	Fri 27/09/19	Tue 08/10/19
29	**Fase 5.3**	**30 d**	**Tue 08/10/19**	**Tue 19/11/19**
30	Demolizione	15 d	Tue 08/10/19	Tue 29/10/19
31	Costruzione	15 d	Tue 29/10/19	Tue 19/11/19
32	**Fase 6.1**	**14 d**	**Tue 19/11/19**	**Mon 09/12/19**
33	Demolizione	7 d	Tue 19/11/19	Thu 28/11/19
34	Costruzione	7 d	Thu 28/11/19	Mon 09/12/19
35	**Fase 6.2**	**21 d**	**Mon 09/12/19**	**Tue 07/01/20**
36	Demolizione	7 d	Mon 09/12/19	Wed 18/12/19
37	Costruzione	14 d	Wed 18/12/19	Tue 07/01/20
38	**Fase 7.1**	**60 d**	**Tue 07/01/20**	**Tue 31/03/20**
39	Demolizione	30 d	Tue 07/01/20	Tue 18/02/20
40	Costruzione	30 d	Tue 18/02/20	Tue 31/03/20
41	**Fase 7.2**	**30 d**	**Tue 31/03/20**	**Tue 12/05/20**

ID		Nome attività	Duration	Start	Finish
42		Demolizione	15 d	Tue 31/03/20	Tue 21/04/20
43		Costruzione	15 d	Tue 21/04/20	Tue 12/05/20
44		**Fase 8**	**60 d**	**Tue 12/05/20**	**Tue 04/08/20**
45		Demolizione	30 d	Tue 12/05/20	Tue 23/06/20
46		Costruzione	30 d	Tue 23/06/20	Tue 04/08/20
47		**Fase 9.1**	**30 d**	**Tue 04/08/20**	**Tue 15/09/20**
48		Demolizione	15 d	Tue 04/08/20	Tue 25/08/20
49		Costruzione	15 d	Tue 25/08/20	Tue 15/09/20
50		**Fase 9.2**	**30 d**	**Tue 15/09/20**	**Tue 27/10/20**
51		Demolizione	15 d	Tue 15/09/20	Tue 06/10/20
52		Costruzione	15 d	Tue 06/10/20	Tue 27/10/20

