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Fakulteta *za gradbeništvo in geodezijo*

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BIM FOR CONSTRUCTION CLAIMS MANAGEMENT AND FORENSIC DELAY ANALYSIS

BIM ZA UPRAVLJANJE GRADBENIH ZAHTEVKOV IN FORENZIČNO ANALIZO ZAMUD

BIM A+ European Master in Building Information Modelling

Master thesis No.:

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Ass. Prof. Tomo Cerovšek

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Izvleček:

Namen te diplomske naloge je podati smernice invstitorjem in izvajalcem o tem, kako vključiti BIM v svoje pogodbe in dokumente za izmenjavo informacij za izboljšanje upravljanja zahtevkov in forenzično analizo zamud.

V uvodnem delu naloge je podan pregled splošnega pravnega okvira ter standardnih pogodb v gradbeništvu. Jedro naloge se osredotoča na forenzično analizo zamud, to je postopek, ki temelji na strokovni analzi vzrokov za zamude pri izvedbi gradbenih projektov. Zato je podan pregled pogojev in metod izdelave forenzičnih analize zamud, ki so osnova za kvantificiranje obsega prekoračitve rokov in analize upravičenosti do dodatnih stroškov v zahtevkih. V tem kontekstu podajamo podroben pregled ključnih vhodnih in izhodnih informacij, ki so bistvene za podporo odločanju pri forenzični analizi zamud ter minimalne zahteve za informacije, ki morajo biti vključene v dokumentaciji zahtevkov.

V osrednjem delu naloge se osredotočamo na zahteve glede podatkov, ki jih je potrebno vključiti v model BIM da se bodo lahko uporabljali kot vir informacij za forenzično analizo zamud in raziskujemo možnosti, kako lahko z uporabo 5D BIM okolja Bexel Managerja zagotavljali podporo za dokumentiranje in analizo zahtevkov, izhajajo iz zamud. Na osnovi izdelanih analiz v sklepnem delu podajmo zahteve, kako je potrebno strukturirati informacijske zahteve EIR (angl. Exchange Information Requirements) z uporabo smernic iz serije standardov ISO 19650.

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BIBLIOGRAPHIC– DOCUMENTALISTIC INFORMATION AND ABSTRACT

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Abstract:

The aim of the thesis is to examine the impact of using BIM protocols with standard contracts on claims management and to provide guidelines to clients and contractors on how to request information pertaining to claims using the EIR (Exchange Information Requirements).

The introductory part of the thesis provides an overview of the general legal framework and standard contracts in the construction industry. The core of the thesis focuses on forensic delay analysis, which is a process of analysing the causes and impact of delays to quantify the extent of schedule overruns and cost claims. Therefore, a synopsis of the methods of producing forensic analysis of delays and conditions for their selection are reported. In this context, the thesis provides a detailed overview of the key input and output information that is essential to support decision-making in forensic delay analysis and for the minimum information and documentation that must be included as part of detailed claims development.

The thesis explores the possibilities of using Bexel Manager to support claim documentation and analysis of delay-based claims and develop protocols to be used in Bexel Manager for creating and maintaining contemporary records. Based on the research carried out, the concluding part examines how requirements for filing claims should be structured within the EIR using the guidelines provided in the ISO 19650 series of standards.

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ACKNOWLEDGEMENTS

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LIST OF ABBREVIATIONS

AACE	Association for the Advancement of Cost Engineering
AC	Alliance Contract
ADR	Alternative Dispute Resolution
AIR	Asset Information Requirements
BEP	BIM Execution Plan
BIM	Building Information Modelling
CAPEX	Capital Expenditure
CDE	Common Data Environment
DBO	Design, Build and Operate
DRSC	Dispute Resolution Service Contract
ECC	Engineering and Construction Contract
ECS	Engineering and Construction Subcontract
ECSC	Engineering and Construction Short Contract
ECSS	Engineering and Construction Short Subcontract
EIR	Exchange Information Requirements
EOT	Extension of Time
FC	Framework Contract
FIDIC	Fédération Internationale des Ingénieurs-Conseils
JCT	Joint Contracts Tribunal
MIDP	Master Information Delivery Protocol
MIP	Method Implementation Protocol
NEC	New Engineering Contract
PIR	Project Information Requirements
PSC	Professional Services Contract
SC	Supply Contract
SCL	Society of Construction Law
SSC	Short Supply Contract
TIA	Time Impact Analysis
TIDP	Task Information Delivery Protocol
TSC	Term Service Contract

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1 INTRODUCTION

The construction industry is a major economic driver, employing 100 million people globally and contributing 13% of the world's GDP[1]. Over the past few years, the industry has delivered some impressive projects like the Burj Khalifa in Dubai, the Three Gorges Dam in China, and the Channel Tunnel between England and France. Today, the industry is pushing the limits of imagination to create even more complex and ambitious projects, such as The Line in Saudi Arabia.

Table 1: Ongoing megaprojects in the world

Project Name	**Country**	**Expected Completion**	**Cost (in USD)**
The Line	KSA	2030	500 billion
California High-speed Railway Project	USA	2030	128 billion
Dubailand	UAE	2025	76 billion
International Airport Al-Maktoum	UAE	2027	32 billion
Cross Rail Project	UK	2022	23 billion
Chuo Shinkansen High Speed Railway	Japan	2027	7 billion
Crown Round III Offshore Wind Farm Development: Zone III Teesside B 1400 MW	UK	2026	4392 million
Madrid Metro Expansion	Spain	2027	2790 million
Krampnitz Housing Development	Germany	2038	1831 million
Nantes New CHU Hospital Development	France	2027	1424 million

Despite this annual productivity growth of construction industry over the past 20 years has been only one-third of the average for the overall economy. One of the main reasons for this is the prevalence of conflicts and litigation in the industry. These disputes divert management resources away from the primary goals of the industry, reduce cost-effectiveness, and achieve little lasting benefit.[2]

Arcadis 2022 Global Construction Disputes Report defines construction disputes as "*A disagreement in which two parties, typically the owner and the contractor, differ in the assertion of a perceived contractual right, resulting in a determination issued by the owner in accordance with the process specified in the contract. If the determination is disputed by the contractor, the matter becomes a formal dispute.*"[3]

1.1 Causes and Effects of Construction Delays

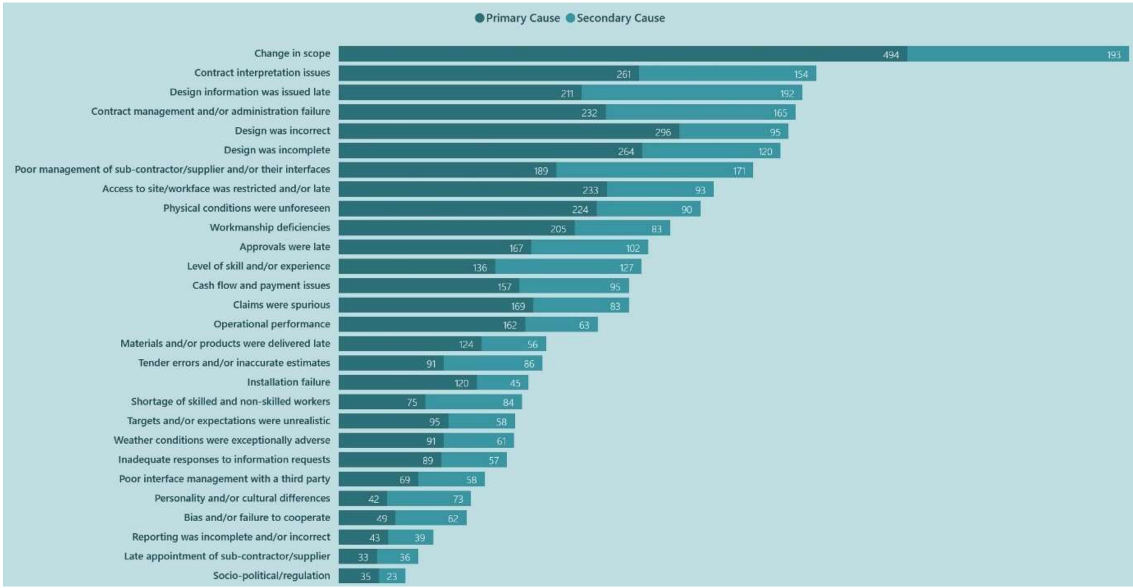

Figure 1: Causes of Claims and Disputes Worldwide[4]

HKA's CRUX Insight 2022 Report after analysing 431 projects in 28 countries of Europe, with a combined value of about $242 billion, found that the claimed costs were at 38.3% of the average project CAPEX despite the smaller scale of the projects and the EOT claimed was 60.5% of the planned programme duration[5]. Within Middle East, after analysing 380 projects from 12 countries with a combined value of $578 billion, it was found that claimed costs were about 35.8% of the project expenditure and the EOT claimed was more than 83% of programme durations.

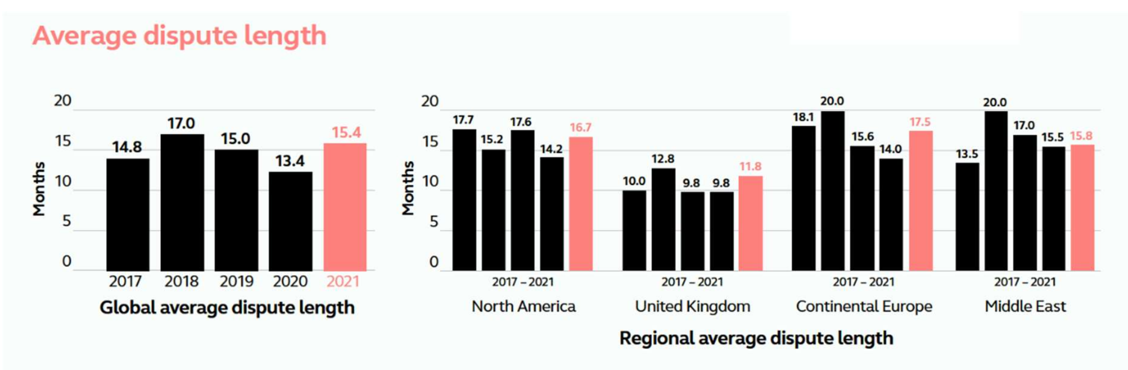

Figure 2: Average Dispute Length [3]

According to the Arcadis 2022 Global Construction Disputes Report, the average value of disputes in continental Europe has increased by 5.7% since 2020, and the average duration to resolve disputes has also climbed to 17.5 months in 2021 from 14 months in 2020. In the Middle East, there was a reported 12% increase in conflicts, with an average resolution time of 15.8 months.[3]

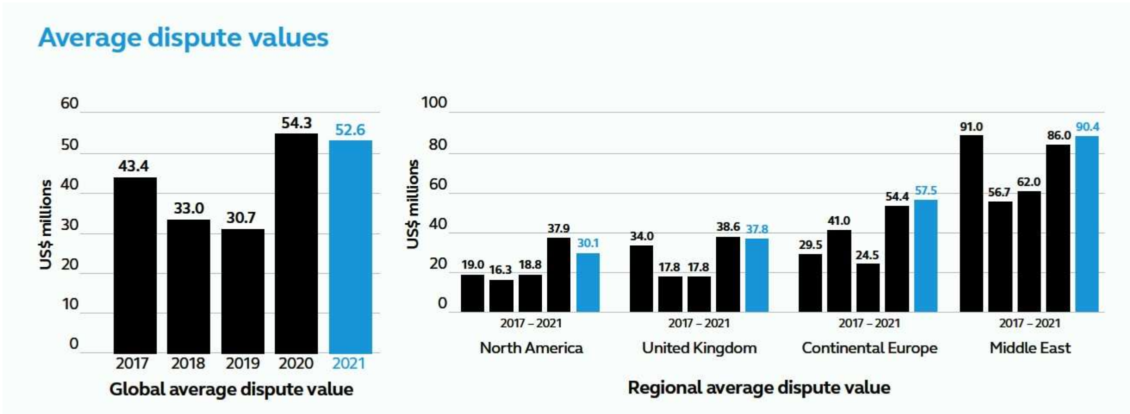

Figure 3: Average Dispute Values [3]

As construction projects become more complex, BIM is becoming an increasingly important tool for minimizing risks and ensuring successful project delivery. BIM simulates construction projects in a virtual environment, which can help to identify and resolve potential problems early on. It also promotes collaboration and knowledge sharing between project parties, which can help to improve communication and coordination. However, there are some barriers to adopting BIM, such as legal and contractual issues. For instance, it is not always clear who owns the BIM model or who is responsible for updating it. Other issue with adopting BIM is the lack of contracts specifically dedicated to BIM projects. Despite these challenges, BIM has the potential to significantly reduce the risk of disputes in construction projects. By providing a single source of truth for all project information, BIM can help to identify and resolve potential problems early-on before they lead to disputes. [6]

1.2 Objectives of the Thesis

The objective of the thesis are as follows:

a) To investigate the processes of forensic delay analysis and claim management, identify the steps involved in each process, and determine the artifacts required to perform delay analysis and substantiate its findings.
b) To create a protocol in Bexel Manager for documenting information relating to delays.
c) To prepare an EIR to request the information required for forensic delay analysis and claim management.

1.3 Research Methodology

The research followed a two pronged approach by studying the contractual dimension and the technical dimension of using BIM for forensic delay analysis and claims management.

The study of contractual dimension included exploring standards contracts widely used by the construction industry and their provisions for use of BIM. While some contracts like CIOB-TCM15 include BIM specific clauses and appendices, others point towards the use of BIM protocols and incorporating them to the contract. Hence the study further explored the various standard BIM Protocols prevalent in use.

The study of technical dimension included research into various types of delays and claims that occur in the construction industry and then moved on to explore the standard methods of delay analysis techniques used by delay analysts to assess the impact of a delay on the project schedule and cost. The documentation requirements for analysing delays and filing claims were identified from various legal articles and publications.

The second part of technical dimension explored the use of Bexel Manager for creating 4D and 5D models and progress monitoring. A protocol was developed to be followed on construction projects if delays of certain kinds occurred to update the information in the 4D model and to attach relevant documentation to the delay activity or activities that were affected by the delay.

Finally, ISO 19650 series of standards were explored to understand how the information requirements identified from all the above steps could be requested in the EIR.

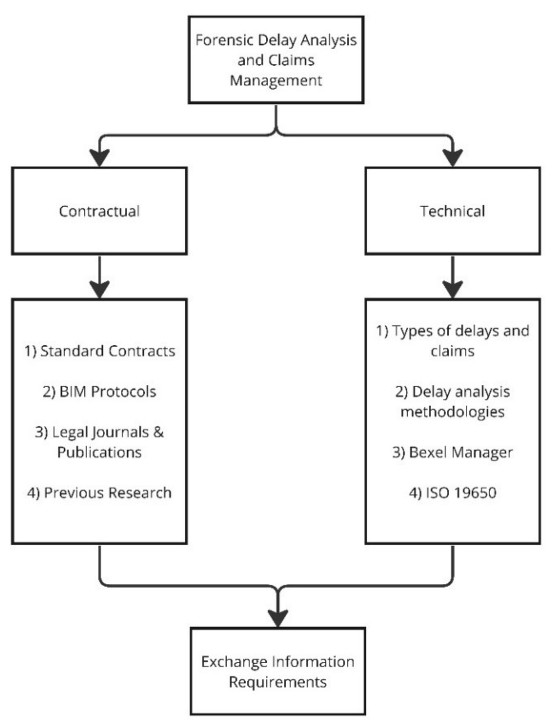

Figure 4: Research Methodology

1.4 Structure of the Thesis

Chapter 1 examines the factors that cause construction delays and the costs associated with them, as well as the trends in construction disputes in Europe and the Middle East. Various industry reports were analysed to identify the major causes of delays and disputes, as well as how, on an average, the time and cost required to resolve these disputes have changed over time. It then explains the goal of the thesis and the methodology used for the research.

Chapter 2 deals with the legal aspects of construction schedules by studying the standard contracts commonly used in construction industry and about how each of them suggests incorporating BIM into the agreement between parties. It then identifies the types of dispute resolution techniques and the provisions for dispute resolution in FIDIC, JCT and NEC contracts. Finally, it discusses the types of construction claims and the general stages of managing claims in construction.

Chapter 3 elaborates on the types of delays in construction, based on criteria like whether the delays occurred on the critical path or if they are considered excusable under contract and so on. It then explains the different methodologies used by delay analysts to quantify the effects of delays on the project schedule and budget, as well as the documentation requirements for supporting the analysis results.

Chapter 4 discusses the advantages of using BIM for construction, how BIM affects delays in general and how it can be used for delay analysis and construction claims. The chapter also explores work that has previously been done to identify the legal issues and challenges of using BIM in courts. Finally, it describes how the use of BIM protocols addresses some of the identified issues.

Chapter 5 discusses the core work of the thesis. It describes the steps involved in claim preparation using Bexel Manager. Based on the workflow in Bexel Manager and the data gathered from the previous chapters, the information requirements for each step of preparing claim documentation is identified. Then it describes how these requirements must be requested using an EIR, considering the provisions in ISO 19650 series.

Chapter 6 concludes the study with a discussion of the findings and recommendations for future research.

2 LEGAL ASPECTS OF CONSTRUCTION SCHEDULES

2.1 Standard Construction Contracts

A contract is defined as a "*a mutually binding agreement that obligates the seller to provide the specified product or service or result and obligates the buyer to pay for it*" [7]

Figure 5: Types of Construction contracts [8]

2.1.1 FIDIC (Fédération Internationale des Ingénieurs-Conseils)

FIDIC was founded in 1913 with the mission "*To promote the business interest of members providing technology-based intellectual services for the built and natural environment, and while so doing, accept and uphold our responsibility to the society*". FIDIC attempts to allocate risks in a balanced manner to the contractual parties and to provide a contractual basis for management of claims and issues and are widely used for international projects both in civil works and building projects. FIDIC is generally divided into two parts: General Conditions and Particular Conditions. 'Part I: General Conditions' consists of clause related to rights and responsibilities of each party, payment procedures, measurement and evaluations, variations and adjustments, termination, and claims and dispute resolution. 'Part II: Particular Conditions' is used for adding project-specific clauses such as applicable law, contract language and the name of Employer's Representative for the project amongst other conditions.

The FIDIC suite of contracts mainly consists of the following:

a. FIDIC Red Book - Conditions of Contract for Construction
b. FIDIC Yellow Book – Conditions of Contract for Plant & Design Build
c. FIDIC Silver Book - Conditions of Contract for EPC/Turnkey Projects
d. FIDIC Green Book – Short Form of Contract
e. FIDIC Gold Book – Conditions of Contract for Design, Build and Operate Projects

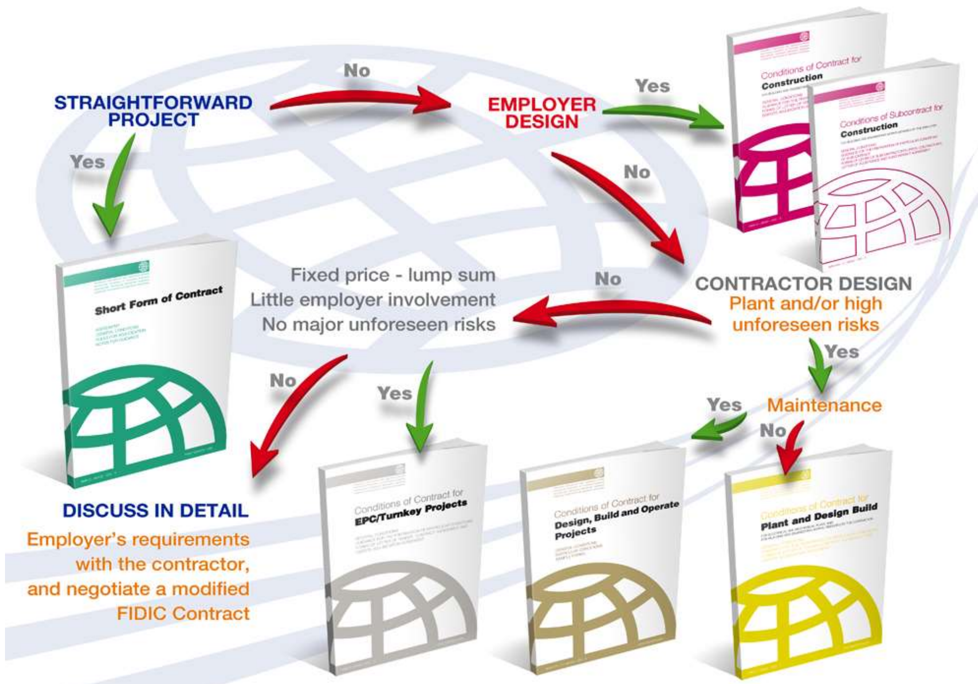

Figure 6: FIDIC suite of Contracts [9]

FIDIC has yet to incorporate BIM into its Rainbow suite and they have not released or recommended any BIM protocol for use with FIDIC contracts. Instead FIDIC, within the Special Provisions, has provided an advisory note for use on BIM projects. Two documents meant to provide detailed guidelines for BIM projects using FIDIC contracts are being developed: a “Technology Guideline” and a “Definition of Scope Guideline Specific to BIM”.

Additional considerations that need to be considered when using BIM on FIDIC projects. These include copyright issues (intellectual property rights), extended confidentiality agreements to include all parties involved in the project, collection and use of data, design obligations of each party, insurance requirements and including provisions that require the development of documents like BEP as a precondition to payment.[10]

2.1.2 JCT (Joint Contracts Tribunal)

JCT was formed by the Royal Institute of British Architects and published the first issue of JCT standard form of building contract in 1931. JCT was formed with the mission "To develop, publish, procure the publication, revise and disseminate in both paper and electronic form suites of standard forms of contract and tender documentation and practice notes". (JCT - Our Mission, 2021). JCT is widely used in UK and Wales and the law that generally applies to JCT is the Law of England.

JCT contracts consists of the following:

a. Standard Building Contract
b. Intermediate Building Contract
c. Minor Works Building Contract
d. Major Project Construction Contract
e. Design and Build Contract
f. Management Building Contract
g. Construction Management Contract
h. JCT-CE Contract
i. Measured Term Contract
j. Prime Cost Building Contract
k. Repair & Maintenance Contract

The Joint Contract Tribunal (JCT) published a Practice Note in May 2019 to help understand the legal and contractual implications of building information modelling (BIM). The Practice Note is split into two parts:

- Part A: A commentary on the provisions in the JCT Design and Build Contract (DB) that are relevant to BIM.
- Part B: A BIM Protocol checklist, suggesting a non-exhaustive list of main topics that may be covered by a BIM Protocol.

The appendices to the Practice Note provide a checklist of items to be considered when drafting the EIR, a glossary of BIM terms and the list of clauses from the JCT DB that were discussed in Part A of the Practice Note for reference purposes.

The practice note provides commentary on issues related to incorporation of BIM protocol with the contract, precedence of contract documents and procedures for submission of design. Other relevant matters that JCT recommends including in the protocol are regarding the monitoring and facilitation of access to CDE, information that should be provided before practical completion, change management and procedures that follow the termination of the contract.

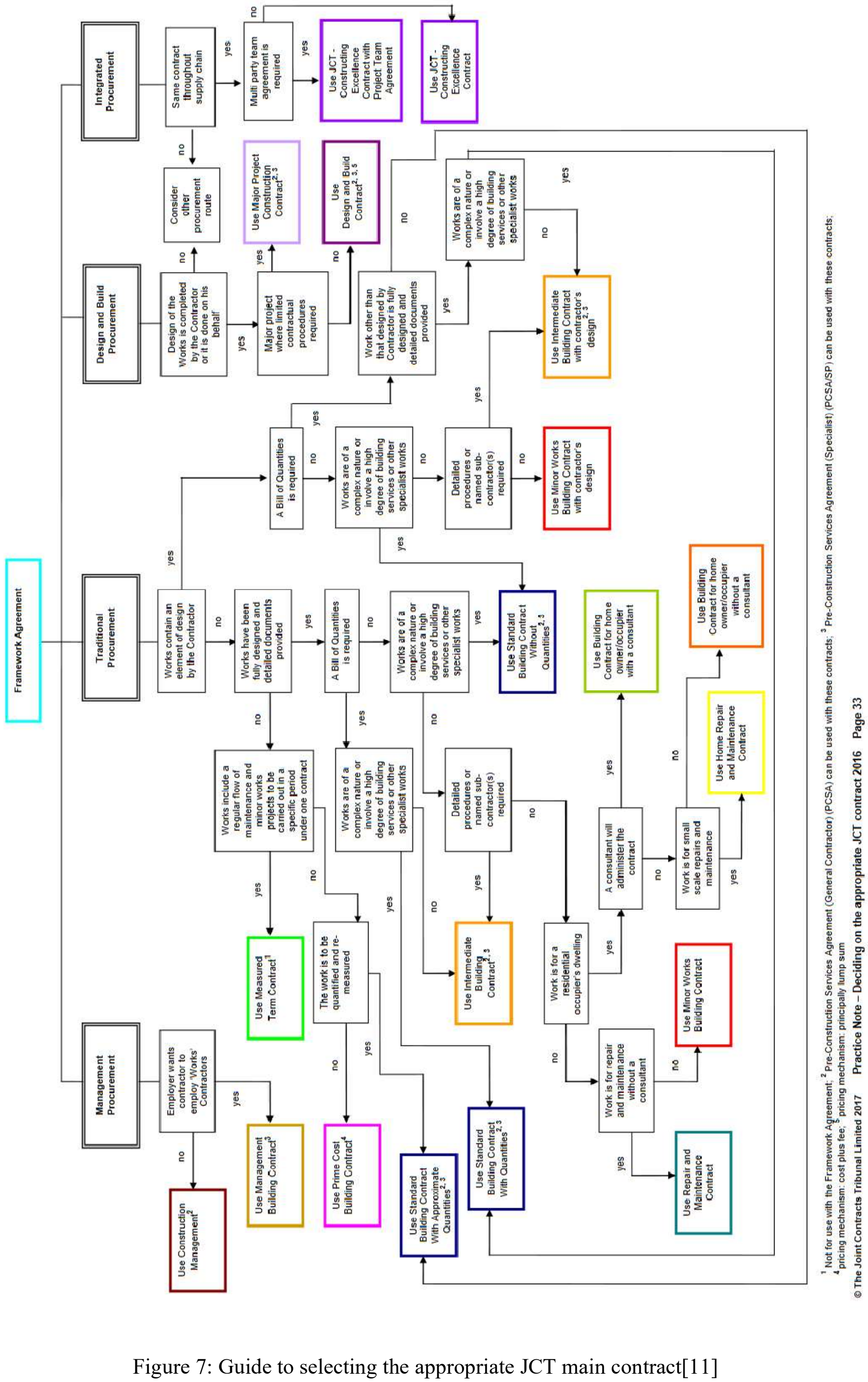

Figure 7: Guide to selecting the appropriate JCT main contract[11]

2.1.3 NEC (New Engineering Contract)

First edition of NEC suite of construction contracts was published in 1993 with the intention to promote partnership and collaboration between the contractual parties: the client and the contractor. The third edition NEC3 which was published in 2005 and the fourth edition NEC4 published in 2017 are currently in use.

The different documents in NEC4 suite of contracts include the following (NEC3, 2021):

a. Engineering and Construction Contract (ECC)
b. Engineering and Construction Subcontract (ECS)
c. Engineering and Construction Short Contract (ECSC)
d. Engineering and Construction Short Subcontract (ECSS)
e. Framework Contract (FC)
f. Term Service Contract (TSC)
g. Supply Contract/Short Supply Contract (SC/SSC)
h. Dispute Resolution Service Contract (DRSC)
i. Design, Build and Operate (DBO)
j. Alliance Contract (AC)

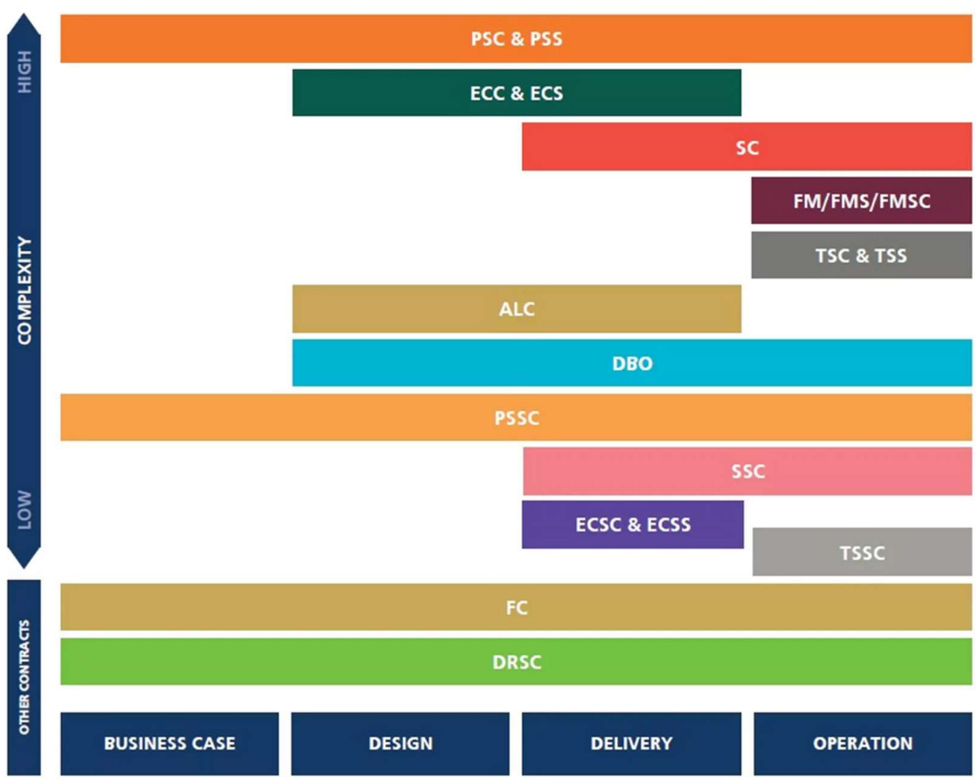

Figure 8: NEC Suite of Contracts[12]

NEC has issued practice notes "How to use the CIC BIM Protocol with NEC4" in 2018 and "How to use the Information Protocol to support BS EN ISO 19650-2 the delivery phase of assets with NEC4" in 2021. It provides clarifications and connections between the terms used in the contract and those in the protocol. For instance, the term 'Appointed Party' in the protocol is equivalent to the term 'Client' in the contract.

TERM IN THE PROTOCOL	EQUIVALENT TERM IN ECC
Material	Project Information (if provided by the *Contractor)*
Federated Information Model	Information Model
Lead Appointed Party, Appointor(s), Appointee(s),	Information Providers
BIM Execution Plan	Information Execution Plan
Works	*works*

Figure 9: Model Scope Entry Terms[13]

The practice note requires that the documents that form the "Information Particulars", when exist before the contract date must be listed in the first page of the Information Particulars in the Protocol and the completed front page and the documents included in the contract and tasks the Project Manager (Appointor) with the responsibility of maintaining a record of documents created after the contract date. It states that changes made to documents present before Contract date would constitute a compensation event. It further provides instructions regarding ownership and liability, adherence to dates in protocol MIDP and TIDP, creation and maintenance of Risk Registers and termination of contract. NEC also has issued Option X10 which is intended to be used without protocol.

2.1.4 PPC2000

PPC2000 is a multi-party contract based on partnering and collaboration between parties and these factors are essential in BIM achieving its full potential. According to the author of the contract, it has been used without any BIM related amendments and without integration of a BIM Protocol by Ministry of Justice, UK on a BIM enabled project[14].

Some of the provisions within PPC2000 that enabled this are[15]:

- It encourages early involvement of contractors and suppliers, and this enhances the design process, pricing, programme development and risk management.

- Whole team can be appointed under a single multi-party contract. This creates transparency and awareness for each party about the obligations, duties, and timescale of performance of all other parties.
- The whole team can sign the same confidentiality agreement, and this improves trust and collaboration between parties and the open sharing of intellectual material contained within the BIM model.
- A single process for communication and a single process for dispute resolution.
- Has a contractual timetable which provides the timeline for input from each project member during both pre-construction and construction phases and a BIM protocol can be integrated to this timetable.

PPC2000 has issued a BIM Supplement that provides for incorporation and compliance with a BIM Protocol. It also provides an alternative to amending the contract by[14]:

- the parties completing PPC2000 such that the role, expertise and responsibilities of a BIM Coordinator is defined under the Lead Design Consultant Services Schedule.
- incorporating the inputs, timings and responsibilities described in the BIM Protocol within the Partnering Timetable and Project Timetable.
- including BIM model as part of the project proposal

2.1.5 CIOB – CPC 2013

Complex Projects Contracts or CPC 2013 was published in 2013 and then subsequently renamed in 2015 as Time and Cost Management Contract (TCM15) to reflect the core strengths of the contract. It was written for use on complex construction projects like major real estate projects, engineering, or infrastructure projects within the UK and overseas. The contract was developed with the aim of reducing the likelihood and severity of disputes by providing explicit guidelines for programming, resources data and record keeping based on industry best practices. It was the first contract to include BIM in its clauses and appendices[16]. It requires that a BIM Protocol be used with it and prescribes AIA E02-2008 BIM Protocol as the default option if there is no project specific protocol[14]. BIM specific clauses within CPC 2013 attempts to address the perceived barriers associated with BIM adoption.[16]

Some BIM specific clauses are as follows[16]:

- Copyright and ownership remain vested with the creator.
- The employer is permitted to use contractor's designs for certain purposes.
- Data security engineer is responsible for ensuring that sensitive documents are accessible by only authorized personnel.

- The federated model and information obtained from it takes precedence over other construction documents.
- Maintenance of the federated model is the responsibility of the design coordination manager.
- Contract prevails over BIM Protocol unless otherwise mentioned in the contract's special conditions.
- Model is only used for the design stage it was intended for and the design contributor for each element is assigned to each stage of the project.
- The required software and the version must be stated in the working schedule and progress reports.
- Contractor is responsible for the suitability and integrity of the selected software and the integrity of information extracted from the model if the contractor was responsible for the design of the whole work.
- Contract promotes the use of CDE for exchanging information.

CPC 2013 User Notes provide an overview of each project team member's roles and responsibilities.