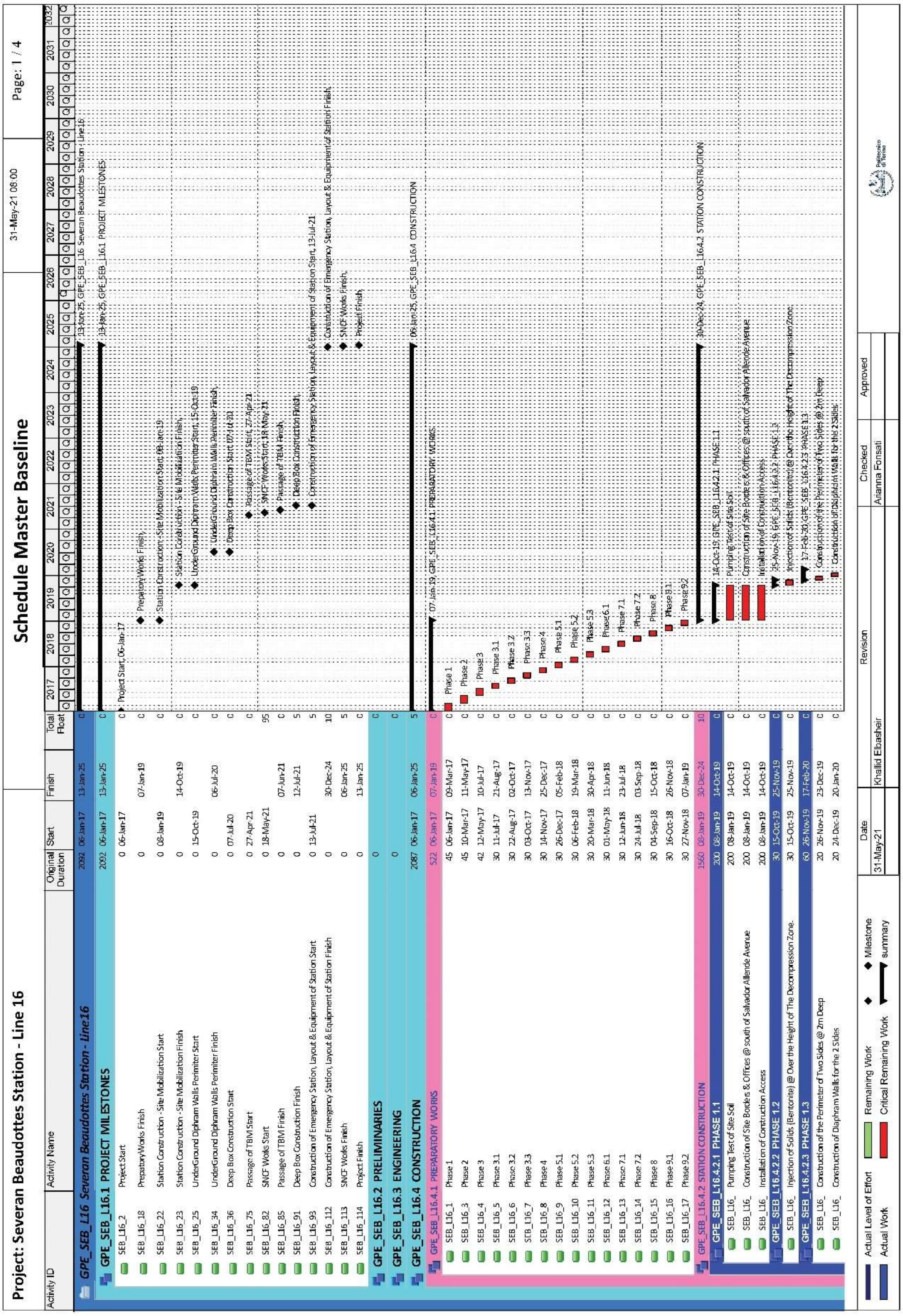


Progetto: Proget1
Data: Sun 06/02/22



Pagina 2

Primavera P6 Gantt Chart



Project: Severan Beaudottes Station - Line 16

Schedule Master Baseline

31-May-21 08:00

Page: 2 / 4

Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
SEB_L16_	Treatment Under 5x5 Mesh Raft	20	21-Jan-20	17-Feb-20	0
GPE_SEB_L16.4.2.4 PHASE 1.4		80	18-Feb-20	08-Jun-20	0
SEB_L16_	Construction of Diaphram Walls for the Other Two Sides	20	18-Feb-20	16-Mar-20	0
SEB_L16_	Construction of Diphram Walls for North-West Extension	20	17-Mar-20	13-Apr-20	0
SEB_L16_	Construction of Provisional Profurdes (T-Section Walls)	20	14-Apr-20	11-May-20	0
SEB_L16_	Testing of Injected Skirts	20	12-May-20	08-Jun-20	0
GPE_SEB_L16.4.2.5 PHASE 1.5		25	09-Jun-20	13-Jul-20	0
SEB_L16_	Crane Tower Installation	20	09-Jun-20	06-Jul-20	0
SEB_L16_	Start of Earthworks @ Deep Box	5	07-Jul-20	13-Jul-20	0
GPE_SEB_L16.4.2.6 PHASE 1.6		10	14-Jul-20	27-Jul-20	0
SEB_L16_	Pre-Casting the Temporary T-Sections	10	14-Jul-20	27-Jul-20	0
GPE_SEB_L16.4.2.7 PHASE 1.7		10	28-Jul-20	10-Aug-20	0
SEB_L16_	Earthworks & Top Down Excavations of Deep Box - 1st Level	10	28-Jul-20	10-Aug-20	0
GPE_SEB_L16.4.2.8 PHASE 1.8		20	11-Aug-20	07-Sep-20	0
SEB_L16_	Installation of Temporary Horizental Struts N1	10	11-Aug-20	24-Aug-20	0
SEB_L16_	Continue Excavations unitll Slab - S1 Level	10	25-Aug-20	07-Sep-20	0
GPE_SEB_L16.4.2.9 PHASE 1.9		20	08-Sep-20	05-Oct-20	0
SEB_L16_	Formwork, Reinforcement & Concrete Casting of Walls,Beams & Slab - S1	10	08-Sep-20	21-Sep-20	0
SEB_L16_	Installation of Composite Columns of S1	10	22-Sep-20	05-Oct-20	0
GPE_SEB_L16.4.2.10 PHASE 1.10		5	06-Oct-20	12-Oct-20	0
SEB_L16_	Construction of New Siphons under RER-B Station	5	06-Oct-20	12-Oct-20	0
GPE_SEB_L16.4.2.11 PHASE 1.11		10	13-Oct-20	26-Oct-20	0
SEB_L16_	Continue Excavations unitll Slab - S2 Level	5	13-Oct-20	19-Oct-20	0
SEB_L16_	Demolition of Temporary part of The T-Sections Diaphram Walls (S1,S2 M)	5	20-Oct-20	26-Oct-20	0
GPE_SEB_L16.4.2.12 PHASE 1.12		5	27-Oct-20	02-Nov-20	0
SEB_L16_	Formwork, Reinforcement & Concrete Casting of Walls,Beams & Slab - S2	5	27-Oct-20	02-Nov-20	0
GPE_SEB_L16.4.2.13 PHASE 1.13		20	03-Nov-20	30-Nov-20	0
SEB_L16_	Suspend S2 by Suspenders from S1	5	03-Nov-20	09-Nov-20	0
SEB_L16_	Continue Excavations unitll Slab - S3 Level	5	10-Nov-20	16-Nov-20	0
SEB_L16_	Waste importing to S1 Level	5	17-Nov-20	23-Nov-20	0
SEB_L16_	Demolition of Temporary part of The T-Sections Diaphram Walls (S3 M)	5	24-Nov-20	30-Nov-20	0
GPE_SEB_L16.4.2.14 PHASE 1.14		5	01-Dec-20	07-Dec-20	0
SEB_L16_	Formwork, Reinforcement & Concrete Casting of Walls,Beams & Slab - S3	5	01-Dec-20	07-Dec-20	0
GPE_SEB_L16.4.2.15 PHASE 1.15		10	08-Dec-20	21-Dec-20	0
SEB_L16_	Removing of Suspenders @ S2	5	08-Dec-20	14-Dec-20	0
SEB_L16_	Continue Excavations unitll Slab - S4 Level	5	15-Dec-20	21-Dec-20	0
GPE_SEB_L16.4.2.16 PHASE 1.16		10	22-Dec-20	04-Jan-21	0
SEB_L16_	Connect New Siphones to the City Network & DEA	5	22-Dec-20	28-Dec-20	0
SEB_L16_	Construction of Piles for Slab N0	5	29-Dec-20	04-Jan-21	0
GPE_SEB_L16.4.2.17 PHASE 1.17		10	05-Jan-21	18-Jan-21	0
SEB_L16_	Partial Casting of S4 Slab	5	05-Jan-21	11-Jan-21	0
SEB_L16_	Installation of Temporary Horizental Struts N2	5	12-Jan-21	18-Jan-21	0
GPE_SEB_L16.4.2.18 PHASE 1.18		10	19-Jan-21	01-Feb-21	0
SEB_L16_	Installation of Temporary Suspenders from S3 to S4	5	19-Jan-21	25-Jan-21	0
SEB_L16_	Continue Excavations unitll Q5 Level	5	26-Jan-21	01-Feb-21	0
GPE_SEB_L16.4.2.19 PHASE 1.19		5	02-Feb-21	08-Feb-21	0
SEB_L16_	Installation of Temporary Horizental Struts N3 @ Q5 lvl (Reuse N1)	5	02-Feb-21	08-Feb-21	0
GPE_SEB_L16.4.2.20 PHASE 1.20		5	09-Feb-21	15-Feb-21	0
SEB_L16_	Continue Excavations unitll Bottom Part of Excavations - FF Level	5	09-Feb-21	15-Feb-21	0
GPE_SEB_L16.4.2.21 PHASE 2.1		10	16-Feb-21	01-Mar-21	0

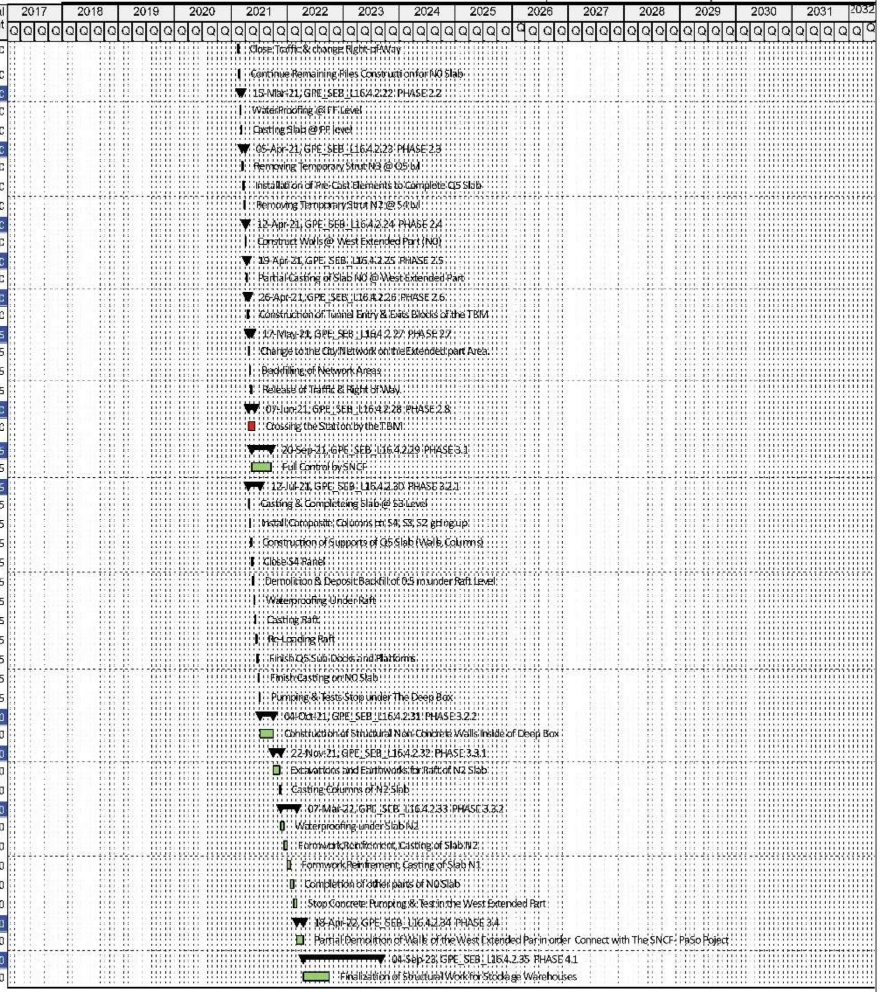
Actual Level of Effort — Remaining Work — Milestone
Actual Work — Critical Remaining Work — summary

Date	Revision	Checked	Approved
31-May-21	Khallid Elbasheir	Arianna Fonsati	

Politecnico di Torino

Project: Severan Beaudottes Station - Line 16 | **Schedule Master Baseline** | 31-May-21 08:00 | Page: 3 / 4

Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
SEB_L16_6	Close Traffic & change Right-of-Way	5	16-Feb-21	22-Feb-21	C
SEB_L16_	Continue Remaining Piles Construction for N0 Slab	5	23-Feb-21	01-Mar-21	C
GPE_SEB_L16.4.2.22	**PHASE 2.2**	10	02-Mar-21	15-Mar-21	C
SEB_L16_	WaterProofing @ FF Level	5	02-Mar-21	08-Mar-21	C
SEB_L16_	Casting Slab @ FF level	5	09-Mar-21	15-Mar-21	C
GPE_SEB_L16.4.2.23	**PHASE 2.3**	15	16-Mar-21	05-Apr-21	C
SEB_L16_	Removing Temporary Strut N3 @ Q5 lvl	5	16-Mar-21	22-Mar-21	C
SEB_L16_	Installation of Pre-Cast Elements to Complete Q5 Slab	5	23-Mar-21	29-Mar-21	C
SEB_L16_	Removing Temporary Strut N2 @ S4 Lvl	5	30-Mar-21	05-Apr-21	C
GPE_SEB_L16.4.2.24	**PHASE 2.4**	5	06-Apr-21	12-Apr-21	C
SEB_L16_	Construct Walls @ West Extended Part (N0)	5	06-Apr-21	12-Apr-21	C
GPE_SEB_L16.4.2.25	**PHASE 2.5**	5	13-Apr-21	19-Apr-21	C
SEB_L16_	Partial Casting of Slab N0 @ West Extended Part	5	13-Apr-21	19-Apr-21	C
GPE_SEB_L16.4.2.26	**PHASE 2.6**	5	20-Apr-21	26-Apr-21	C
SEB_L16_	Construction of Tunnel Entry & Exits Blocks of the TBM	5	20-Apr-21	26-Apr-21	C
GPE_SEB_L16.4.2.27	**PHASE 2.7**	15	27-Apr-21	17-May-21	5
SEB_L16_	Change to the City Network on the Extended part Area.	5	27-Apr-21	03-May-21	5
SEB_L16_	Backfilling of Network Areas	5	04-May-21	10-May-21	5
SEB_L16_	Release of Traffic & Right of Way.	5	11-May-21	17-May-21	5
GPE_SEB_L16.4.2.28	**PHASE 2.8**	30	27-Apr-21	07-Jun-21	C
SEB_L16_	Crossing the Station by the TBM	30	27-Apr-21	07-Jun-21	C
GPE_SEB_L16.4.2.29	**PHASE 3.1**	90	18-May-21	20-Sep-21	5
SEB_L16_	Full Control by SNCF	90	18-May-21	20-Sep-21	5
GPE_SEB_L16.4.2.30	**PHASE 3.2.1**	55	27-Apr-21	12-Jul-21	5
SEB_L16_	Casting & Completeing Slab @ S3 Level	5	27-Apr-21	03-May-21	5
SEB_L16_	Install Composite Columns on S4, S3, S2 going up	5	04-May-21	10-May-21	5
SEB_L16_	Construction of Supports of Q5 Slab (Walls, Columns)	5	11-May-21	17-May-21	5
SEB_L16_	Close S4 Panel	5	18-May-21	24-May-21	5
SEB_L16_	Demolition & Deposit Backfill of 0.5 m under Raft Level	5	25-May-21	31-May-21	5
SEB_L16_	Waterproofing Under Raft	5	01-Jun-21	07-Jun-21	5
SEB_L16_	Casting Raft	5	08-Jun-21	14-Jun-21	5
SEB_L16_	Re-Loading Raft	5	15-Jun-21	21-Jun-21	5
SEB_L16_	Finish Q5 Sub-Docks and Platforms	5	22-Jun-21	28-Jun-21	5
SEB_L16_	Finish Casting on N0 Slab	5	29-Jun-21	05-Jul-21	5
SEB_L16_	Pumping & Tests Stop under The Deep Box	5	06-Jul-21	12-Jul-21	5
GPE_SEB_L16.4.2.31	**PHASE 3.2.2**	60	13-Jul-21	04-Oct-21	10
SEB_L16_	Construction of Structural Non-Concrete Walls Inside of Deep Box	60	13-Jul-21	04-Oct-21	10
GPE_SEB_L16.4.2.32	**PHASE 3.3.1**	35	05-Oct-21	22-Nov-21	10
SEB_L16_	Excavations and Earthworks for Raft of N2 Slab	30	05-Oct-21	15-Nov-21	10
SEB_L16_	Casting Columns of N2 Slab	5	16-Nov-21	22-Nov-21	10
GPE_SEB_L16.4.2.33	**PHASE 3.3.2**	75	23-Nov-21	07-Mar-22	10
SEB_L16_	Waterproofing under Slab N2	15	23-Nov-21	13-Dec-21	10
SEB_L16_	Formwork,Reinfrement, Casting of Slab N2	15	14-Dec-21	03-Jan-22	10
SEB_L16_	Formwork,Reinfrement, Casting of Slab N1	15	04-Jan-22	24-Jan-22	10
SEB_L16_	Completion of other parts of N0 Slab	15	25-Jan-22	14-Feb-22	10
SEB_L16_	Stop Concrete Pumping & Test in the West Extended Part	15	15-Feb-22	07-Mar-22	10
GPE_SEB_L16.4.2.34	**PHASE 3.4**	30	08-Mar-22	18-Apr-22	10
SEB_L16_	Partial Demolition of Walls of the West Extended Par in order Connect with The SNCF-	30	08-Mar-22	18-Apr-22	10
GPE_SEB_L16.4.2.35	**PHASE 4.1**	360	19-Apr-22	04-Sep-23	10
SEB_L16_	Finalization of Structual Work for Stockage Warehouses	120	19-Apr-22	03-Oct-22	10



Legend: Actual Level of Effort; Actual Work; Remaining Work; Critical Remaining Work; ◆ Milestone; summary

Date	Revision	Checked	Approved
31-May-21	Khallid Elbasheir	Arianna Fonsati	

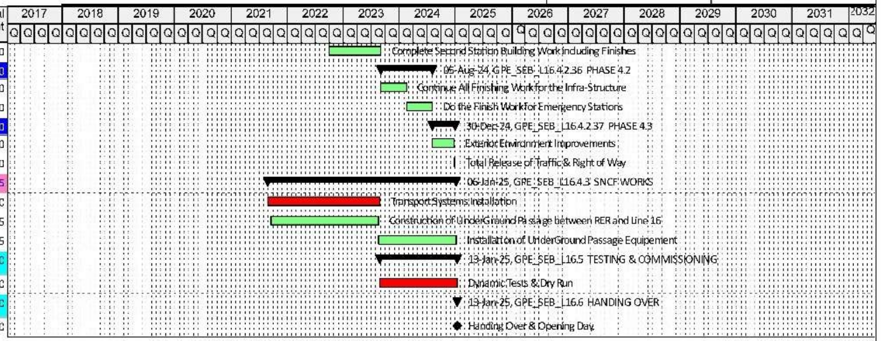
Project: Severan Beaudottes Station - Line 16

Schedule Master Baseline

31-May-21 08:00

Page: 4 / 4

Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
SEB_L16_	Complete Second Station Building Work including Finishes	240	04-Oct-22	04-Sep-23	10
GPE_SEB_L16.4.2.36	PHASE 4.2	240	05-Sep-23	05-Aug-24	10
SEB_L16_	Continue All Finishing Work for the Infra-Structure	120	05-Sep-23	19-Feb-24	10
SEB_L16_	Do the Finish Work for Emergency Stations	120	20-Feb-24	05-Aug-24	10
GPE_SEB_L16.4.2.37	PHASE 4.3	105	06-Aug-24	30-Dec-24	10
SEB_L16_	Exterior Environment Improvements	100	06-Aug-24	23-Dec-24	10
SEB_L16_	Total Release of Traffic & Right of Way	5	24-Dec-24	30-Dec-24	10
GPE_SEB_L16.4.3	SNCF WORKS	875	31-Aug-21	06-Jan-25	5
SEB_L16_94	Transport Systems Installation	520	31-Aug-21	28-Aug-23	0
SEB_L16_95	Construction of UnderGround Passage between RER and Line 16	500	21-Sep-21	21-Aug-23	5
SEB_L16_106	Installation of UnderGround Passage Equipement	360	22-Aug-23	06-Jan-25	5
GPE_SEB_L16.5	TESTING & COMMISSIONING	360	29-Aug-23	13-Jan-25	0
SEB_L16_107	Dynamic Tests & Dry Run	360	29-Aug-23	13-Jan-25	0
GPE_SEB_L16.6	HANDING OVER	0	13-Jan-25	13-Jan-25	0
SEB_L16_115	Handing Over & Opening Day	0		13-Jan-25	0

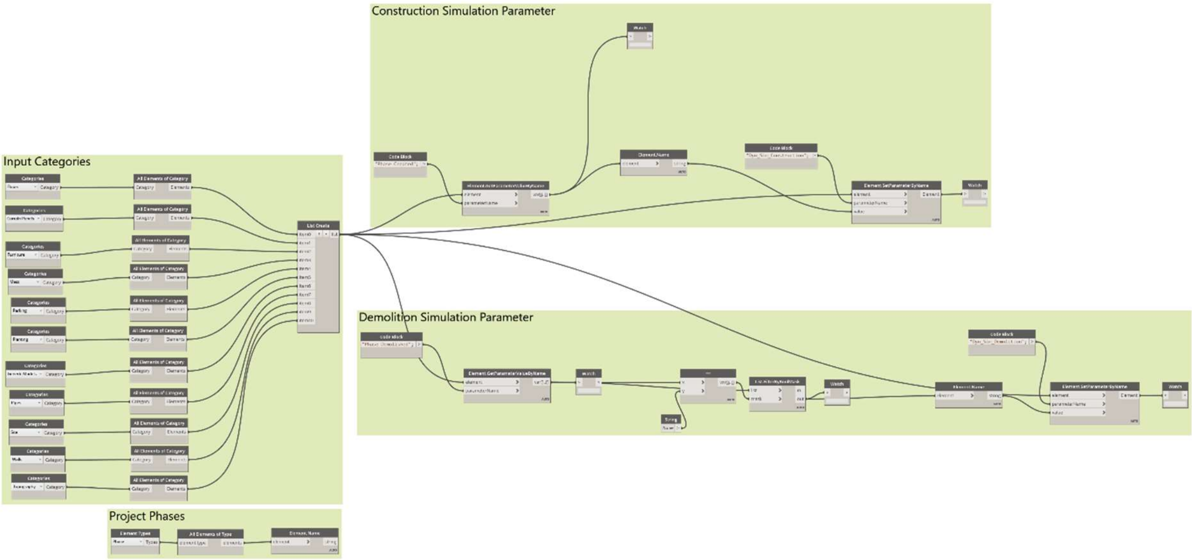


Actual Level of Effort — Actual Work — Remaining Work — Critical Remaining Work — Milestone — summary

Date	Revision	Checked	Approved
31-May-21	Khallid Elbasheir	Arianna Fonsati	

Politecnico di Torino

Dynamo Script



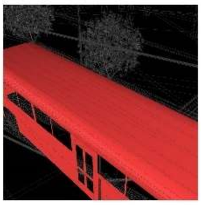
Clash Reports – Navisworks:

Rapporto sulle interferenze

Report Batch

Traffic vs Works_Bus_Hard_0.01m Interferenza

Tolleranza	0.010m
Autointersecante	0
Autointersecante	0
Totale	11
Nuovo	11
Attivo	0
Rivista	0
Approvata	0
Risolta	0
Tipo	Per intersezione
Stato	OK



Nome	Interferenza1
Distanza	-0.088m
Descrizione	Per intersezione
Stato	Nuovo
Punto di interferenza	78.378m, 62.512m, 1.794m
Data creazione	2021/12/1 12:13