2.2 Disputes

The 2017 FIDIC Contracts distinguishes between claims and disputes and divides them into separate clauses: Clause 20 – Employer's and Contractor's Claims and Clause 21 – Disputes and Arbitration[17]. It defines claims as "*request for entitlement under the Contract*" and disputes arise when claims are rejected or ignored.

2.2.1 Causes for Disputes

As per FIDIC Red Book, the contractor is entitled to an extension of time (EOT) claim and/or additional costs if the following event(s) occur and cause significant delay to the completion of the Project, subject to the provisions of Cl. 20.2 of the Contractor's Claims[17]:

- Defective and deficient contract documents provided to the contractor (Cl 1.9)
- Delay in access to site (Cl 2.1)
- Disruption (Cl 4.6) caused by Employer's personnel, or any other contractors employed by the Employer.
- Differing site conditions (Cl 4.12) – Unforeseeable physical conditions an experienced contractor could not reasonably identify.
- Delay in issue of owner-furnished items (Cl 4.20)
- Directed changes (Cl 7.4) for example in the location or details of specified tests.
- Delays caused by authorities (Cl 8.5)

- Suspension of work (Cl 8.9) unless due to the failure of contractor to comply with requirements for the project.
- Acts of God/Weather, strikes (Cl 17.4) - Unforeseeable climatic conditions an experienced contractor could not reasonably identify.
- Changes (Cardinal, Constructive and directed), Variation in Quantities (Cl 3.3) caused by additional or modified drawings issued by the Engineer.
- Force Majeure (Cl 19.4)

Likewise, the Employer is entitled to make a claim in case of defective workmanship (Cl 2.5) or in case of poor quality of workmanship.

2.2.2 Provisions for Dispute Resolution in Standard Contracts

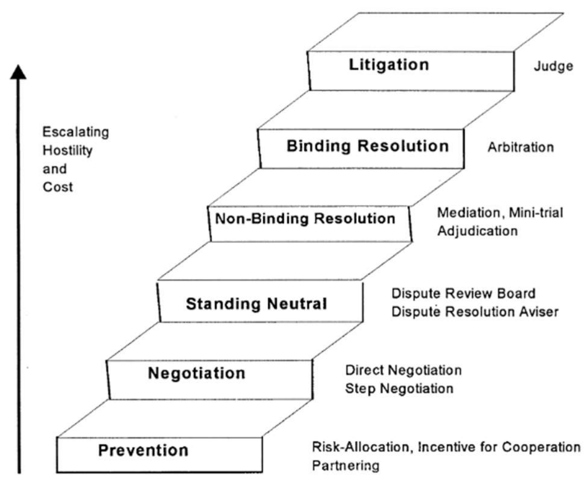

Figure 10: Steps in construction dispute resolution [18]

Negotiation: The parties involved in the dispute try to reach an amicable resolution amongst themselves.

Mediation: A neutral third party appointed by the parties in dispute, assists the parties to resolve the dispute and reach an agreement.

Arbitration: The parties involved in the dispute appoint a neutral third party with relevant experience (arbitrator) to help resolve the dispute and the verdict given by the arbitrator is legally binding.

Litigation: Involves trials in courts and is a complex, slow, and expensive process resorted to when all other methods of dispute resolution fail.

2.3 Construction Claims

Construction claims are requests made by either party bound by a contract, for compensation either in terms of additional time or payment or both, when the other party fails to fulfil his duties and obligations as mentioned in the contract. Over the past two years, the construction industry has been severely impacted by COVID-19 in the form of project disruptions, labour impacts and job losses, time overruns, cost overruns and supply-chain disruptions[19]. 2021 saw an increase in the number of disputes and claims due to the impact of COVID-19, as project stakeholders were unable to anticipate the ensuing interruptions.

2.3.1 Types of Construction Claims

Claim Type	Forms	Damages
Accelaration	Directed Constructive	Increased hours Increased manpower
Delay	Excusable Non-Excusable	Office overhead Cost of financing
Disruption		Additional Manpower Labor inefficiency
Tort	Negligence Negligent misrepresentation	Economic

Figure 11: Types of Construction Claims

2.3.2 Construction Claims Management

Claim management is quite unavoidable in construction and requires effective management throughout the project life cycle. Construction projects have four phases: Pre-tender, contract formulation, construction, and post completion[20].

Claim management process involves 4 phases:

Claim Prevention: While most construction claims occur due to conditions encountered during the construction phase, the pre-tender phase presents the best opportunity to prevent claims. Pre-contract preparation of reliable and complete design and documentation are vital for effective claim prevention.

Claim Mitigation: Due to the highly complex nature of construction activities and evolving environment in which they are carried out, it is impossible to fully prevent claims from arising. Through good coordination, open and honest communication the project players can ensure timely resolution of disputes and mitigate the circumstances of the dispute and thereby prevent claims from occurring. A well-developed scope and scheme for risk distribution, plan for management, selection of Form of

Contract and procedure for dealing with emergent issues will decrease the chances of claims occurring[20].

Pursing Claims: This phase involves claim identification and claim quantification. Scope of work, contract terms, description of extra work and extra time requested, and record of hold-ups and delays serve as input for claim identification. Once claims are identified, they need to be quantified in terms of payment or EOT. EOT can be quantified by analysing the schedule to identify the works affected by the claimed activity and the direct and indirect costs calculated by estimating loss of profit and other opportunities the party lost due to the delays in the project completion.[20]

Claim Resolution: When questions arise regarding whether a claim is a change is contract or scope or whether the claimed time or compensation is correct, the situation is approached in a step-by-step manner towards resolution. Depending on the terms of the contract the claim may proceed to Alternative Dispute Resolution (ADR) methods like negotiation, mediation, and arbitration and if the parties are unable to resolve the dispute completely through these methods, the claim may enter litigation stage.[20]

3 CONSTRUCTION DELAYS

3.1 Types of Delays

The figure below gives an overview of types of delays. In the follow up subsection we analyse the nature of this delays.

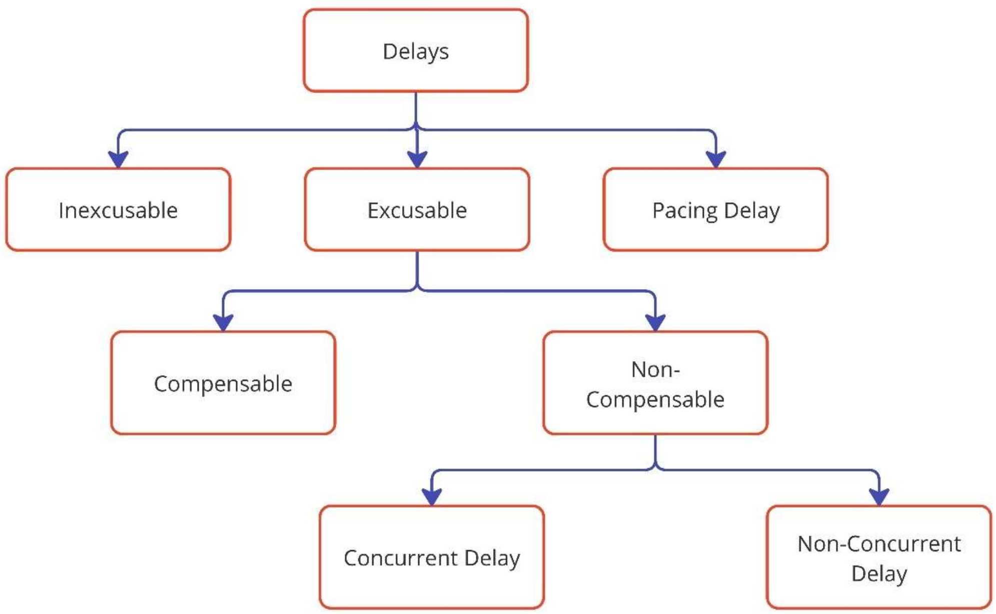

Figure 12: Classification of construction delays

3.1.1 Critical vs. Non-Critical Delays

Critical delays are those that affect activities on the critical path or near critical path, resulting in extension of project completion date or a delivery milestone. Only critical delays are eligible for consideration for Extension of Time (EOT) claims. Non-critical delays are those that affect activities on non-critical path and therefore does not contribute towards extension of project/milestone delivery.

3.1.2 Excusable vs. Inexcusable Delays

Critical delays could be either compensable or non-compensable. Compensable delays entitle the contractors for an EOT or compensation or both. These are delays that are out of the contractor's control such as major changes in plans and specifications during construction, delayed approval of submissions, owner failure to provide timely and adequate access to work site, delays in procurement of owner-furnished materials etc. When an EOT is granted, the contractor is excused from paying the liquidated damages. Inexcusable delays are when the contractor is entirely responsible for the delay in the activity. In this case, the contractor is liable to pay liquidated damages to the owner as specified in the contract documents. Examples of contractor induced delays are performance of defective work, slow mobilization, inadequate control of cost and schedule, inadequate investigation of site before bidding, under-quoting during bidding etc.

3.1.3 Compensable vs. Non-compensable Delays

Compensable delays are those that qualify the contractor for an EOT as well as monetary compensation. Non-compensable delays are excusable delays on the critical path, caused by events such as strikes, unusually extreme weather, acts of God or war etc. They are entitled to an EOT, but no additional monetary compensation will be granted.

3.1.4 Concurrent Delays

Concurrent delay is when two separate events occur at the same time, where one is excusable and other non-excusable in nature, resulting in extension of project/milestone delivery. Concurrent delays are generally non-compensable unless the contractor can adequately prove that the loss they incurred would have occurred even if the non-excusable delay had not occurred. SCL Delay and Disruption Protocol 2nd Edition states that *"Where Employer Delay to Completion and Contractor Delay to Completion are concurrent and, as a result of that delay the Contractor incurs additional costs, then the Contractor should only recover compensation if it is able to separate the additional costs caused by the Employer Delay from those caused by the Contractor Delay. If it would have incurred the additional costs in any event as a result of Contractor Delay, the Contractor will not be entitled to recover those additional costs."*[21]

3.1.5 Pacing Delays

Pacing delays are conscious or self-imposed delay in which either the owner or contractor suspends or slows down the completion of an activity on the schedule in response to a delay in the preceding activity caused by the other party. When the contractor decides to pace his work, it is important to notify the owner else it may be considered as a non-compensable delay.

3.2 Delay Analysis Methodologies

Society of Construction Law lists 6 methods for performing forensic delay analysis and each of these approaches is more effective than the others for certain purposes based on various factors. Braimah et al identifies records availability, baseline programme availability, the amount in dispute, nature of baseline programme, updated programme availability, and the number of delaying events as the top 6 factors that influences the selection of delay analysis methodology based on studies conducted on the UK construction industry[22]. Most frequently used delay analysis methodologies are as described below.

3.2.1 Impacted As planned Analysis

This method involves modifying the approved baseline schedule by inserting delay events as new activities and related logic, to determine the hypothetical impact of those delay events. The modified schedule is called the *impacted as-planned* schedule. This is a simple method which does not rely on an as-built schedule and hence considered a hypothetical model. The delay is quantified as the difference between the project completion date as in the impacted as-planned schedule and the approved as-planned schedule.

3.2.2 Collapsed As-Built Analysis

This method reverse engineers the as-built schedule by removing the delay events from it, to determine the time of project completion had the delay events not occurred. The modified schedule is called the *but-for* schedule. It does not require an as-planned schedule or a contemporaneous schedule update. The delay is quantified as the difference between completion time as in the as-built schedule and the but-for schedule.

3.2.3 As Planned vs. As-Built Windows Analysis

This method uses both the approved as-planned schedule and the as-built schedule and is usually used in shorter projects where the critical path remained the constant throughout the project. It is performed by first identifying the critical path and near-critical path in the approved as-planned schedule and then comparing the planned start and finish dates of activities on these paths with their respective actual start and finish dates as per the as-built schedule.

3.2.4 Time Impact Analysis (TIA)

In this method, each delay event is analysed individually in the order that they occurred to calculate its impact on the schedule. The delay event is quantified as the difference between the project completion date before and after the event, based on schedule immediately before and after the delay event. It does not require the as-built schedule and is widely used during the project to mitigate effects of delay.

3.2.5 Time Slice Windows Analysis

This method is carried out retrospectively by dividing the total project duration into multiple segments (windows) of shorter duration and quantifies the as-built critical path delays for each of these windows. The as-built conditions for each of the selected windows are reflected in this method by comparing the critical path in the approved as-planned schedule to the as-built schedule.

Method of Analysis	Analysis Type	Critical Path Determined	Delay Impact Determined	Requires
Impacted As-Planned Analysis	Cause & Effect	Prospectively	Prospectively	• Logic linked baseline programme. • A selection of delay events to be modelled.
Time Impact Analysis	Cause & Effect	Contemporaneously	Prospectively	• Logic linked baseline programme. • Update programmes or progress information with which to update the baseline programme. • A selection of delay events to be modelled.
Time Slice Windows Analysis	Effect & Cause	Contemporaneously	Retrospectively	• Logic linked baseline programme. • Update programmes or progress information with which to update the baseline programme.
As-Planned versus As-Built Windows Analysis	Effect & Cause	Contemporaneously	Retrospectively	• Baseline programme. • As-built data.
Retrospective Longest Path Analysis	Effect & Cause	Retrospectively	Retrospectively	• Baseline Programme. • As-built programme.
Collapsed As-Built Analysis	Cause & Effect	Retrospectively	Retrospectively	• Logic linked as-built programme. • A selection of delay events to be modelled.

Figure 13: Delay Analysis Methodologies [23]

3.3 Contemporary Records/Evidence used in Forensic Delay Analysis

Clause 20.2.3 of FIDIC Yellow Book defines contemporary records as "*records that are prepared or generated at the same time, or immediately after, the event or circumstance giving rise to the claim"*[24]. Contemporary records are the most reliable type of evidence to support claims, and FIDIC contracts require contractors to keep these records as a necessary part of substantiating any claims that may arise during the performance of the contract. Unlike conventional delay analysis, forensic schedule delay analysis relies on a broader range of evidence, including not only schedules and updates, but also a comprehensive range of contemporary records. The more contemporary records that are available, the stronger the case will be for establishing the facts of the delay. Examples of contemporary records are as described below.

3.3.1 Baseline Programme

The Baseline Programme is a detailed plan of all the activities that need to be completed under the contractual scope of works. It includes the durations of each activity, the interdependencies between activities, and the milestones that need to be achieved. The baseline schedule may also include information such as activity durations, contingency reserves, resource requirements, underlying constraints, or assumptions, activities that the client is responsible for, such as providing site access, designs, or free-issue materials. The approved baseline schedule is used as a benchmark for tracking the project's progress and budget.

3.3.2 Resource Loaded Schedules

Resource loaded schedules are schedules that reflect the constraints of resources such as labour, equipment, materials, and budgeted costs on the activity progression. They provide insights into bottlenecks and constraints caused by these constraints on the project schedule. They can also help to identify areas where resources can be optimized.

3.3.3 Programme Updates

Programme updates are the most important records in a project because they provide a detailed overview of the project's progress and any delays that have occurred. They should be supported by other records, such as technical submittals, delivery notes, inspection and test sheets, progress reports, etc. Modifications to programme updates, such as changing planned dates, durations, or logic, and discrepancies, such as past dates being changed or inconsistent or illogical data between updates, can limit the credibility of a claim. To avoid this, it is a good practice to accurately record modifications and discrepancies with an explanation as to why they occurred.

3.3.4 Progress Reports & Meeting Minutes

Progress Reports: Progress Reports are important documents that provide details of the resources used, duration, location, and date on which an activity was performed. The credibility of a claim can be affected if any of this information is missing from a progress report, or if there are missing reports, or if there are inconsistencies between daily, weekly, and monthly reports. Mentioning delay and disruption events in the progress reports can help to establish the causes of these events and to estimate their costs[25].

Daily reports: Daily reports can provide a detailed overview of the work that was performed each day. This can be helpful in identifying any delays, as well as providing supporting evidence for the actual start and finish dates of an activity, the percentage of progress stated in progress reports, and labour productivity.

Project meeting minutes: Project meeting minutes can provide insights into discussions about the project's progress, any delays that occurred, and the measures that were discussed to mitigate them.

3.3.5 Documentation

Photographs and videos: Properly dated and geo-tagged photos can provide visual evidence of the project's progress. This can be helpful in identifying any delays, as well as in tracking the project's overall progress[25].

Drawing & Document Registers: Drawing & Document Registers are comprehensive lists of all drawings, documents and other relevant information that were available to the contractors at any given time and the timeline of submission, review, and approval for construction. An accurate and complete document register can prove valuable in identifying the responsibility for delays caused by delays in communication.

Change orders: Change orders can indicate changes that were made to the project scope, which can be helpful in identifying any delays, variations, and changes made to the baseline schedule.

RFIs, emails and letters: These documents can provide insights into the communications between the parties, and they serve as a formal record of the agreements, disputes, or changes that were made to the overall scope during these communications. This can be helpful in establishing the timeline of events and identifying any causes for delays.

Site Instructions: Instructions from the engineer or project manager help to define the scope and timeline of an activity. Records of these instructions provide an additional layer of progress monitoring and control and can be used to substantiate progress reports.

Weather Records: They provide evidence of any unforeseen climate conditions that resulted in delays to the project.

Subcontractor records: They provide evidence of the work performed by subcontractors and the impact these activities had on the project schedule.