Elemento 1

Element ID	734041
Layer	Livello 1
Elemento Nome	BMCD2AR3\Solid Materials \Metals\Colors\Normal\White
Elemento Tipo	Solid

Elemento 2

Element ID	620601
Layer	Livello 1
Elemento Nome	350x250cm
Elemento Tipo	Solid

Collegamento attività

Inizio	0:0:0
Fine	0:0:11
Nome attività	
Scena Animator	Bus_phase5.1

Nome	Interferenza2

Distanza	-0.078m
Descrizione	Per intersezione
Stato	Nuovo
Punto di interferenza	80.931m, 59.896m, 0.993m
Data creazione	2021/12/1 12:13

Elemento 1

Element ID	734041
Layer	Livello 1
Elemento Nome	BMCD2AR3\Solid Materials \Metals\Colors\Normal\White
Elemento Tipo	Solid

Elemento 2

Element ID	620604
Layer	Livello 1
Elemento Nome	350x250cm
Elemento Tipo	Solid

Collegamento attività

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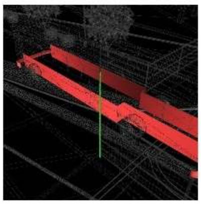
Nome attività	
Scena Animator	Bus_phase5.1



Nome	Interferenza3
Distanza	-0.066m
Descrizione	Per intersezione
Stato	Nuovo
Punto di interferenza	80.713m, 60.175m, 0.999m
Data creazione	2021/12/1 12:13

Elemento 1

Element ID	734041
Layer	Livello 1
Elemento Nome	BMCD2AR3\Solid Materials \Matte\Normal\Black
Elemento Tipo	Solid

Elemento 2

Element ID	620604
Layer	Livello 1
Elemento Nome	350x250cm
Elemento Tipo	Solid

Collegamento attività

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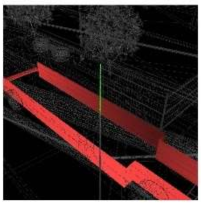
Fine	0:0:11
Nome attività	
Scena Animator	Bus_phase5.1



Nome	Interferenza4
Distanza	-0.053m
Descrizione	Per intersezione
Stato	Nuovo
Punto di interferenza	78.642m, 62.233m, 1.031m
Data creazione	2021/12/1 12:13

Elemento 1

Element ID	734041
Layer	Livello 1
Elemento Nome	BMCD2AR3\Solid Materials \Matte\Normal\Black
Elemento Tipo	Solid

Elemento 2

Element ID	620601
Layer	Livello 1
Elemento Nome	350x250cm
Elemento Tipo	Solid

Collegamento attività

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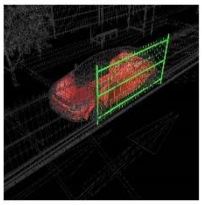
Fine	0:0:11
Nome attività	
Scena Animator	Bus_phase5.1



Nome	Interferenza5
Distanza	-0.021m
Descrizione	Per intersezione
Stato	Nuovo
Punto di interferenza	43.124m, 82.959m, 0.746m
Data creazione	2021/12/1 12:13

Elemento 1

Element ID	799038
Layer	Livello 1
Elemento Nome	CARS-SKETCHUP_BLACK
Elemento Tipo	Solid

Elemento 2

Element ID	581445
Layer	Livello 1

Elemento Nome	350x250cm
Elemento Tipo	Solid

Collegamento attività

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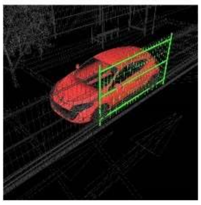
Fine	0:0:11
Nome attività	
Scena Animator	Bus_phase5.1



Nome	Interferenza6
Distanza	-0.017m
Descrizione	Per intersezione
Stato	Nuovo
Punto di interferenza	43.135m, 82.817m, 0.832m
Data creazione	2021/12/1 12:13

Elemento 1

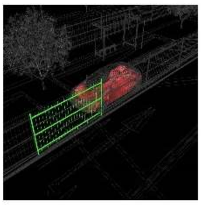
Element ID	799038
Layer	Livello 1
Elemento Nome	CARS-SKETCHUP_BODY-Megane(2009)
Elemento Tipo	Solid

Elemento 2

Element ID	581445
Layer	Livello 1
Elemento Nome	350x250cm
Elemento Tipo	Solid

Collegamento attività

Inizio	0:0:0
Fine	0:0:11
Nome attività	
Scena Animator	Bus_phase5.1



Nome	Interferenza7
Distanza	-0.014m
Descrizione	Per intersezione
Stato	Nuovo
Punto di interferenza	43.099m, 82.735m, 0.749m
Data creazione	2021/12/1 12:13

Elemento 1

Element ID	799038
Layer	Livello 1
Elemento Nome	CARS-SKETCHUP_BLACK

Elemento Tipo	Solid

Elemento 2

Element ID	581447
Layer	Livello 1
Elemento Nome	350x250cm
Elemento Tipo	Solid

Collegamento attività

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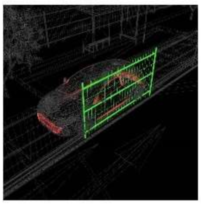
Fine	0:0:11
Nome attività	
Scena Animator	Bus_phase5.1



Nome	Interferenza8
Distanza	-0.014m
Descrizione	Per intersezione
Stato	Nuovo
Punto di interferenza	43.132m, 83.474m, 1.034m
Data creazione	2021/12/1 12:13

Elemento 1

Element ID	799038
Layer	Livello 1
Elemento Nome	CARS-SKETCHUP_PLASTIC-BLACK
Elemento Tipo	Solid

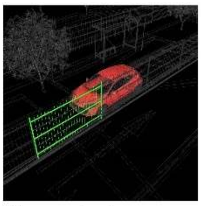
Elemento 2

Element ID	581445
Layer	Livello 1
Elemento Nome	350x250cm
Elemento Tipo	Solid

Collegamento attività

Inizio	0:0:0
Fine	0:0:11
Nome attività	
Scena Animator	Bus_phase5.1

Nome	Interferenza9
Distanza	-0.014m
Descrizione	Per intersezione
Stato	Nuovo
Punto di interferenza	43.104m, 82.725m, 0.873m
Data creazione	2021/12/1 12:13



Elemento 1

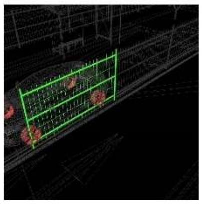
Element ID	799038
Layer	Livello 1
Elemento Nome	CARS-SKETCHUP_BODY-Megane(2009)
Elemento Tipo	Solid

Elemento 2

Element ID	581447
Layer	Livello 1
Elemento Nome	350x250cm
Elemento Tipo	Solid

Collegamento attività

Inizio	0:0:0
Fine	0:0:11
Nome attività	
Scena Animator	Bus_phase5.1



Nome	Interferenza10
Distanza	-0.012m
Descrizione	Per intersezione
Stato	Nuovo
Punto di interferenza	43.139m, 85.549m, 0.240m
Data creazione	2021/12/1 12:13

Elemento 1

Element ID	799038
Layer	Livello 1
Elemento Nome	CARS-SKETCHUP_WHEEL
Elemento Tipo	Solid

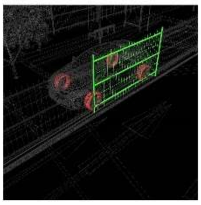
Elemento 2

Element ID	581445
Layer	Livello 1
Elemento Nome	350x250cm
Elemento Tipo	Solid

Collegamento attività

Inizio	0:0:0

Fine	0:0:11
Nome attività	
Scena Animator	Bus_phase5.1



Nome	Interferenza11
Distanza	-0.011m
Descrizione	Per intersezione
Stato	Nuovo
Punto di interferenza	43.130m, 83.083m, 0.244m
Data creazione	2021/12/1 12:13

Elemento 1

Element ID	799038
Layer	Livello 1
Elemento Nome	CARS-SKETCHUP_TYRE
Elemento Tipo	Solid

Elemento 2

Element ID	581445
Layer	Livello 1
Elemento Nome	350x250cm
Elemento Tipo	Solid

Collegamento attività

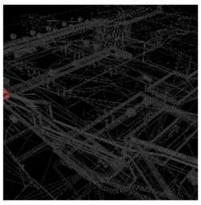
Inizio	0:0:0
Fine	0:0:11
Nome attività	
Scena Animator	Bus_phase5.1

Rapporto sulle interferenze

Report Batch

Traffic vs Works_Bus_Soft_0.01m Interferenza

Tolleranza	0.010m
Autointersecante	0
Autointersecante	0
Totale	17
Nuovo	17
Attivo	0
Rivista	0
Approvata	0
Risolta	0
Tipo	Margine di spazio
Stato	OK



Nome	Interferenza1
Distanza	-0.088m
Descrizione	Margine di spazio
Stato	Nuovo
Punto di interferenza	78.378m, 62.512m, 1.794m
Data creazione	2021/12/1 12:09

Elemento 1

Element ID	734041
Layer	Livello 1
Elemento Nome	BMCD2AR3\Solid Materials \Metals\Colors\Normal\White
Elemento Tipo	Solid

Elemento 2

Element ID	620601
Layer	Livello 1
Elemento Nome	350x250cm
Elemento Tipo	Solid

Collegamento attività

Inizio	0:0:0
Fine	0:0:11
Nome attività	
Scena Animator	Bus_phase5.1

Nome	Interferenza2

Distanza	-0.078m
Descrizione	Margine di spazio
Stato	Nuovo
Punto di interferenza	80.931m, 59.896m, 0.993m
Data creazione	2021/12/1 12:09

Elemento 1

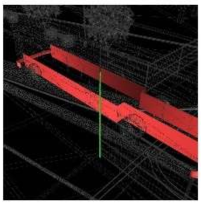
Element ID	734041
Layer	Livello 1
Elemento Nome	BMCD2AR3\Solid Materials \Metals\Colors\Normal\White
Elemento Tipo	Solid

Elemento 2

Element ID	620604
Layer	Livello 1
Elemento Nome	350x250cm
Elemento Tipo	Solid

Collegamento attività

Inizio	0:0:0
Fine	0:0:11
Nome attività	
Scena Animator	Bus_phase5.1



Nome	Interferenza3
Distanza	-0.066m
Descrizione	Margine di spazio
Stato	Nuovo
Punto di interferenza	80.713m, 60.175m, 0.999m
Data creazione	2021/12/1 12:09

Elemento 1

Element ID	734041
Layer	Livello 1
Elemento Nome	BMCD2AR3\Solid Materials \Matte\Normal\Black
Elemento Tipo	Solid

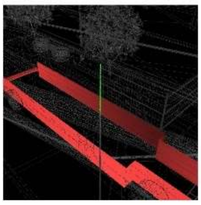
Elemento 2

Element ID	620604
Layer	Livello 1
Elemento Nome	350x250cm
Elemento Tipo	Solid

Collegamento attività

Inizio	0:0:0

Fine	0:0:11
Nome attività	
Scena Animator	Bus_phase5.1



Nome	Interferenza4
Distanza	-0.053m
Descrizione	Margine di spazio
Stato	Nuovo
Punto di interferenza	78.642m, 62.233m, 1.031m
Data creazione	2021/12/1 12:09

Elemento 1

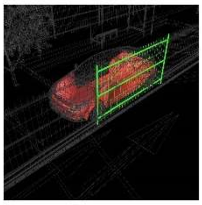
Element ID	734041
Layer	Livello 1
Elemento Nome	BMCD2AR3\Solid Materials \Matte\Normal\Black
Elemento Tipo	Solid

Elemento 2

Element ID	620601
Layer	Livello 1
Elemento Nome	350x250cm
Elemento Tipo	Solid

Collegamento attività

Inizio	0:0:0
Fine	0:0:11
Nome attività	
Scena Animator	Bus_phase5.1



Nome	Interferenza5
Distanza	-0.021m
Descrizione	Margine di spazio
Stato	Nuovo
Punto di interferenza	43.124m, 82.959m, 0.746m
Data creazione	2021/12/1 12:09

Elemento 1

Element ID	799038
Layer	Livello 1
Elemento Nome	CARS-SKETCHUP_BLACK
Elemento Tipo	Solid

Elemento 2

Element ID	581445
Layer	Livello 1

Clash Reports – Synchro Pro:

Car Vs Crane

Number of Clashes: 4
Test Mode: Time range
What was tested: Selection of 11 3D objects
Type of Test: Hard
Tolerance: 0.01 Meters
Ignored: nothing

3D Object 1:
Name : crane-3_4778 [799674]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (350)\crane-3_4778 (2)\crane-3_4778 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

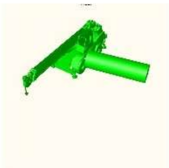
Status : Clash
Responsible :
Resolution :
Start time : 24/04/2019
End time : 24/04/2019

3D Object 2:
Name : Pipe Types [799745]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Pipes (6)\Pipe Types (6)\Default 2 (6)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 1:
Name : crane-3_4778 [799674]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (350)\crane-3_4778 (2)\crane-3_4778 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 25/04/2019
End time : 25/04/2019

3D Object 2:
Name : Pipe Types [799745]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Pipes (6)\Pipe Types (6)\Default 2 (6)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx



3D Object 1:
Name : crane-3_4778 [799674]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (350)\crane-3_4778 (2)\crane-3_4778 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 25/04/2019
End time : 26/04/2019

3D Object 2:
Name : Pipe Types [799745]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Pipes (6)\Pipe Types (6)\Default 2 (6)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 1:
Name : crane-3_4778 [799674]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (350)\crane-3_4778 (2)\crane-3_4778 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 28/04/2019
End time : 29/04/2019

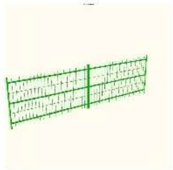
3D Object 2:
Name : Pipe Types [799745]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Pipes (6)\Pipe Types (6)\Default 2 (6)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Project title		Dated	10/12/2021	Drawn by	Administrator	Programme No
Programme title		Rev No		Rev comments		
Client		Notes				Printed 27/02/2022

<D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\Correct Synchro\Cantiere_Sub_DWF_V03.sp>, Page 1 of 1

Car Vs Crane

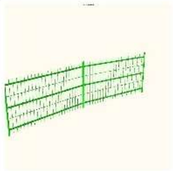
Number of Clashes: 8
Test Mode: Time range
What was tested: Selection of 11 3D objects
Type of Test: Soft
Clearance: 0.01 Meters
Ignored: nothing



3D Object 1:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [578437]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (138)\SEB_pannellodifacciatacontinua_constructionsitefencing (138
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [578435]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (90)\SEB_pannellodifacciatacontinua_constructionsitefencing (90)\
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

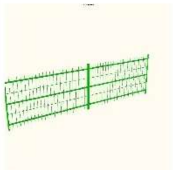
Status : Clash
Responsible :
Resolution :
Start time : 11/03/2019
End time :



3D Object 1:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [578430]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (138)\SEB_pannellodifacciatacontinua_constructionsitefencing (138
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [578244]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (90)\SEB_pannellodifacciatacontinua_constructionsitefencing (90)\
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

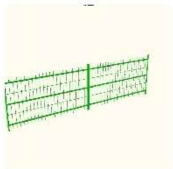
Status : Clash
Responsible :
Resolution :
Start time : 11/03/2019
End time :



3D Object 1:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [578433]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (138)\SEB_pannellodifacciatacontinua_constructionsitefencing (138
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [578430]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (138)\SEB_pannellodifacciatacontinua_constructionsitefencing (138
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 11/03/2019
End time :



3D Object 1:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [578433]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (138)\SEB_pannellodifacciatacontinua_constructionsitefencing (138
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [578435]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (90)\SEB_pannellodifacciatacontinua_constructionsitefencing (90)\
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 11/03/2019
End time :

Project title		Dated	10/12/2021	Drawn by	Administrator	Programme No
Programme title		Rev No		Rev comments		
Client		Notes				Printed: 27/02/2022

<D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\Correct Synchro\Contesto_Subs_DWF_V03.sp>, Page 1 of 2

3D Object 1:
Name : Pipe Types [799705]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Pipes (2)\Pipe Types (2)\Default 2 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : Pipe Types [799745]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Pipes (6)\Pipe Types (6)\Default 2 (6)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 11/04/2019
End time :

3D Object 1:
Name : crane-3_4778 [799674]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (350)\crane-3_4778 (2)\crane-3_4778 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : Pipe Types [799745]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Pipes (6)\Pipe Types (6)\Default 2 (6)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 24/04/2019
End time : 25/04/2019

3D Object 1:
Name : crane-3_4778 [799674]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (350)\crane-3_4778 (2)\crane-3_4778 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : Pipe Types [799745]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Pipes (6)\Pipe Types (6)\Default 2 (6)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 25/04/2019
End time : 26/04/2019

3D Object 1:
Name : crane-3_4778 [799674]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (350)\crane-3_4778 (2)\crane-3_4778 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : Pipe Types [799745]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Pipes (6)\Pipe Types (6)\Default 2 (6)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 28/04/2019
End time : 29/04/2019

Project title	Dated	10/12/2021	Drawn by	Administrator	Programme No
Programme title	Rev No	Rev comments			
Client	Notes				Printed: 07/02/2022

<D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\Correct Synchro\Contesto_Subs_DWF_V03.sp>, Page 2 of 2

Bus Vs Fence

Number of Clashes: 5
Test Mode: Time range
What was tested: Selection of 5 3D objects
Type of Test: Hard
Tolerance: 0.01 Meters
Ignored: nothing

3D Object 1:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620604]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

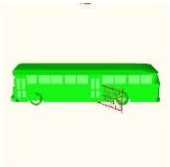
3D Object 2:
Name : Bus02 [734041]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (380)\Bus02 (2)\Bus02 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time :

3D Object 1:
Name : Bus02 [734041]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (380)\Bus02 (2)\Bus02 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620601]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

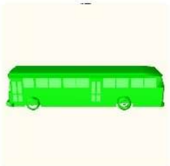
Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time :