Method statements: They provide records on how unusual, unplanned, or repeated activities were performed.

Claim documentation: They are useful in establishing the timeline of events and identifying any delays and the corresponding notices and claims filled by either party.

4 REVIEW OF USE OF BIM FOR DELAY ANALYSIS

4.1 Building Information Modelling

A survey by buildingSMART International titled “Understanding the Role of BIM and CDEs Today and Expectations for the Future” found that the top three reasons why organizations use BIM are[26]:

- It provides a faster means to identify and resolve clashes
- It improves the visibility of design decisions
- It provides a collaborative project environment

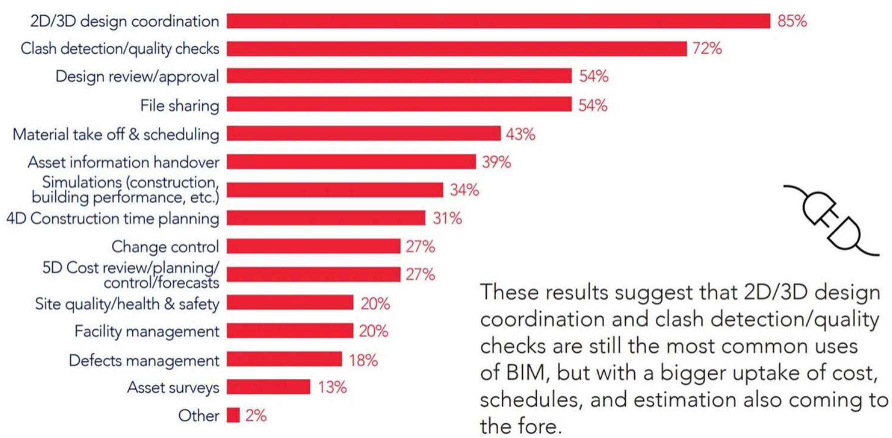

Figure 14: Commonly adopted BIM Uses within organizations [26]

CDE forms an essential part of all BIM enabled project, as improves project collaboration, increases efficiency, and transparency of information management. A project CDE is vital is for storing and retrieving information and documents related to claims and disputes for the following reasons:

- CDE captures the full audit trail of changes to project information which can ensure the reliability of the information stored within it.
- It helps improve communication and coordination between project stakeholders which can lead to increased trust and thereby more efficient and effective project management.
- The information stored within the CDE during one stage of the project can easily be accessed and used in the subsequent stages of the project.
- Automated checks can be implemented on the file naming and metadata stored within the information containers stored within it and thereby reducing the effort it takes to approve documents to be shared or published.
- The container structure of the CDE ensures that all the stakeholders are accessing up-to-date information.

4.2 BIM for Construction Delay Analysis

BIM Uses related to forensic delay analysis are 'Author 4D model' and 'Author 5D model' and the information created are used for the purpose of progress monitoring, delay analysis and documentation. Some of the companies using BIM for forensic delay analysis are HKA, Driver Trett and J.S Held.

Gibbs et al. found that delay analysts face two major challenges: retrieving information and presenting their analysis clearly[27]. They found that most claims are rejected due to inconsistencies in the information presented or because each party refers to a different version of the same document. Using a centralized electronic database that is accessible to all project stakeholders ensures that everyone has access to the latest information and that all parties are referring the same version of a document. Electronic data management systems are beneficial over paper documents because the information can be easily filtered, sorted, and accessed, which is essential in the event of a claim[28].

4.2.1 Benefits of BIM in Delay Analysis

Oral testimony in courts tends to leave much to the imagination of the listener and this may lead to them filling in the gaps with information of their own based on their biases. According to O'Flaherty in Narayanan, 2001, the use of visual display and animations could help with conveying complex and technical information to non-technical people with relative ease, and this enhances the retention of the conveyed information in their memory. A single animation could be used to convey information contained within various files and folders thus saving time and effort[29]. The value of a 4D simulation is directly correlated to the supporting information used in its development[30]. Hence, a good record-keeping system must be implemented, and proper change control and approval procedures must be developed to ensure that the information stored can be used for delay analysis and act as supporting documentation.

Guevremont et al found in a survey of lawyers specialized in construction delay claims that 4D simulations are most valuable in courts when they are developed as a contractual requirement[31]. The majority of lawyers interviewed agreed that 4D models and simulations would be useful for all forms of dispute resolution, from negotiation to litigation since they can provide a better understanding of the stakeholders' viewpoint, visualize the merits of a claim, and make the interrogation process more efficient.

Gibbs et al recommends using visualizations side-by-side to compare the as-built and the as-planned progress to make it easier to identify the delays on the project and their effects on the overall schedule[32]. 4D simulations can also be used to visualize the impact of a design change on the overall schedule, and to compare the different factors that were considered when developing the schedule, or the circumstances that led to changes in the approved schedule during the project[33].

4.2.2 Issues Regarding the use of BIM in Courts

Bodea et al. (2018) identified two dimensions of the legal implications of using BIM: the contract dimension and the technical dimension[34]. The contract dimension addresses the legal status of a BIM model at any given time during the project, including whether it is contractually binding, for information and referencing purposes, or to be reused and developed further. The technical dimension addresses matters concerning software use, version control, data storage, data loss, interoperability, copyright, and intellectual property rights.

Soltani et al. (2017) interviewed several construction lawyers and forensic delay analysts to identify the reasons behind not using BIM in courtrooms for forensic delay cases[35]. They concluded that the novelty of BIM and the complexity of performing forensic delay analysis are the main factors. The major hurdles in creating a forensic information model (FIM) where 3D models do not exist are the cost and resources required, as well as concerns about its reliability.

Ellatif (2021) conducted an extensive literature review to identify the risks associated with using BIM[36]. These risks can be classified into two categories: Contractual risks and technical risks.

Contractual risks include:

a) Intellectual property rights: ownership rights of BIM data and models.
b) Professional liability: liability for errors or omissions in the shared work.
c) Risk allocation: no clarity in the distribution of risks between the parties involved.
d) Legal validity of BIM models: legal admissibility of BIM models and other electronic formats in court as evidence.
e) Insurance requirements: Participants should be aware of the terms of their agreement so that they are not exposed to risks that are not covered by insurance.
f) Protocol, processes, and responsibilities: scope and requirements of a BIM project need to be clearly defined, as well as the protocols, processes, and responsibilities of the parties involved.

Technical risks include:

a) Interoperability: ability of various software applications to transfer data between them.
b) Data security: BIM data must be secured from unauthorized access or modification.
c) Model management: ability to keep track of changes, maintain data accuracy and manage the file sizes as the project progresses.
d) Software versions: different versions of the same software are sometimes incompatible.
e) Data loss: loss of BIM data due to hardware failure, software corruption, or human error.
f) Data misuse: unauthorized use of BIM data.
g) Database management: organization, use and storage of BIM data.

h) Reliability of models: accuracy and completeness of the model and whether other parties can fully rely on the models provided by designers.

The Winfield-Rock Report, published in 2018, examined the legal community's understanding of BIM, as well as the challenges and opportunities that BIM presents to lawyers. The report was published by two leading lawyers, May Winfield, and Sarah Rock, based on a survey response from 158 industry professionals and interviews with 44 key stakeholders. The report identified the following as major hurdles in using BIM for legal purposes[14]:

a) The knowledge divide between legal professionals and the project delivery team
b) Lack of standard legal definitions
c) Use of umbrella terms like "BIM Level 2" instead of clearly defined requirements
d) Lack of consensus between standard forms of contract and BIM protocols
e) Varying terminology used by different contracts to define the same thing adding an extra layer of confusion.
f) Lack of clarity in ownership rights and responsibilities related to the models and risk allocation between parties.

Olatunji (2015) argues that it is better to have dispute resolution plans in place before disputes occur[37]. This is because disputes that are not resolved quickly can damage relationships and derail progress. Olatunji suggests using scenario thinking methodology to identify potential disputes and develop efficient solutions. This methodology involves studying disputes that have occurred in previous projects, both those that used BIM and those that did not, to identify common problems and solutions and further to strengthen the contract language to address these eventualities.

4.3 BIM Protocols

BIM protocols are used supplementary to standard forms of contract and aims to provide legal definitions to BIM terminology, define the roles, responsibilities and liabilities of parties involved in a BIM project and the security requirements for the project data.

UK Government Construction Client Group said that "*little change is required in the fundamental building blocks of copyright law, contracts, or insurance to facilitate working at Level 2 of BIM maturity. Some essential investment is required in simple, standard protocols and services schedules to define BIM-specific roles, ways of working and desired outputs*."[14] While some standard forms of contract, such as JCT and NEC, have issued guidelines on how to incorporate BIM protocols, little has been done to incorporate BIM-specific clauses into these contracts.

4.3.1 CIC BIM Protocol

The CIC BIM Protocol was first published in 2013 in response to the UK Government's BIM Strategy. It was developed to provide a BIM framework for use on construction projects. The second edition of protocol was issued in 2018 considering the comments and criticisms on the first edition and in better alignment with PAS 1192. It is a supplementary legal document that can be used with all standard forms to provide legal definitions for BIM terminology and to define obligations, liabilities and rights of the employer and the project delivery team. The protocol also provides appendices to outline the security requirement for the data and to define the information required to be produced based on the RACI matrix and information particulars like the EIR and BEP. All references in the Protocol to Information Requirements includes both EIR and BEP.

CIC BIM Protocol was drafted such that minimum changes were required to be made to the existing standard forms of contract. It is important to note that the protocol must be implemented in all contracts and subcontracts across the project to ensure consistency in the BIM framework. The employer’s information manager is responsible for establishing and managing the processes, protocols and procedures defined in the information particulars and the Built asset security manager is responsible for the security management of the project. The protocol defines a list of obligations for the employer as well as the project delivery team.

Overview of Obligations of the Employer as per the protocol [38]:

a) Incorporation of the completed protocol in all the project agreements.
b) Compliance with project standards, methods, and procedures as in Information Particulars.
c) Review and update of Information Particulars and Responsibility Matrix.
d) Appointment of Employer’s Information Manager and Built Asset Security Manager.
e) Enabling continued access to CDE for Project Team Member.
f) Ensuring access for Project Team Member to retain a copy of information in case of early termination of the agreement.

Overview of Obligations of the Project delivery team as per the protocol [38]:

a) Exercise relevant skill and care in preparing the Specified Information and in a timely manner.
b) Produce, share, and publish specified information according to Information Particulars.
c) Use information shared by other team members in accordance with Information Particulars.
d) Cooperate with Built Asset Security Manager.
e) Provide information required for Asset Information Model.
f) Comply with project security requirements.
g) Arrange for the protocol to be incorporated into all their sub-contracts.

4.3.2 Information Protocol – UK BIM Framework

The Information Protocol is developed by UK BIM Framework to fulfil requirements under ISO 19650 to define the various rights, roles, and responsibilities of the parties to achieve compliance with BS EN ISO 19650-2. It is developed with CIC BIM Protocol as the reference. The Information Particulars should be attached at the beginning of the Protocol since the successful implementation of the protocol is highly dependent on the completeness of these documents. The information protocol provides obligations to be fulfilled by both the Appointor and the Appointee with respect to requesting, creating, and managing information on the project in accordance with the Information Particulars.

Overview of obligations of the Appointor as per the protocol [39]:

a) Reviewing and updating Information Particulars until project completion.
b) Appointment of individuals to undertake tasks required to be performed by the Appointor.
c) Perform sensitivity assessment and security triage to establish the need for security minded approach.
d) Develop and implement security minded approach, security strategy and security management plan.
e) Plan and establish sharing agreements and prepare shared data for pre-tender stage.
f) Ensuring the consistency of information requirements when requirements for asset information. model is included in the project information requirements.
g) Appoint individual to manage information within the CDE.
h) Confirming acceptance of information model.
i) Establishing the EIR and compiling information for invitation to tender

Overview of obligations of the Appointee as per the protocol [39]:

a) Arranging tests for methods and procedures and delivery of results to the Appointor.
b) Establishing and maintaining delivery team's risk register.
c) Ensuring the delivery team's continued capability and capacity to comply with the protocol.
d) Comply with the security requirements of the Appointor.
e) Incorporation of Protocol into all their sub-contracts.
f) Prepare or assist the Appointor in preparation and updating of information management documents.

Common obligations for both parties:

a) Using CDE solution and workflow to produce, share and publish information related to the project.

b) In case of EOT claims or claims for additional claims, both parties should provide information and assistance as required by the Information Particulars and it should be provided in the time stipulated in therein.
c) Assist in updating Information Particulars from time-to-time.
d) Ensure that the task team under their supervision creates, maintains, and updates the TIDP as required.
e) Ensure compliance with their TIDP and arrange task teams to review information generated by them.

The Information Protocol defines how and who manages the information, the contractually required level of information need and how information should be used. It requires that the information requirements be specified in as much detail as possible. It also provides certain amendments that could be required in the contract it is used along with.

4.4 BIM Protocols and Standard Contracts

Although, in 2011, JCT published a public sector supplement which addressed the use of BIM Protocol alongside the JCT suite of contracts[14], CIOB's Complex Projects Contract (CPC 2013) was the first standard form of contract to include BIM related clauses in its provisions and appendices [16]. JCT initially prescribed the use of CIC BIM Protocol, the provisions in JCT 2016 suite of contract are flexible enough to facilitate the use of any bespoke BIM Protocol. CPC 2013 specifies the AIA's E202-2008 BIM Protocol as the default option stating that it is more detailed and extensive in comparison to the CIC BIM Protocol[14].

NEC4 suite released in 2017 includes the Option X10: Information Management to cover the BIM process and does not include the provision for the use of a BIM Protocol. Option X10 covers the legal issues corresponding to liability, ownership, and obligation in terms of production of information[14]. Along with the second edition of Rainbow suites, FIDIC issued a special Advisory Note within the Special Provisions highlighting the issues to be considered when using FIDIC contracts on a BIM enabled project. FIDIC is in the process of preparing two documents a "Technology guideline" and a "Definition of Scope" to provide further guidance on the topic [10].

4.4.1 BIM Protocols in Standard Contracts

The CIC Protocol states that for the Protocol to have a contractual effect, an incorporation clause must be inserted into every contract the Protocol is meant to be incorporated into and the incorporation clause should be developed on a contract-to-contract basis with the aid of legal advice. If amendments need to be made to appendices attached to the Protocol after the contract has been signed, this provision should be included and agreed upon in the contract.

The Protocol requires the amendment of certain clauses within the contract to include certain rights and responsibilities to the parties of the contract in addition/omission to those stated within the contract.

- Copyright: Amendment should be made to contract provisions regarding copyright of material, information or document provided by the project team member to extend to proprietary work contained in or extracted from the material and to enable the employer to grant licenses and sub-licenses to other project team members. If the project team member is to retain ownership of any "background intellectual property" after transferring the ownership of intellectual property (specified in the Information Particulars) to the employer, this must be clearly stated in the agreement.
- Liability: Provisions in the contract regarding proprietary material should be amended to ensure that the project team member is not held responsible for modifications, amendments, and use of proprietary work by the employer or other project team members except for which the work was permitted to be used for.
- Right to terminate: The employer's right to terminate the contract must be extended to allow the employer to terminate the contract if the Project team member does not cooperate with the Built Asset Security Manager or if they do not take reasonable measure to uphold the security requirements required by the employer.

Clauses related to document precedence, coordination and resolution of conflicts, obligation of employer, security requirements that the project member should adhere to, electronic data exchange, use of information and employer's right to terminate the agreement apply to the parties despite the termination of the agreement.

4.4.2 Document Precedence

The CIC Protocol states that the Protocol takes precedence over the contract in matters concerning the obligations of the employer, the obligations of the project team member, Responsibility Matrix, and Information Particulars except for in the case of JCT contracts which states that "nothing will override or modify the Agreement or the contract conditions". (Clause 1.3, JCT Design and Build Contract, 2016). If the parties signing the contract wishes for the Protocol to take precedence to the contract, it must be clearly stated and agreed upon in the order of priority of documents.

5 INFORMATION EXCHANGE FOR FORENSIC DELAY ANALYSIS

5.1 Gap Analysis

5.1.1 As-Is Status

Claims management is a complex and challenging process that requires knowledge of both the contracts as well as the principles and practices of project management. The following requirements need to be met for each claim [40]:

- Providing structured and sufficient evidence to substantiate a claim.
- Fulfilling the requirements for specific details to be included in the claim.
- Following procedures set out in the contract.
- Adhering to specified time limits.

This is further complicated when the process for record keeping is inadequate and in the absence of an efficient system for managing documentation, the knowledge created during the project remains the tacit knowledge of the contract manager and other project members. This is especially problematic on large construction projects, where staff turnover is high. When key personnel leave the project, they take their knowledge with them, which can make it difficult to substantiate claims.

When BIM is implemented at the start of a project, all project information can be stored in a centralized database linked to a 3D model, provided all record-keeping recommendations are followed. This database can help to identify, quantify, and visualize delays and their effects on projects[41].

To present information from BIM models, it is important to explore the legal aspects of BIM. Issues related to ownership, intellectual property, and permitted use of information, must be considered based on the applicable contractual documents and protocols. In consideration to using the information contained within the model as evidence to support claims, it is vital to specify the requirements for the documentation, proposed uses, formats, acceptance criteria and the role responsible for their preparation, approval, and maintenance within the contractual documents. Most standard contracts are silent on the requirements for the type of documentation that needs to be maintained to substantiate a claim[42]. However, some standard forms of contracts, such as the FIDIC Red Book requires the contractor to maintain “*contemporary records as may be necessary to substantiate any claims*”.