3D Object 1:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620604]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : Bus02 [734041]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (380)\Bus02 (2)\Bus02 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time : 05/03/2020



3D Object 1:
Name : Bus02 [734041]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (380)\Bus02 (2)\Bus02 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620601]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time : 10/03/2020

Project title	Dated	10/12/2021	Drawn by	Administrator	Programme No
Programme title	Rev No		Rev comments		
Client	Notes				

3D Object 1:

Name : Bus02 [734041]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (380)\Bus02 (2)\Bus02 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:

Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620604]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time : 09/03/2020

Project title	Dated	10/12/2021	Drawn by	Administrator	Programme No
Programme title	Rev No	Rev comments			
Client	Notes				Printed: 07/02/2022

<D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\Correct Synchro\Contesto_Subs_DWF_V03.sp>, Page 2 of 2

Bus Vs Fence

Number of Clashes: 11
Test Mode: Time range
What was tested: Selection of 6 3D objects
Type of Test: Soft
Clearance: 0.01 Meters
Ignored: nothing

3D Object 1:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620604]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

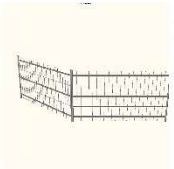
3D Object 2:
Name : Bus02 [734041]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (380)\Bus02 (2)\Bus02 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time :

3D Object 1:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620604]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620601]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

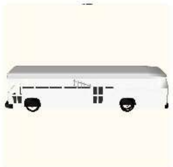
Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time :



3D Object 1:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620604]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620689]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time :



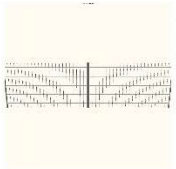
3D Object 1:
Name : Bus02 [734041]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (380)\Bus02 (2)\Bus02 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620601]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time :

Project title		Dated	10/12/2021	Drawn by	Administrator	Programme No
Programme title		Rev No		Rev comments		
Client		Notes				

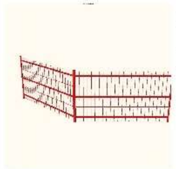
SYNCHRO
Printed: 27/02/2022
<D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\Correct Synchro\Contesto_Subs_DWF_V03.sp>, Page 1 of 3



3D Object 1:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620689]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620692]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time :



3D Object 1:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620604]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620689]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time : 25/03/2020

3D Object 1:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620604]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

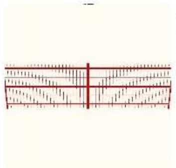
3D Object 2:
Name : Bus02 [734041]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (380)\Bus02 (2)\Bus02 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time : 05/03/2020

3D Object 1:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620604]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620601]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time : 25/03/2020



3D Object 1:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620692]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:
Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620689]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time : 25/03/2020

Project title		Dated	10/12/2021	Drawn by	Administrator	Programme No
Programme title		Rev No		Rev comments		
Client		Notes				Printed 27/02/2022

<D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\Correct Synchro\Contesto_Stubs_DWF_V03.sp>, Page 2 of 3

3D Object 1:

Name : Bus02 [734041]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (380)\Bus02 (2)\Bus02 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:

Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620601]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time : 10/03/2020

3D Object 1:

Name : Bus02 [734041]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Site (380)\Bus02 (2)\Bus02 (2)
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

3D Object 2:

Name : SEB_pannellodifacciatacontinua_constructionsitefencing [620604]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-fase3-1\Curtain Panels (301)\SEB_pannellodifacciatacontinua_constructionsitefencing (301
Filename : D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\another\Fase-3DView-fase3-1.dwfx

Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time : 09/03/2020

Project title	Dated 10/12/2021	Drawn by Administrator	Programme No
Programme title	Rev No	Rev comments	
Client	Notes		Printed: 07/02/2022

<D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\Correct Synchro\Contesto_Subs_DWF_V03.sp>, Page 3 of 3

Fence Vs Car

Number of Clashes: 3

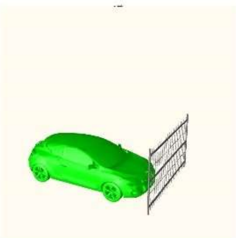
Test Mode: 4D (entire project)

What was tested: Selection of 3 3D objects

Type of Test: Soft

Clearance: 1.00 Meters

Ignored: nothing



3D Object 1:

Name : Renault-Megane(2009) [799054]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-
Filename : D:\Torino - MSc - 4th Semester\Thesis\Prc

3D Object 2:

Name : SEB_pannellodifacciatacontinua_construc
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-
Filename : D:\Torino - MSc - 4th Semester\Thesis\Prc

Status : Clash
Responsible :
Resolution :
Start time : 15/12/2019
End time : 20/12/2019

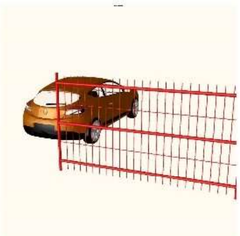
3D Object 1:

Name : Renault-Megane(2009) [799054]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-
Filename : D:\Torino - MSc - 4th Semester\Thesis\Prc

3D Object 2:

Name : SEB_pannellodifacciatacontinua_construc
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-
Filename : D:\Torino - MSc - 4th Semester\Thesis\Prc

Status : Clash
Responsible :
Resolution :
Start time : 27/12/2019
End time :



3D Object 1:

Name : SEB_pannellodifacciatacontinua_construc
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-
Filename : D:\Torino - MSc - 4th Semester\Thesis\Prc

3D Object 2:

Name : Renault-Megane(2009) [799054]
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-
Filename : D:\Torino - MSc - 4th Semester\Thesis\Prc

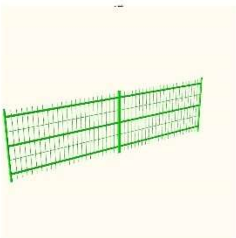
Status : Clash
Responsible :
Resolution :
Start time : 05/03/2020
End time : 25/03/2020

Project title	Dated	10/12/2021	Drawn by	Administrator	Programme No	SYNCHRO CONNECT Edition
Programme title	Rev No		Rev comments			
Client	Notes					Printed: 13/12/2021

<D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\Correct Synchro\Contesto_Subs_DWF_V03.sp>, Page 1 of 1

Car2 Vs Fence

Number of Clashes: 15
Test Mode: 4D (entire project)
What was tested: Selection of 7 3D objects
Type of Test: Soft
Clearance: 1.00 Meters
Ignored: nothing



3D Object 1:
Name : SEB_pannellodifacciatacontinua_construc
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-
Filename : D:\Torino - MSc - 4th Semester\Thesis\Prc

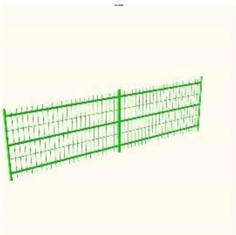
3D Object 2:
Name : SEB_pannellodifacciatacontinua_construc
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-
Filename : D:\Torino - MSc - 4th Semester\Thesis\Prc

Status : Clash
Responsible :
Resolution :
Start time : 28/02/2019
End time :

3D Object 1:
Name : SEB_pannellodifacciatacontinua_construc
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-
Filename : D:\Torino - MSc - 4th Semester\Thesis\Prc

3D Object 2:
Name : SEB_pannellodifacciatacontinua_construc
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-
Filename : D:\Torino - MSc - 4th Semester\Thesis\Prc

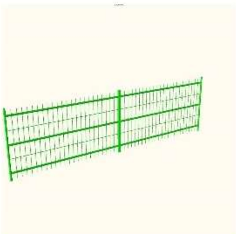
Status : Clash
Responsible :
Resolution :
Start time : 28/02/2019
End time :



3D Object 1:
Name : SEB_pannellodifacciatacontinua_construc
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-
Filename : D:\Torino - MSc - 4th Semester\Thesis\Prc

3D Object 2:
Name : SEB_pannellodifacciatacontinua_construc
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-
Filename : D:\Torino - MSc - 4th Semester\Thesis\Prc

Status : Clash
Responsible :
Resolution :
Start time : 28/02/2019
End time :



3D Object 1:
Name : SEB_pannellodifacciatacontinua_construc
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-
Filename : D:\Torino - MSc - 4th Semester\Thesis\Prc

3D Object 2:
Name : SEB_pannellodifacciatacontinua_construc
Group : Fase-3DView-fase3-1.dwfx\Fase-3DView-
Filename : D:\Torino - MSc - 4th Semester\Thesis\Prc

Status : Clash
Responsible :
Resolution :
Start time : 28/02/2019
End time :

Project title	Dated 10/12/2021	Drawn by Administrator	Programme No	SYNCHRO CONNECT Edition
Programme title	Rev No	Rev comments		
Client	Notes			Printed: 14/12/2021

<D:\Torino - MSc - 4th Semester\Thesis\Project Files\My Working Files\synchro\Correct Synchro\Contesto_Subs_DWF_V03.sp>, Page 1 of 4

Assessment Tool Revit-Plugin C# Code:

Plugin Identifier:

```
<?xml version="1.0" encoding="utf-8"?>
<RevitAddIns>
  <AddIn Type="Command">
    <Text>Assessment Tool</Text>
    <Description>This tool provides an indication of the 4D BIM workflow the user should follow
according to the assessment study carried on Politecnico di Torino </Description>
    <Assembly>AssessmentTool.dll</Assembly>
    <FullClassName>AssessmentTool.Command</FullClassName>
    <ClientId>dd571aa6-a8fe-4e82-a341-a9e3ff54659b</ClientId>
    <VendorId>com.typepad. thebuildingcoder</VendorId>
    <VendorDescription>The  Building  Coder,  http://thebuildingcoder.typepad.com</VendorDescrip-
tion>
  </AddIn>
</RevitAddIns>
```

Form1 cs:

```
using System.
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Forms;
using System.Web;
namespace AssessmentTool
{
    public partial class Form1 : Form
    {
        int i;
        public Form1()
        {

            InitializeComponent();
        }

        private void button1_Click(object sender, EventArgs e)
        {


        }

        private void Form1_Load(object sender, EventArgs e)
        {
            label1.Visible = true;
        }

        private void checkBox1_CheckedChanged(object sender, EventArgs e)
        {

            label2.Text = "Are you familiar with Visual Programming e.g: Dynamo?";
            label2.Visible = true;
            checkBox7.Visible = true;
            checkBox8.Visible = true;
            checkBox2.Enabled = false;

        }

        private void checkBox4_CheckedChanged(object sender, EventArgs e)
        {
            checkBox3.Enabled = false;

            string filename = @"D:/Torino - MSc - 4th Semester/Thesis/Project Files/My Working
Files/AHP/Workflow 1.pdf";
            System.Diagnostics.Process.Start(filename);

        }

        private void checkBox2_CheckedChanged(object sender, EventArgs e)
```

```
        {

            label2.Visible = true;
            label3.Visible = true;
            label4.Visible = true;
            checkBox3.Visible = true;
            checkBox4.Visible = true;
            checkBox1.Enabled = false;

        }
        private void checkBox3_CheckedChanged(object sender, EventArgs e)
        {
            checkBox4.Enabled = false;
            label5.Visible = true;
            checkBox5.Visible = true;
            checkBox6.Visible = true;
        }
        private void checkBox6_CheckedChanged(object sender, EventArgs e)
        {
                Form2 = new Form2();
                form2.ShowDialog();
        }
        private void checkBox5_CheckedChanged(object sender, EventArgs e)
        {
            MessageBox.Show("Sorry This Tool Can not help you !");
            Application.Exit();
        }

        private void checkBox7_CheckedChanged(object sender, EventArgs e)
        {
            label4.Text = "The 4D Software in use:";
            label4.Visible = true;
            label6.Visible = true;
            checkBox9.Visible = true;
            checkBox10.Visible = true;
            checkBox8.Enabled = false;
            MessageBox.Show("Note: You Have to Initiate a Project Shared Paramter for The Simula-
tion");
        }

        private void checkBox9_CheckedChanged(object sender, EventArgs e)
        {
            label5.Visible = true;
            checkBox5.Visible = true;
            checkBox6.Visible = true;
        }

        private void checkBox10_CheckedChanged(object sender, EventArgs e)
        {
            label7.Visible = true;
            label8.Visible = true;
            checkBox13.Visible = true;
            checkBox14.Visible = true;
            checkBox9.Enabled = false;
        }
        private void checkBox11_CheckedChanged(object sender, EventArgs e)
        {
            Application.Exit();
        }
        private void checkBox12_CheckedChanged(object sender, EventArgs e)
        {
            string filename = @"D:/Torino - MSc - 4th Semester/Thesis/Project Files/My Working
Files/AHP/Workflow 2.pdf";
            System.Diagnostics.Process.Start(filename);
            checkBox11.Enabled = false;
        }

        private void checkBox13_CheckedChanged(object sender, EventArgs e)
        {
            checkBox14.Enabled = false;
            label9.Visible = true;
            checkBox11.Visible = true;
            checkBox12.Visible = true;
        }
        private void checkBox14_CheckedChanged(object sender, EventArgs e)
```

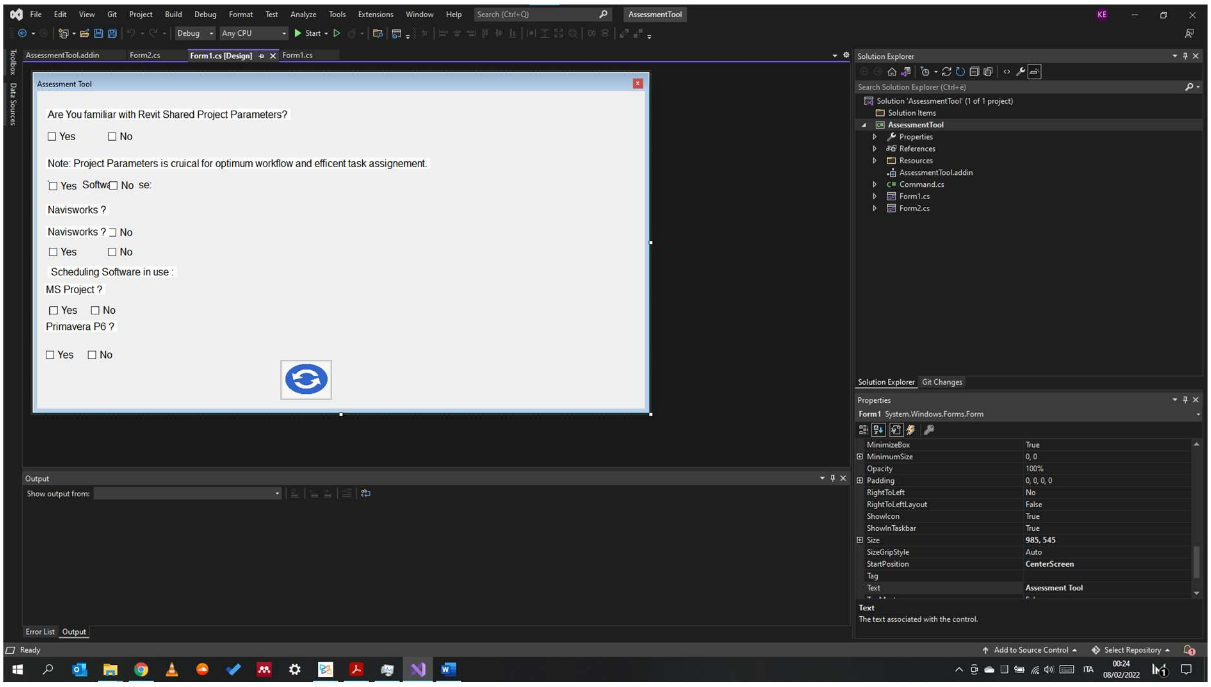
```
        {
            string filename = @"D:/Torino - MSc - 4th Semester/Thesis/Project Files/My Working
Files/AHP/Workflow 3.pdf";
            System.Diagnostics.Process.Start(filename);
            checkBox13.Enabled = false;
        }
        private void checkBox8_CheckedChanged(object sender, EventArgs e)
        {
            checkBox7.Enabled = false;
            label4.Text = "The 4D Software in use:";
            label4.Visible = true;
            label6.Visible = true;
            checkBox9.Visible = true;
            checkBox10.Visible = true;
        }
        private void button1_Click_1(object sender, EventArgs e)
        {
            this.Hide();
            Form1 form = new Form1() ;
            form.Show();
        }
        private void label1_Click(object sender, EventArgs e)
        {
        }
        private void label5_Click(object sender, EventArgs e)
        {
        }
    }
}
```

Form 2cs:

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Forms;
namespace AssessmentTool
{
    public partial class Form2 : Form
    {
        public Form2()
        {
            InitializeComponent();
        }

        private void Form2_Load(object sender, EventArgs e)
        {
            int i;
            progressBar1.Minimum = 0;
            progressBar1.Maximum = 200;
            for (i = 0; i <= 200; i++)
            {
                progressBar1.Value = i;
            }
                string filename = @"D:/Torino - MSc - 4th Semester/Thesis/Project Files/My Working
Files/AHP/Workflow 4.pdf";
                System.Diagnostics.Process.Start(filename);
                this.Close();
        }
    }
}
```

Form 1 design:

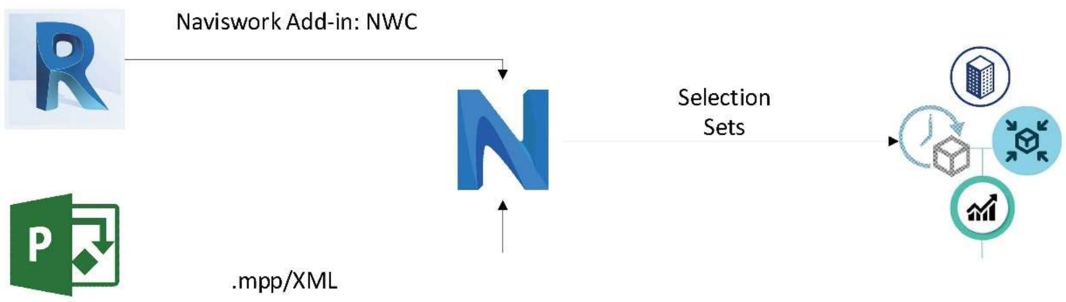


Assessment Tool – Workflow Patterns Documentation:

"This Documentation is based on the research thesis conducted by Khalid Elbasheir, a M.Sc. student at Politecnico di Torino, under the supervision of Prof. Anna Osello & Arch. Arianna Fonsati."

Documentation of 4D BIM - Workflow Pattern

Option 1:



1. Export the desired model in NWC (Navisworks Cache) format, it is advised to use the Existing Navisworks Plugin in Revit.
2. In Navisworks, Append the Model, all geometry and properties associated with the model should be appended if the export process is well done.
3. If another linked model existed or there are annex structures needs to be added, a careful check on location and coordinates should be done.
4. On the Timeliner tool, add your Microsoft project schedule .mpp format or XML format. Then rebuild task hierarchy.
5. Now, according to your model create selection sets, and search sets to be added to the sets list. However, this list should be well concurrent with the tasks on your schedule.
6. Assign these sets to their correspondent task on the TimeLiner.
7. Play the animation.

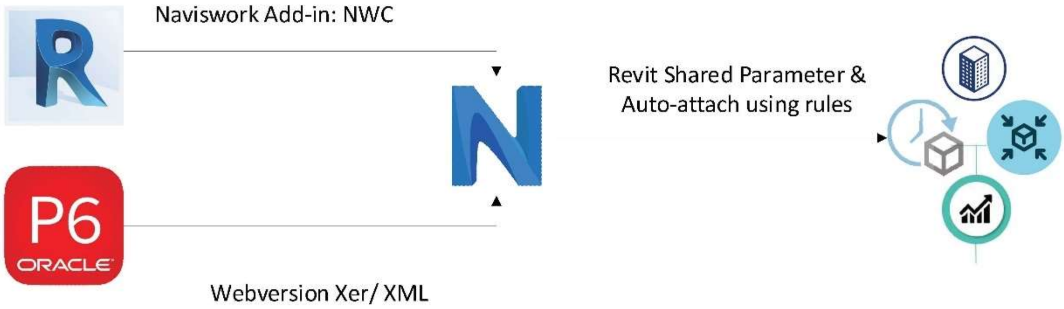
Note: this method is not accurate and can get the timeline to animate elements in a wrong task. in addition, the time needed to create these lists will be high if the model is typically large.

"According to the Research Thesis conducted in Politecnico di Torino, this method achieved a Score of 0.2392 on the AHP (Analytical Hierarchy Process) method scale, and it is ranked on number 3 out of 4 workflow patterns."

"This Documentation is based on the research thesis conducted by Khalid Elbasheir, a M.Sc. student at Politecnico di Torino, under the supervision of Prof. Anna Osello & Arch. Arianna Fonsati."

Documentation of 4D BIM - Workflow Pattern

Option 2:



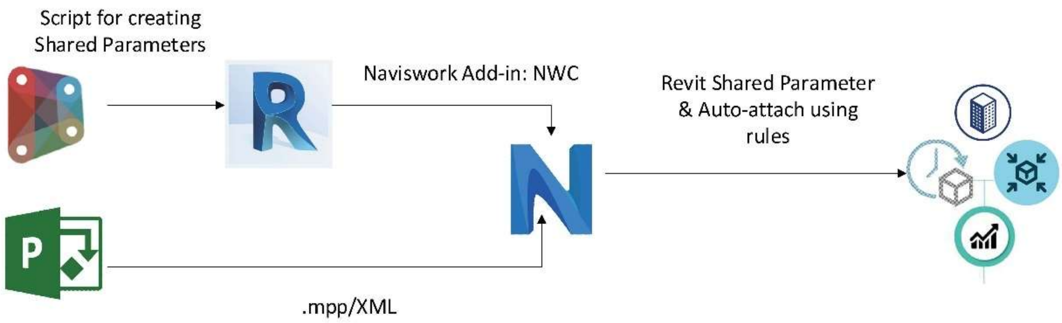
1. In Revit, create a Shared parameter that corresponds to Simulation tasks available in your schedule. The accurate way is to use WBS Code/ID related to the activity, then to put it in the shared parameter corresponding field. With this, all elements selected would have a shared parameter corresponds to your task list.
2. Export the desired model in NWC (Navisworks Cache) format, it is advised to use the Existing Navisworks Plugin in Revit.
3. In Navisworks, Append the Model, all geometry and properties associated with the model should be appended if the export process is well done.
4. If another linked model existed or there are annex structures needs to be added, a careful check on location and coordinates should be done.
5. On the Timeliner tool, add your Primavera P6 schedule in XER format Web Version or XML format. Then rebuild task hierarchy.
6. Now, using auto-assignment rules tool available in TimeLiner, attach your shared Parameter with corresponding task ID or WBS code.
7. Play the animation.

"According to the Research Thesis conducted in Politecnico di Torino, this method achieved a Score of 0.1462 on the AHP (Analytical Hierarchy Process) method scale, and it is ranked on number 4 out of 4 workflow patterns."

"This Documentation is based on the research thesis conducted by Khalid Elbasheir, a M.Sc. student at Politecnico di Torino, under the supervision of Prof. Anna Osello & Arch. Arianna Fonsati."

Documentation of 4D BIM - Workflow Pattern

Option 3:



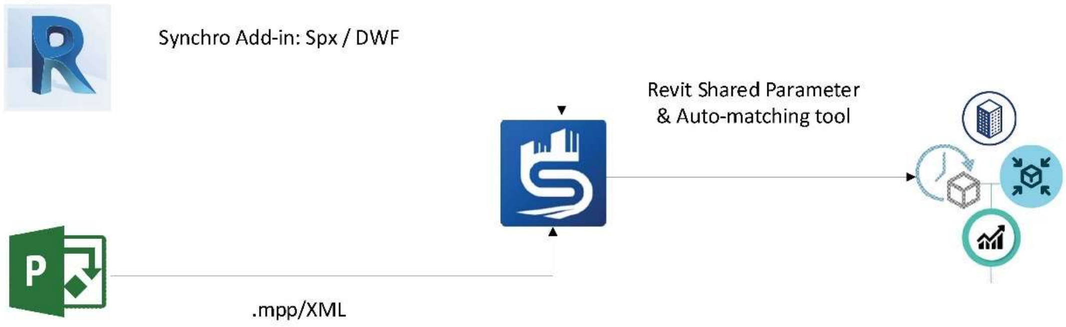
1. In Revit, create a Shared parameter that corresponds to Simulation tasks available in your schedule. Using Dynamo, this process is fast and do not take much time.
2. In Dynamo, start a new script, you would need to install two packages from the server named DataShapes and PracticalBIM, now, your script would depend on what element category you want to simulate, if the project has a detailed WBS this process is clear. If project has construction phases, you can use these phases to create your simulation parameter. If not, you have to use Slabs and ground levels to automate the simulation parameter. The dynamo scripting is very customisable according to your case.
3. Export the desired model in NWC (Navisworks Cache) format, it is advised to use the Existing Navisworks Plugin in Revit.
4. In Navisworks, Append the Model, all geometry and properties associated with the model should be appended if the export process is well done, If another linked model existed or there are annex structures needs to be added, a careful check on location and coordinates should be done.
5. On the Timeliner tool, add your Microsoft project schedule .mpp format or XML format. Then rebuild task hierarchy.
6. Now, using auto-assignment rules tool available in TimeLiner, attach your shared Parameter with corresponding task ID or WBS code.
7. Play the animation.

"According to the Research Thesis conducted in Politecnico di Torino, this method achieved a Score of 0.3254 on the AHP (Analytical Hierarchy Process) method scale, and it is ranked on number 1 out of 4 workflow patterns."

"This Documentation is based on the research thesis conducted by Khalid Elbasheir, a M.Sc. student at Politecnico di Torino, under the supervision of Prof. Anna Osello & Arch. Arianna Fonsati."

Documentation of 4D BIM - Workflow Pattern

Option 4:



1. In Revit, create a Shared parameter that corresponds to Simulation tasks available in your schedule. The accurate way is to use WBS Code/ID related to the activity, then to put it in the shared parameter corresponding field. With this, all elements selected would have a shared parameter corresponds to your task list. If project has phases also phases parameters can be used in automating assignment. The other way is to use Dynamo to create the shared parameter.
2. Export the Project using Synchro-Pro Plugin in Revit the format will be synchro project Spx format. However, this process result in a large model if the Revit model is having a large size. Because Synchro-Pro creates 3D Resources for each entity. DWF formats can be accepted in Synchro Pro.
3. In Synchro Pro, add the 3D whether it is a RVT, DWF or Spx. Create 3D resources for corresponding elements.
4. Add you construction schedule, Synchro accept Primavera P6 Xer files, Microsoft Project mpp files and XML files.
5. Use Resource Assignment to task, auto matching tool will appear, define your rule according to your parameter.
6. Create viewpoints in your animation and play the animation.

"According to the Research Thesis conducted in Politecnico di Torino, this method achieved a Score of 0.2893 on the AHP (Analytical Hierarchy Process) method scale, and it is ranked on number 2 out of 4 workflow patterns."