The thesis aims to provide a guideline on explicitly specifying the information requirements for delay analysis and claims management using the EIR, as it is part of the contractual documents.

5.1.2 Potential of BIM and CDE for Delay Analysis

To assess the potential of BIM and CDE in delay analysis and maintaining contemporary records, it is first important to understand the types of data stored in a BIM model and how they are stored and shared between parties involved in the project. ISO 19650 defines BIM as "*a digital representation of physical and functional characteristics of an asset, which can be used for decision-making throughout the asset lifecycle*". A BIM model consists of three categories of information – graphical, non-graphical and other associated documents stored with the CDE.

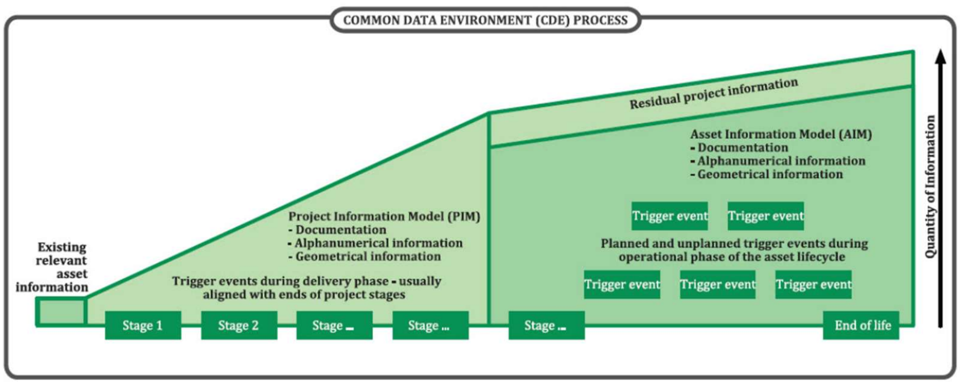

Figure 15: Data gathered during a project lifecycle according to ISO 19650-1

Graphical Information: The graphical data which is generally modelled in 3D provides visual information regarding size, location, and relationship with respect to the space and other components within the model.

Non-graphical Information: BIM enables the storage of information in the form of machine readable digital attributes within the model, which can then be searched and extracted for the purposes of analysis, monitoring and reporting. The amount of non-graphical information contained in a model depends on the Level of Information Need for the intended BIM uses as specified in the EIR.

Documents: Construction projects are information intensive, and many documents are required to correctly define and execute a project. A non-exhaustive list of these documents includes the initial client briefs about the project scope and technical requirements, contracts, bill of quantities, performance security, insurances, method statements, calculations, certifications, minutes of meetings, correspondences, RFIs, payment certificates and technical submittals and approvals. ISO 19650 proposes the use of a CDE for the storage and exchange of information by and between the parties involved in the project.

The information stored in a BIM model can be used for the purposes of progress monitoring & reporting, change management, providing site instructions and in improving the quality and accuracy of the schedule.

Table 2: Effect of BIM Model and CDE on construction activities and delay causes

	BIM Model	**CDE**
Accuracy of design	High	Medium
Adverse weather conditions	Low	Low
Assessment of quality of construction	Low	Low
Calculating extension of time for delays	High	Medium
Change control	High	High
Construction planning	High	Low
Communication to stakeholders	High	High
Contract management	Medium	Medium
Creation of Look-ahead plans	High	Low
Estimation of cost	High	Low
Estimation of quantities	High	Low
Historical data storage	Low	High
Identification of delays	High	Low
Improving collaboration	High	High
Improving trust between parties	High	High
Issuing interim payments	Medium	Medium
Issuing timely approvals	Medium	Medium
Labour strikes	Low	Low
Management of subcontractors	Medium	Medium
Preparing mitigation plans for delays	Medium	Low
Preventing changes in scope	Low	Low
Progress monitoring	High	Low
Progress reporting	High	Medium
Providing audit trail for changes	High	High
Quantification of cost of delays	High	Medium
Record keeping	Medium	High
Reducing changes in design	High	Medium
Reduction in RFIs	High	Medium
Sharing of organizational assets	Low	High
Skill of workforce	Low	Low
Slow decision making	Medium	Medium
Visualization of delays	High	Low
Visualization of variations	High	Low

In [43] the authors investigated the intangible benefits of using BIM in construction. They found that the most critical benefit was an improvement in the quality of works. This improvement was seen in several areas, including the understanding of design, documentation, communication, and clash detection. Study [44] investigated the effect of BIM on construction claims and found that BIM can significantly reduce construction claims by improving coordination and collaboration, reducing variations in quantities and errors in designs and drawings, and improving the planning and scheduling of works. Other benefits of BIM include reduced change in scope of works and improved decision-making processes.

5.2 Implementation of Information Requirements for Delay Analysis

PMBOK states that if there are 'n' number of stakeholders involved in a project, then the number of communication channel can be calculated using the formula n*(n-1)/2, i.e., if there are 10 stakeholders involved in the project then the number of communication channels would be equal to 45. Often this leads to miscommunication and loss of information in transmission. From the time of initiation to the end, construction projects generate a variety of data and documentation. To name a few: land registry information, design brief, geotechnical reports, building permits, bill of quantities, technical specifications, survey records, design drawings and documentation, insurances, change orders, request for information, material submittals, vendor approvals, site inspection reports, checklists, progress reports, emails, letters, minutes of meetings, and payment slips. Accurate and timely exchange of information between stakeholders plays an essential role in the success of the project. Poor information management is attributed to be one of the major reasons behind delays, disputes, and cost- overruns on an AECO project. This is a given, considering the sheer number of documents created during a construction project and the number of communication channels required to transmit information between stakeholders within a traditional project environment.

Adoption of BIM reduces the number of communication channel and provides richer, clearer, and accurate information in a single source of truth using a centralized BIM model and CDE. This combined with the availability of information that can be accessed by any stakeholder as they need, improves the transmission of information, and reduces misinterpretation of information [45]. The increased dependency on a single source for information created a need for standards to streamline the creation and delivery of information.

Following the UK Government's strategy to implement Level-2 BIM on centrally procured public projects, the British Standards Institution published PAS 1192 series to provide specifications for information management for construction projects using BIM to be used in the UK. As the benefits of using PAS 1192 became evident, these standards were widely used, especially in the Middle East and

Australia[46]. Since PAS 1192 series was developed based on the UK standards and ISO 19650 series was created to accommodate the needs of the international construction industry.

ISO 19650-1:2018 - Concepts and principles: Outlines the concepts and principles of information management, the framework for collaborative working and information delivery, common data environment and proposed workflow and how to apply the framework throughout the life cycle of a built asset.

ISO 19650-2:2018 - Delivery phase of the assets: Provides guidelines for assessing the need for information and the manner of delivering the information and defines the information management process during each stage of the project delivery namely invitation to tender, tendering, appointment, mobilization, model delivery and project close out.

ISO 19650-3:2020 - Operational phase of the assets: Provides guidelines for assessing the need for information and the manner of delivering the information and defines the information management process during operational phase of the assets. Although it informs about the information management process during operational phase, it contains clauses that asset owners must consider even before a project is initiated to ensure delivery of complete and accurate information to enable effective operation and maintenance of the asset[47].

ISO 19650-4:2022 - Information exchange: Introduces a list of considerations the person in charge of decision making must keep in mind when reviewing an information exchange and/ or approving the change of state of information.

ISO 19650-5:2020 - Security-minded approach to information management: Outlines the principles to assess the need for a security-minded approach and provides guidance on developing a security strategy and security management.

5.2.1 Information Exchange Requirements

RIBA Plan of Work 2020 defines Information Requirements as "*The formal issue of information for review and sign-off by the client at key stages of the project. The project team may also have additional formal information exchanges as well as the many informal exchanges that occur during the iterative design process*" [48]. This is because the information delivered at the end of one stage forms the basis for the next stage. Secondly, this information encapsulates all the decisions made by the client during that stage and they affect how the project will progress in the next stage.

ISO 19650-1:2018 - Concepts and principles describes various information exchange requirements and BS EN ISO 19650 Guidance Part D: Developing information requirements provides further insight into the need for these documents, the information they contain, who is responsible for producing them, and how they relate to each other. A clear understanding of information requirements is essential for efficient planning of the delivery schedule, resources required, and the means of delivering information. Information requested by these documents should ensure that just enough information is created at any stage of the project and avoid duplication and excessive detailing. The information requirements should be developed in such a way that each of them is consistent with the others and fulfils the purpose of the project as well as the specifier's organization.

Information requirements consists of high level information requirements, which defines the purpose of the information, and detailed information requirements. High level requirements are described in the Organizational Information Requirements and the Project Information Requirements. For specifying detailed information requirements, ISO 19650 introduced the terminology 'Level of Information Need' and defined it as "*as the quantity, quality and granularity of information*" and include geometrical information, alphanumerical information, and documentation[49].

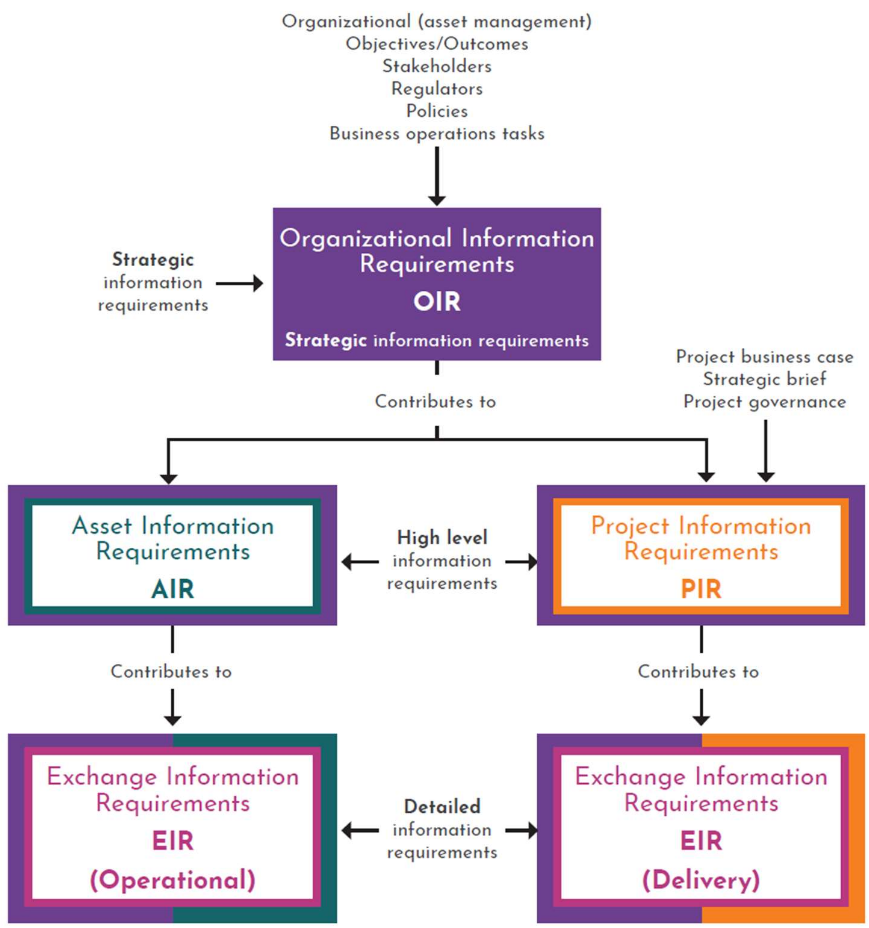

Figure 16: Information Requirements [50]

Organizational Information Requirements: OIR is defined by the appointing party as part of their business activities with inputs from different departments for managing the whole portfolio of the organisation's assets. OIR contributes to developing the business for creating a digital information model and therefore it is essential for the organisation to identify the potential benefits, efforts required to identify information requirements, collect, and store the data and the software tools required. OIR defines the high level requirements and the purposes for which the specified information is required. The specified information could contribute towards strategic, tactic and operational activities of the organisation. Examples being creation of budgets, facility and asset management, energy efficiency and life cycle costing of an asset. OIR contributes to the creation of PIR and AIR and acts as a building block for the information receiver to develop their detailed requirements.

Asset Information Requirements: AIR is created by the appointing party's team responsible for asset management to provide the managerial, commercial, and technical aspects of producing the information for a specific asset. AIR is prepared to be consistent with the OIR regarding the asset management requirements of the organization. It defines information required to answer key questions that may arise during the lifecycle of an asset. For instance, during evaluation of asset performance, for planning, maintaining, or decommissioning, and for adapting to changes in regulations or organizational policies. AIR species information to be incorporated in the Asset Information Model (AIM) and contributes towards the creation of EIR for operational phase of assets[51].

Project Information Requirements: PIR is created by the client to meet the high-level objectives of the client as defined in the OIR. PIR informs the preparation of Project Information Model (PIM) and the EIR for the delivery phase of the project. When defining the PIR, the seven points should be considered, as defined by the ISO 19650-2, are as follows:

- Understanding of what is being built, the reason and objectives of the project.
- Purpose for which the appointing party will use the information.
- Stages and timescale of the project.
- The type of procurement route which in turn affects the types of contractual relationships and information flow.
- The key decision points during the project when the appointing party is required to make informed decisions.
- The decisions that appointing party needs to make at key decision points.
- The questions that the appointing party needs answers to in-order to make informed decisions.

5.2.2 Exchange Information Requirements

ISO 19650-2 defines two types of EIR: the appointing party's EIR to the lead appointed party and the lead appointed party's EIR to the appointed party(s)[50]. EIR is the main document produced by the information specifier to describe their needs and strategic goals for using BIM methodology on the project. It is created at every pre-tender/pre-appointment stage of the project to provide guidance on the information that is needed at each stage of the project to facilitate effective decision-making. It outlines the information that needs to be delivered, the standards that need to be adhered to, and the processes and milestones for information delivery. The key to creating a clear and concise EIR that can ensure the continued use of information produced at each stage into the next stages of the project is to "begin with the end in mind". This enables the information providers i.e., the designers and the collaborators to understand what is expected by the information specifier and to develop their BIM execution plan that outlines the methods and schedules for delivering the requirements. The content of the EIR describes three different aspects of information delivery: technical, management and commercial. These are further described in section 5.4.

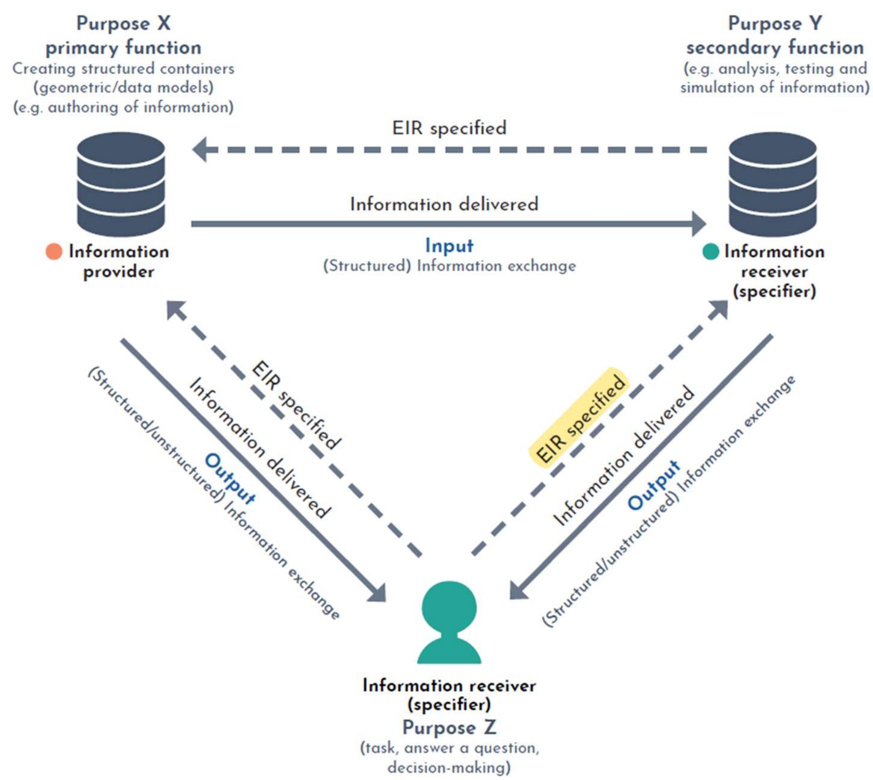

Figure 17: Exchange Information Requirements between software applications and people [50]

5.2.3 Information Delivery Plans

BIM Execution Plan (BEP) – PAS 1192-2:2013 defines BEP as a “plan prepared by the suppliers to explain how the information modelling aspects of a project will be carried out[52]. It is prepared as a direct response to the EIR. BEP along with the EIR comprise the information particulars referred to by CIC BIM Protocol. BEP is useful in communicating the project BIM goals and objectives to the team members and assign responsibilities to them. BEP is created both in the pre-contract stage and the post-contract stage.

Pre-Contract BEP is produced during the tender phase by potential suppliers to demonstrate to the appointing party, their capability, capacity, competence, and approach to meeting the requirements set out in the EIR.

Post-Contract BEP is produced by the lead appointed party to provide a comprehensive plan of how they intend to deliver the information required by the EIR. It is more detailed than the Pre-Contract BEP and includes details on working procedures, key milestones, key deliverables and their delivery plan, software and hardware proposed to be used, training requirements for project team members and assessment and management of risks arising from use of BIM on the project. It also consists of two other documents: Master Information Delivery Plan (MIDP) and Task Information Delivery Plan (TIDP).

TIDP is created by each supplier under the lead appointed party and sets out when, how and who will prepare the project information. MIDP sets out a consolidated plan for the delivery of project information by compiling all the TIDPs. It contains a detailed description of all the planned deliverables with information about the project stage when they will be delivered, file names, description, responsible person, and the schedule for delivery.

5.3 Information Requirements for Forensic Delay Analysis and Claim Management

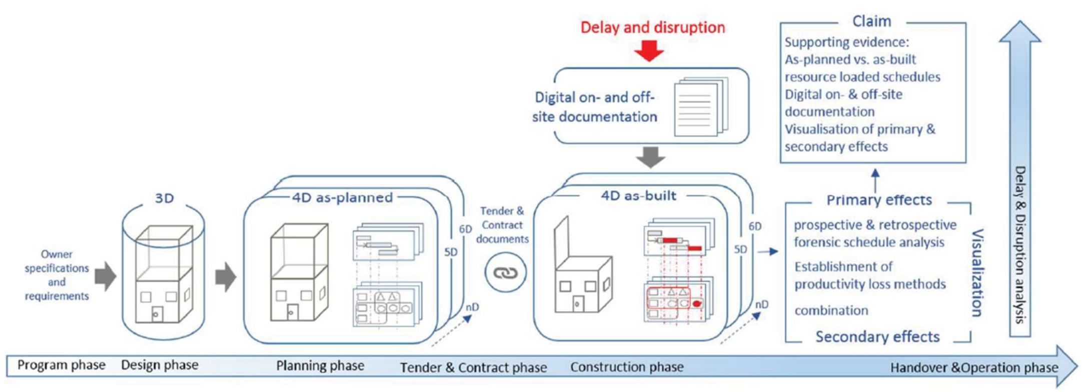

Figure 18: Sequence of BIM based claim preparation [53]

The figure describes the workflow that is to be implemented to use BIM for claim preparation. The first step involves the preparation of a 3D Model which is geometrically accurate and optimized for quantity take off. The next step is the creation of 4D As-planned Model and the 5D Model.

5.3.1 Author 4D and 5D Models

4D Model (Time linked 3D Model) Information Requirements: PMBOK defines five processes that lead to the creation of the project schedule, and they are:

- Plan Schedule Management
- Define Activities
- Sequence Activities
- Estimate Activity Durations
- Develop Schedule

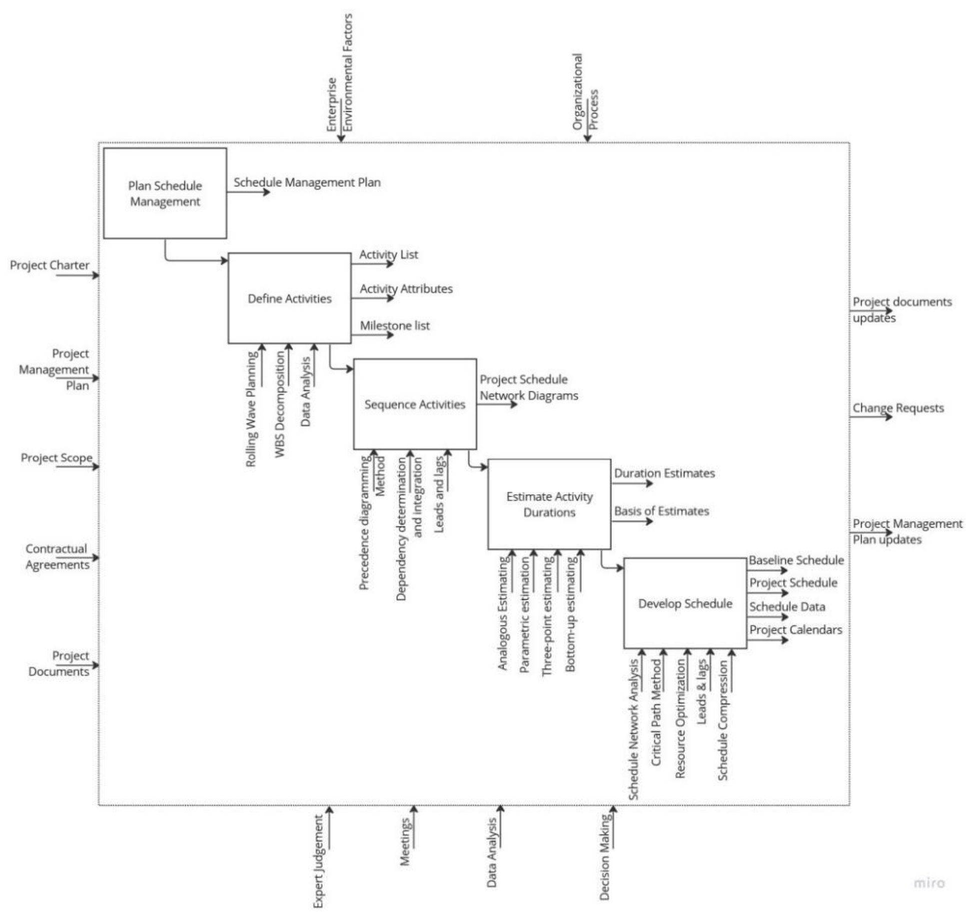

Figure 19: IDEF0 diagram of processes involved in developing the Project Schedule (adapted from PMBOK)

5D Model (Cost linked 3D Model) Information Requirements: PMBOK defines five processes that lead to the creation of the cost estimates for the project, and they are:

- Plan Cost Management
- Estimate Costs
- Determine Budget

The information requirements for performing these processes are categorized into project charter, project management plan, project documents, enterprise environmental factors, and organizational process assets. The project charter provides the summary milestones that the project schedule must adhere to and the approved financial resources while the project management plan provides scope definition, the method of scheduling, tools for scheduling, and the techniques used for estimation of the timeline and controlling the schedule. Enterprise environmental factors provides information such as resource availability, commercial databases and scheduling software and organizational process assets include historical information from previous projects of the organization, templates, and policies, procedures, and guidelines. Organizational process assets include historical information and lessons learned repositories, templates and forms, policies and procedures and monitoring and reporting tools. The enterprise environmental factors and organisational process assets are provided by the organization as shared resource for use on the project to develop the schedule and the 4D and 5D Model.

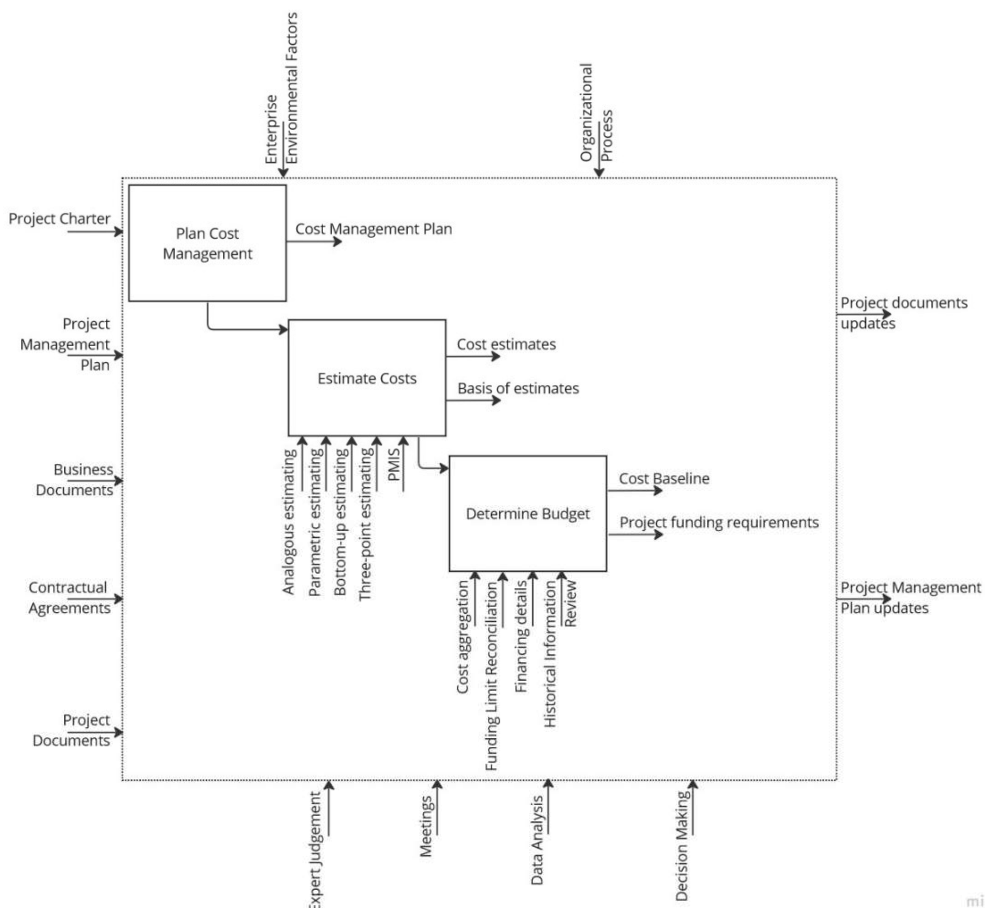

Figure 20: IDEF0 diagram of processes involved in Project Cost Estimation (adapted from PMBOK)

Project schedule provides a detailed plan that outlines activities that are required to complete a project, the duration taken to complete each activity and their interdependencies. It establishes milestones to be met to complete the project on time. The initial project schedule once approved by all the stakeholders becomes the baseline schedule for the program and this baseline schedule serves as the basis for measuring project progress and identifying delays and potential issues within the project. It is used to inform the stakeholders regarding the work that needs to be completed in each period. Schedules can be presented in various forms to suit different stakeholders. Traditionally schedules are presented mainly as Gantt charts. With the use of 4D models, schedules can be linked to the 3D model to create visualizations and animations which makes communication with stakeholders easier and clearer. Schedules are dynamic documents that are updated throughout the project to accommodate the changes within the project.

5.3.1.1 Workflow in Bexel Manager for creating 4D & 5D Models

The 3D model is imported into Bexel Manager using IFC format or .bx3 format, the native transfer format created when using Bexel Manager plugins in the authoring software.

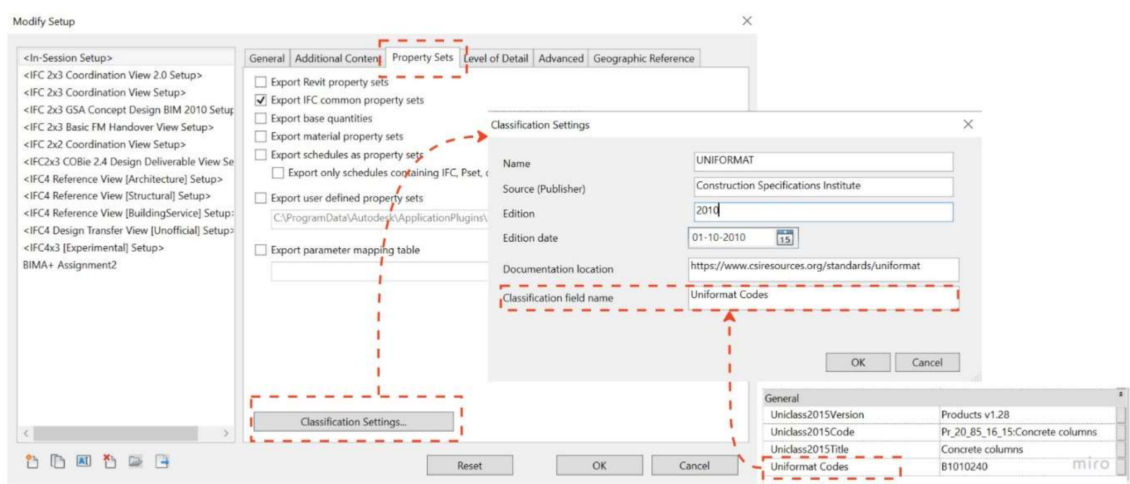

Figure 21: Input of Classification Codes in Revit and linking it for IFC Export

Before loading the 3D model into Bexel Manager, ensure that the UNIFORMAT II Classification Codes provided by Bexel Manager in the “Data Enrichment Template_UniFormat_Basic_(IFC) [6P0VC1]” are assigned to the elements in the 3D model and that these codes are reflected in the classification settings of the IFC export, as shown above. UNIFORMAT is a functional classification system for building information that can be used to identify functional elements in BIM models, and to organize preliminary project descriptions and early cost estimates. The Property checker function within Bexel Manager can be used to verify that all elements have been assigned the classification codes.

	BEXEL Added Text	BEXEL Added Text
Category	Uniformat Assembly Code	Uniformat Assembly Description
Columns	C3010300	Column Finishes
Curtain Panels	B2020220	Curtain Walls - Panels
Curtain Wall Mullions	B2020210	Curtain Walls - Framing
Members	B1029100	Other Roof System
Doors	B2030900	Other Exterior Doors
Floors	B1010400	Upper Floor Framing - Systems
Floors	C3020100	Floor Toppings & Coatings
Furniture	E2020200	Furniture & Accessories
Furniture Systems	E2020200	Furniture & Accessories
Parkings	G2020600	Painted Lines & Markings
Planting	G2050500	Planting
Railings	B2010500	Balcony Walls & Handrails
Ramps	B1010600	Ramps
Roads	G2010200	Roadway Paving & Surfacing
Roofs	B1020300	Flat Roof Framing - Systems
Sites	G2040900	Other Site Development
Stairs	B1010700	Exterior Stairs & Fire Escapes
Topography	G1030100	Site Grading Excavation & Disposal
Walls	B2010100	Exterior Wall Construction
Walls	B1010210	Bearing Walls - CIP
Walls	C1010100	Fixed Partitions
Windows	B2020100	Windows
Structural Columns	B1010240	Columns - CIP
Structural Columns	A1020100	Pile Foundations
Structural Foundations	A1010100	Footings & Pile Caps
Structural Framing	B1010300	Upper Floor Framing - Horizontal Elements
Beams	B1010300	Upper Floor Framing - Horizontal Elements

Figure 22: Extended Uniformat Classification Codes provided by Bexel Manager

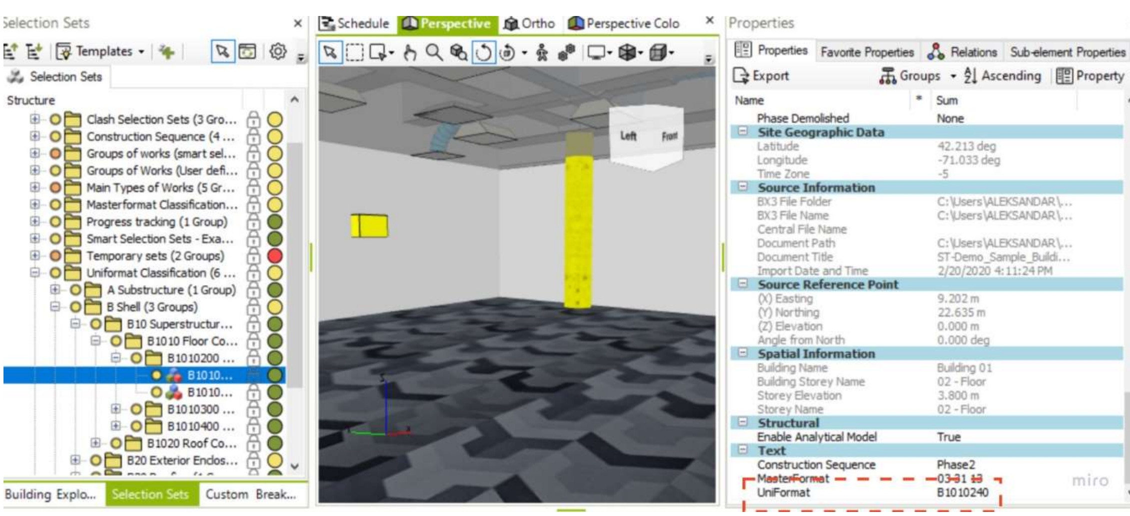

Figure 23: 3D Model element with Uniformat Classification Code and exported to Bexel Manager

To define the work breakdown structure and associate it with the corresponding elements in the 3D model, the UNIFORMAT classification codes are used which systematically arranges the elements of the construction project are based on their function. Bexel Manager leverages this to create the cost breakdown structure.

Figure 24: UNIFORMAT Classification of Building Elements based on their function

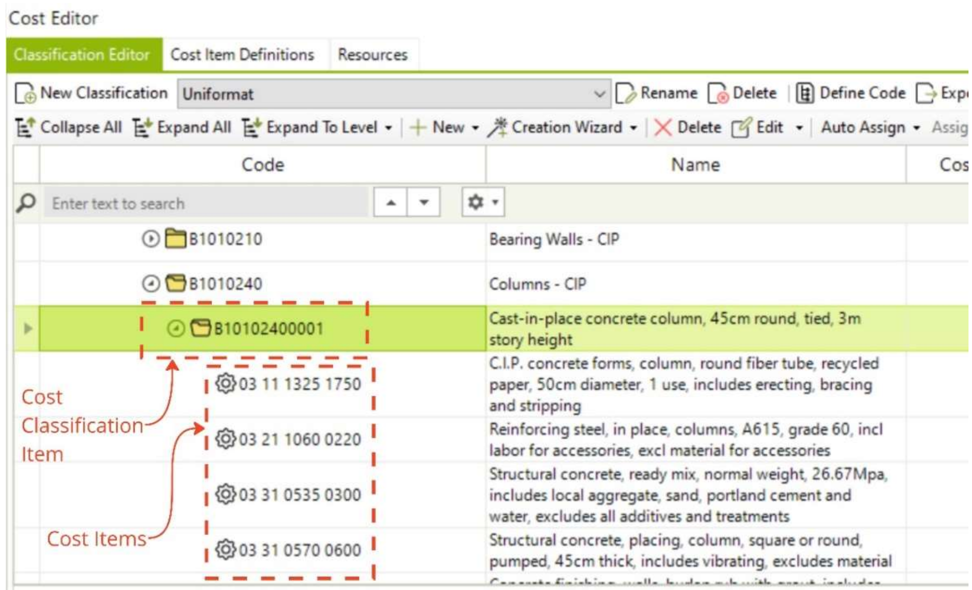

Figure 25: Cost Classification Items and Cost Items created based on UNIFORMAT codes

The level of granularity required for estimating costs are decided based on the cost management plan and this is used to define the Cost Items under each Cost Classification Item. The Cost Items are activities to which resources and cost are assigned and which are further used in the creation of the project schedule. Cost items provide a definition of the activity to be performed, the quantity type, daily output, unit cost, the resource requirements, and the formula for calculating the quantity. The Cost Item is then mapped to the element in the 3D model using a query. When updating the progress of the project, these assignments can be altered to reflect the actual state.

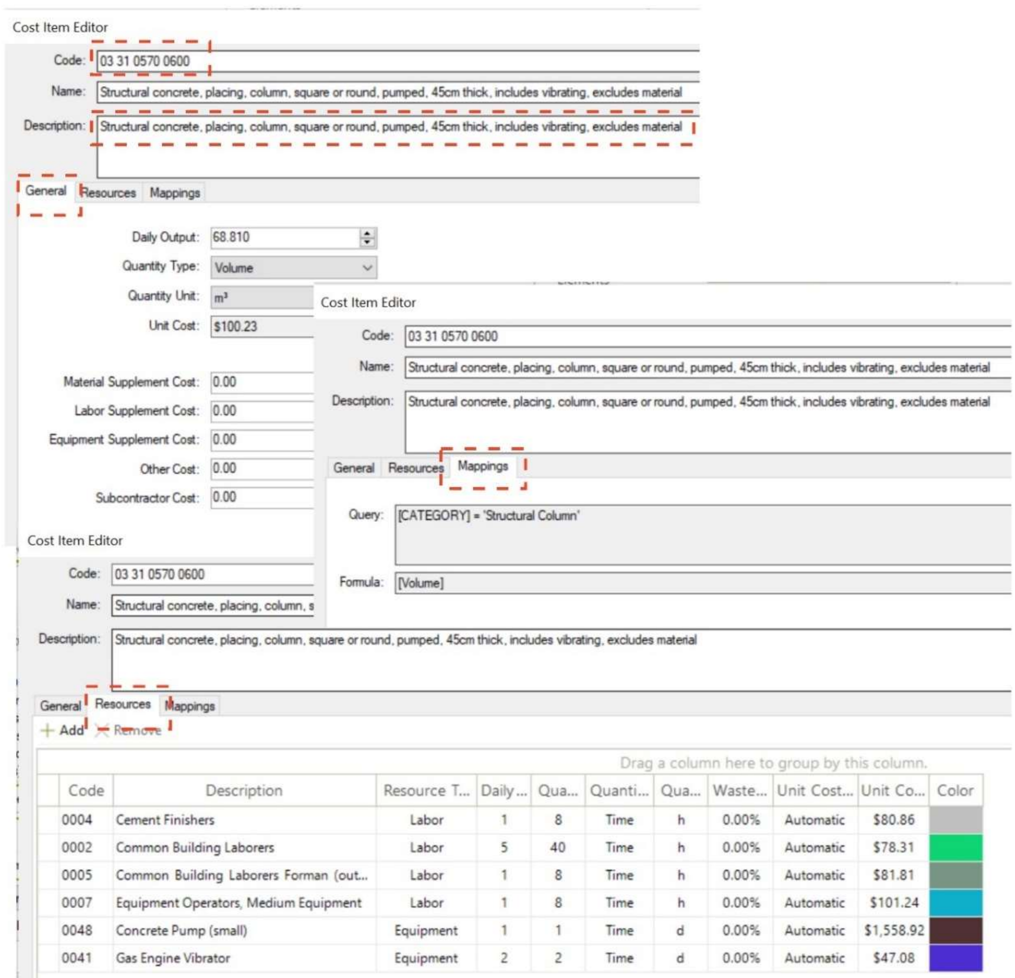

Figure 26: Data input in the Cost Item Editor Tab of Bexel Manager

Once the cost items are assigned to the cost version, the cost breakdown structure and the total cost for all activities can be found in the Cost Estimates tab.

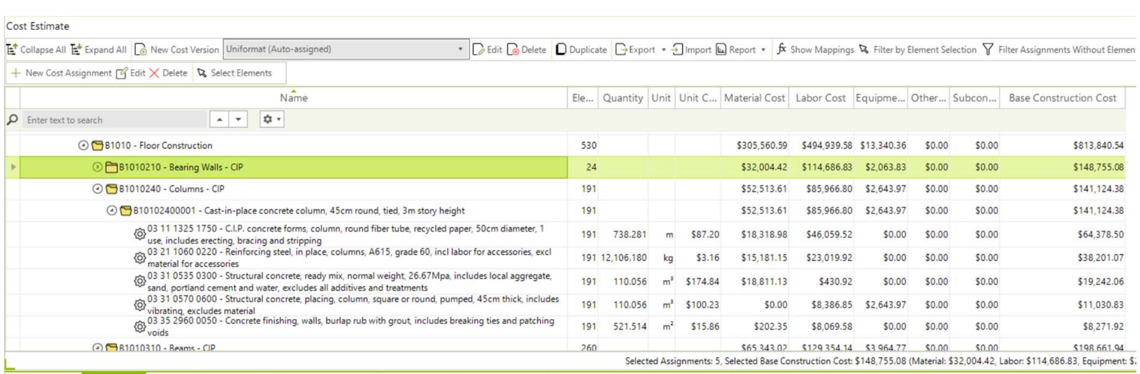

Figure 27: Cost Breakdown Structure and total cost estimates

Import and federate the 3D model of the building/asset consisting of architectural works, structural works, and the services. Also import the site model and the model for temporary works.

Using the Cost Items developed for the 5D model, the basic schedule can be created using the Methodology Editor function. This is especially useful in projects like high-rise buildings where the tasks are repetitive for each level. The Methodology Editor utilizes the Cost Classification Items and the Cost Items as the basis for developing the schedule, since they describe all the work that needs to be completed on the project. In the Methodology Editor, there can be levels for the methodology. The first level of methodology is where logical relationships between the Cost Classification Items are created.

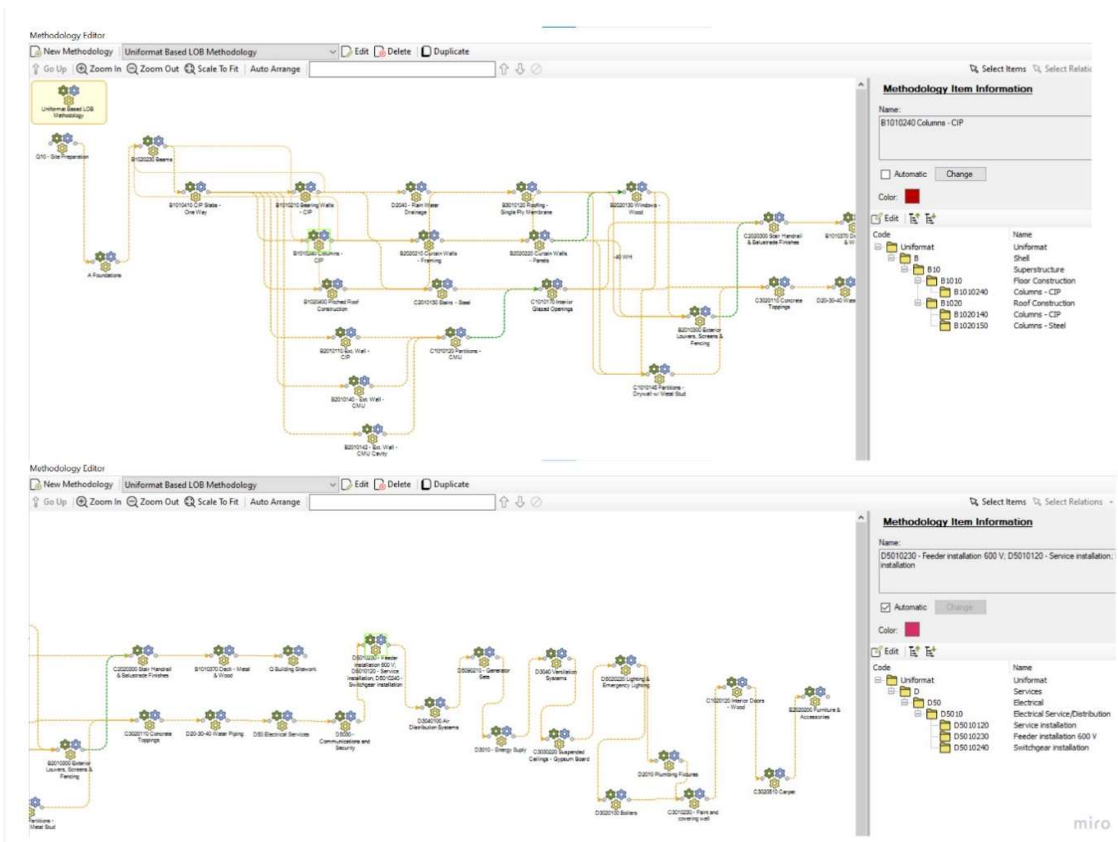

Figure 28: Methodology Editor – Level 1 of Methodology

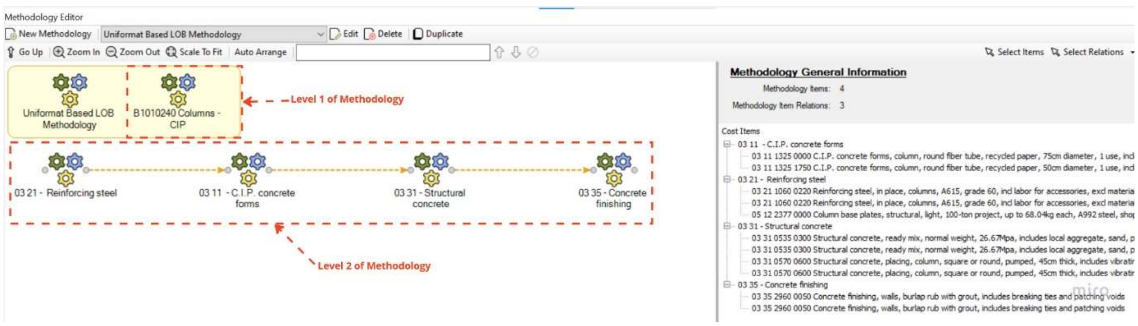

Figure 29: Methodology Editor – Level 2 of Methodology

In the second level of methodology, logical relationships between Cost Items within a particular Cost Classification Item are created.

The construction works are also grouped into Zones based on their spatial distribution. Spatial distribution consists of levels, which are the storeys in case of buildings, and construction sequence or phase of construction. If constructive relationships are used within the methodology, then the Zone that affects these relationships must be selected in the 'Zone Item Information' of the 'Zone Editor'.

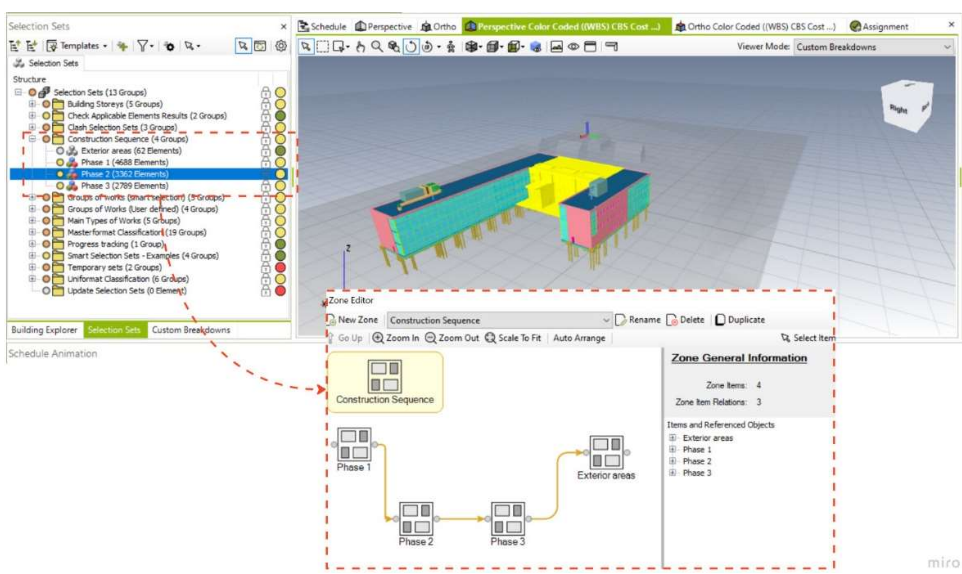

Figure 30: Selection set based on the phases of construction

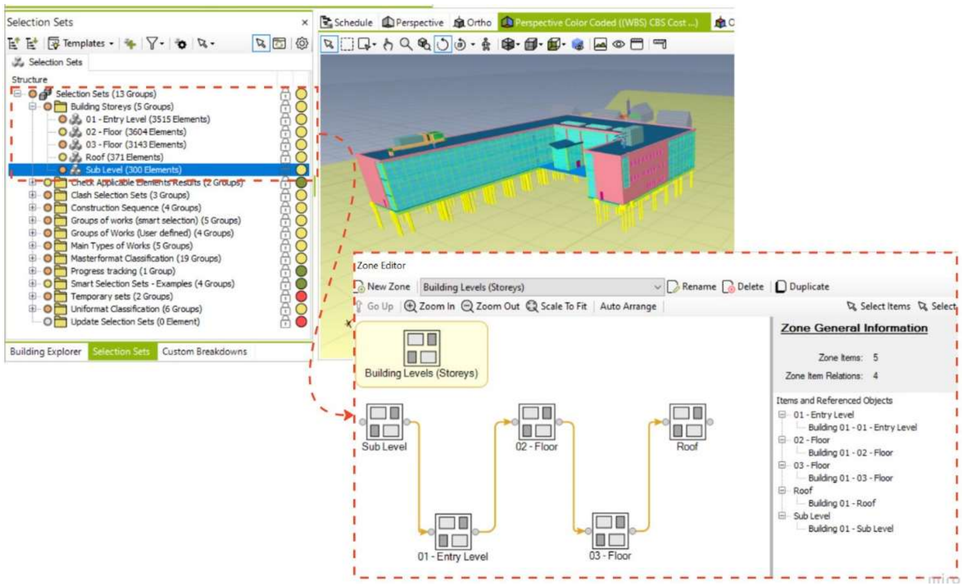

Figure 31: Selection set based on the levels or storey in the building

The Creation Template Editor is used to generate the basic schedule by combining the Construction Methodologies and the Zones.

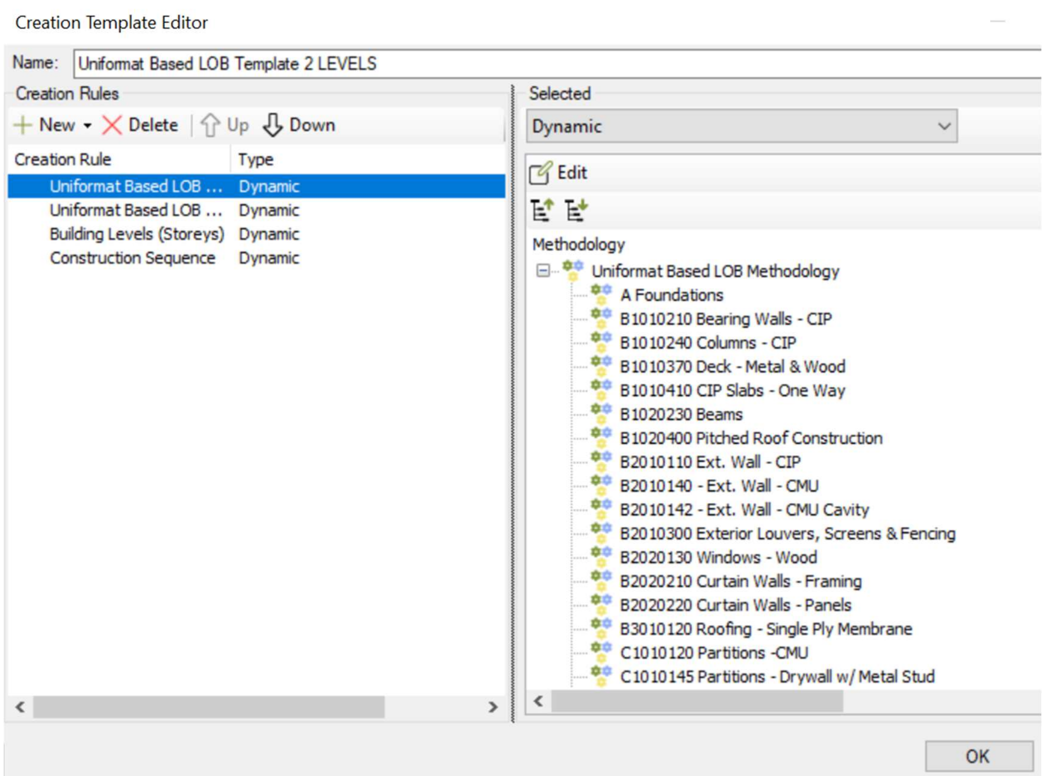

Figure 32: Creation Template for combining Methodologies and spatial distributions

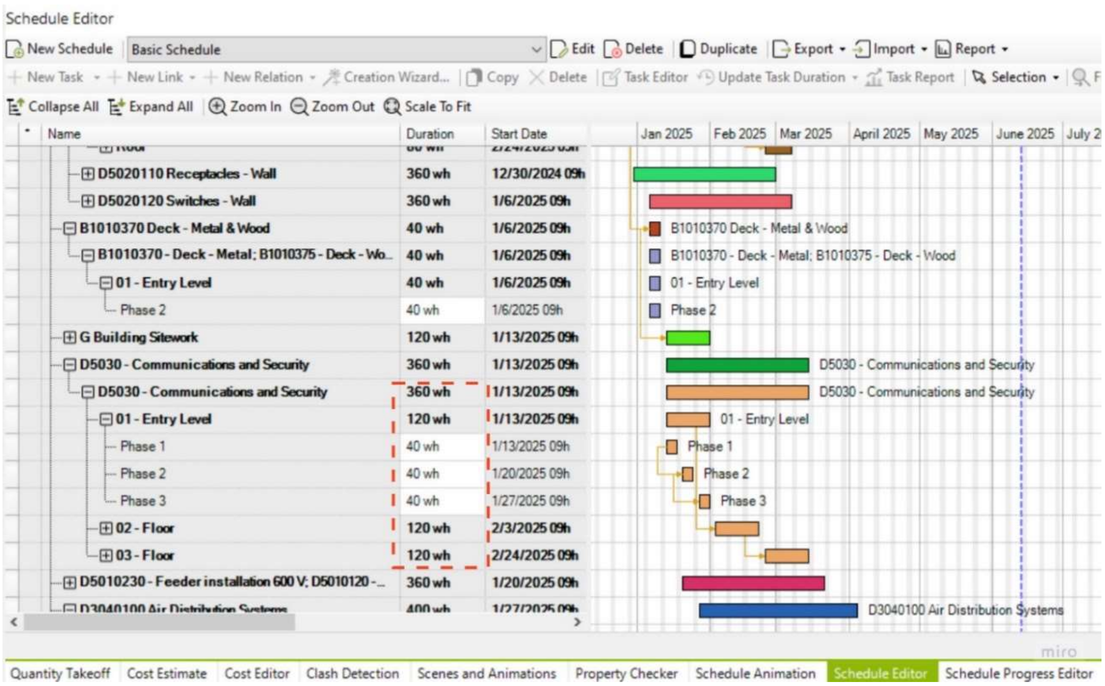

Figure 33: Schedule created using the Creation Template Editor

After the creation of the basic schedule, each activity on the schedule is modified to reflect the accurate the start and end dates, task dependencies and time-period for each activity. The schedule can be further optimized using the line of balance diagrams and task reports within Bexel Manager.

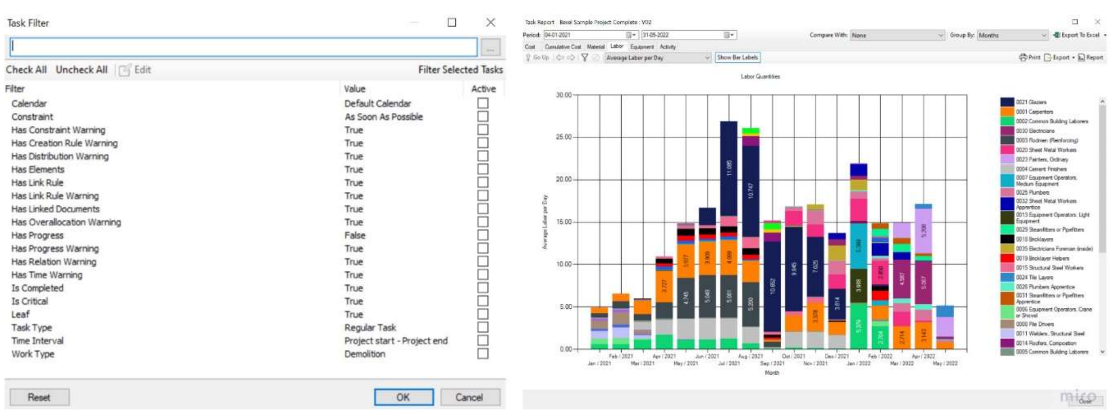

Figure 34: Bexel Manager Tasks Filters and Task Report

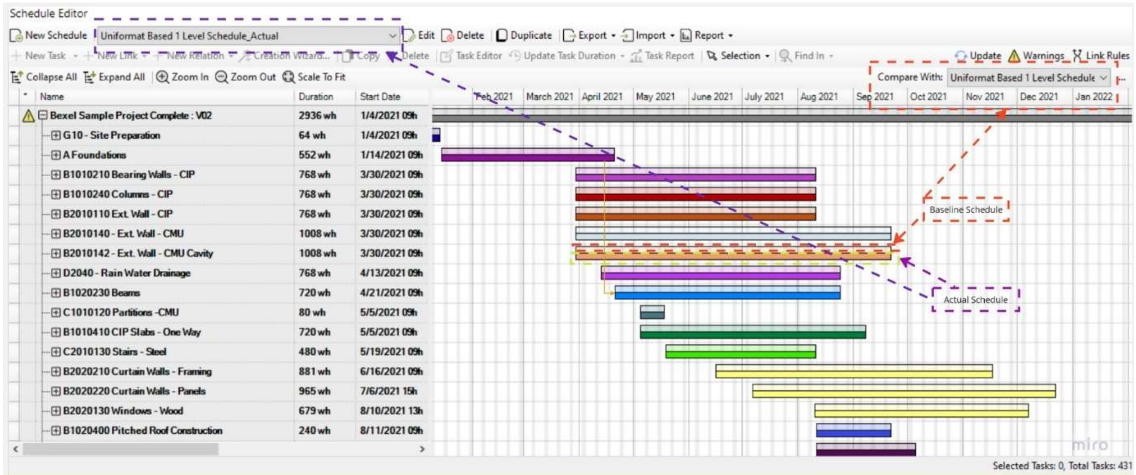

Figure 35: Schedule comparison between Baseline Schedule and Actual Schedule

5.3.2 Progress Monitoring

5.3.2.1 Information Requirements

Based on PMBOK, monitoring the progress and status of a project consists of two main processes: Control Schedule and Control Costs.

Control Schedule: The functions performed within this process includes identifying the status of the project and the factors that influenced the changes, creating countermeasures for factors influencing the schedule, making necessary changes to the schedule reserves, and managing the changes and updating the schedule as required.

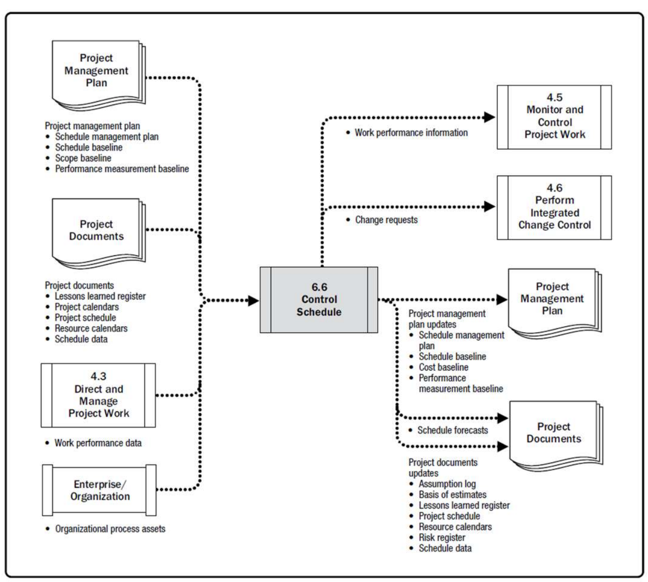

Figure 36: Data flow diagram for Control Schedule Process [7]

Control Costs: The functions performed within this process includes identifying and mitigating factors caused changes to the cost baseline, managing changes and responding to change requests, reconciling expenses to the funding availability and limiting the cost overruns, monitoring work performance in relation to the expenses incurred, performing earned value assessments and informing all stakeholders regarding the approved and unproved changes so that unapproved changes are not included in reports related to cost and resource usage.

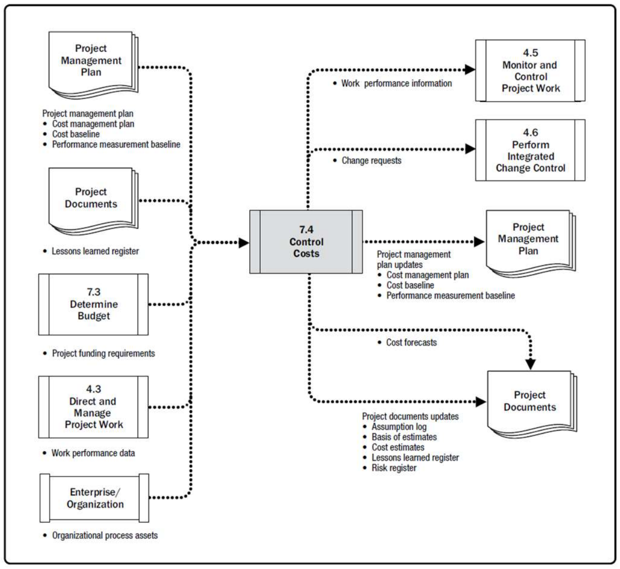

Figure 37: Data flow diagram for Control Costs Process [7]

Earned Value analysis is performed to identify the earned value of a project, the variances in Schedule and Cost, the performance index for Schedule and Cost and to estimate the cost at completion based on the status of the project. It is performed based on four main measures calculated based on the Cost estimates and actual cost incurred and they are Planned Value (PV), Earned Value (EV), Actual Cost (AC) and Budget at Completion (BAC).

PV is the cost estimated for all the works that were meant to be completed until the point of consideration. EV is the sum of the planned value of works that were completed and AC is the actual cost incurred to complete the work. The basis for calculating the AC is from the progress reports, resource utilization reports, procurement data and other information collated from site on a day-to-day basis. These values are further used in variance analysis, trend analysis using S-curves, to forecast the estimate at completion and for understanding the effectiveness of mitigation measures.

Variance analysis is used to explain the performance of cost, schedule, and budget at completion.

- Schedule Variance (SV) indicates if the project is ahead or behind the planned baseline schedule at a given time and it is calculated as: $SV = EV – PV$

- Cost Variance (CV) indicates the cost performance of the project. It is the amount budget deficit or surplus at a given time and is calculated as: CV = EV – AC
- Variance at Completion (VAC) indicates the difference between budget at completion calculated at the initial stage of the project and the estimated cost at completion based on current data and is calculated as: VAC = BAC – EAC
- Schedule Performance Index (SPI) indicates the efficiency of the project team in completing the planned work. It is expressed as a ratio and a value above 1 indicates that the project is progressing on schedule or ahead of schedule and a value less than 1 indicates that the progress is less than planned. SPI = EV/PV
- Cost Performance Index (CPI) indicates the efficiency of the budgeted resources. It is expressed as a ratio and a value equal to or greater than 1 indicates that the project is within the budgeted cost for the time and if the value is less than 1, it indicates that the project is over budget. It is calculated as: CPI = EV/AC

Based on the Planned Value, Earned Value and the Actual Cost, S-curves are used to compare the performance of the project over time, and to create forecasts for the future performance of the project.

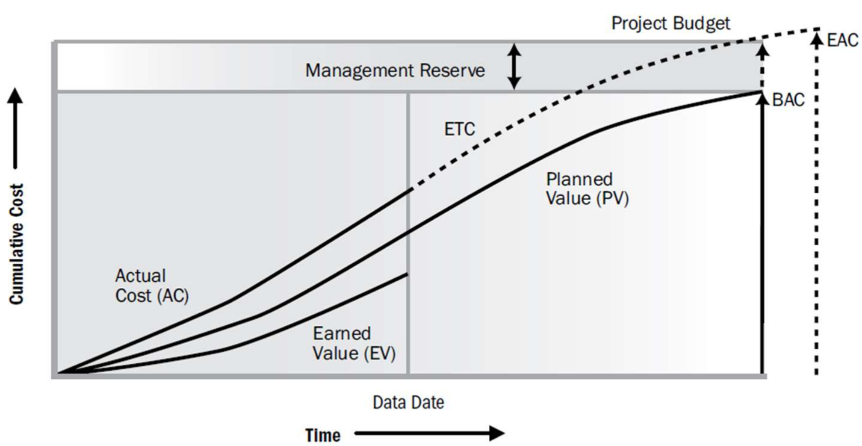

Figure 38: S-Curve showing the comparison of PV, EV, and AC over time [7]

The efficiency and accuracy of these Key Performance Indicators (KPI) and the forecasts greatly depend on the accuracy of initial cost and duration estimates, the correctness of the basis of these estimates and the integration of cost and scheduling aspects as well as the data obtained from site regarding the progress of the work. BIM based quantity take off greatly improves the accuracy of the quantity estimates and thereby the costs associated with them. Using BIM for monitoring and reporting progress makes the process efficient and less time consuming.

5.3.2.2 Workflow in Bexel Manger for Progress Monitoring

The 4D model is created according to 'Author 4D Model' section of this thesis, it is then approved by the employer to become the baseline for the project. The progress on the project will be compared to this schedule and the key performance indicators and earned value management will be based on the baseline schedule. Any variation from the baseline schedule should be identified and the causes for variation should be studied for developing measures to mitigate the effects of the variation. If there are delays on the critical path, the reasons must be identified and communicated to the employer. If the contractor is eligible for an EOT and the employer the EOT, this is then reflected in the actual schedule and this schedule will become the Baseline Schedule for future comparison with site progress.

In Bexel Manager, the Baseline schedule is duplicated to create the Actual Schedule to track the progress of work. The Cost Version assigned to the Baseline Schedule will continue to be applied to the Actual Schedule to monitor the variation in Planned Cost and Actual Cost as the project progresses. Look-Ahead Plans are created based on the Actual Schedule to visually communicate the upcoming works to the project team members and stakeholders.

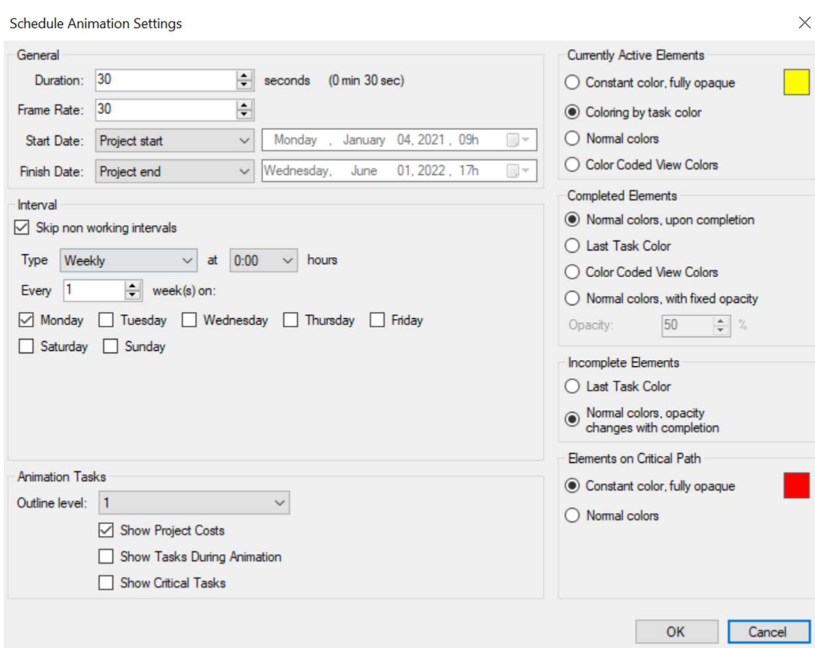

Figure 39: Creation of Look-Ahead Plans using Schedule Animation Settings in Bexel Manager

Look-Ahead Plans can be created on a weekly, bi-weekly, or monthly basis. Using the Schedule Animation Settings, the required time-period can be set in the interval (in this case, weekly) and run the schedule animation. Each frame of the schedule animation will provide the elements that should be completed on a weekly basis.

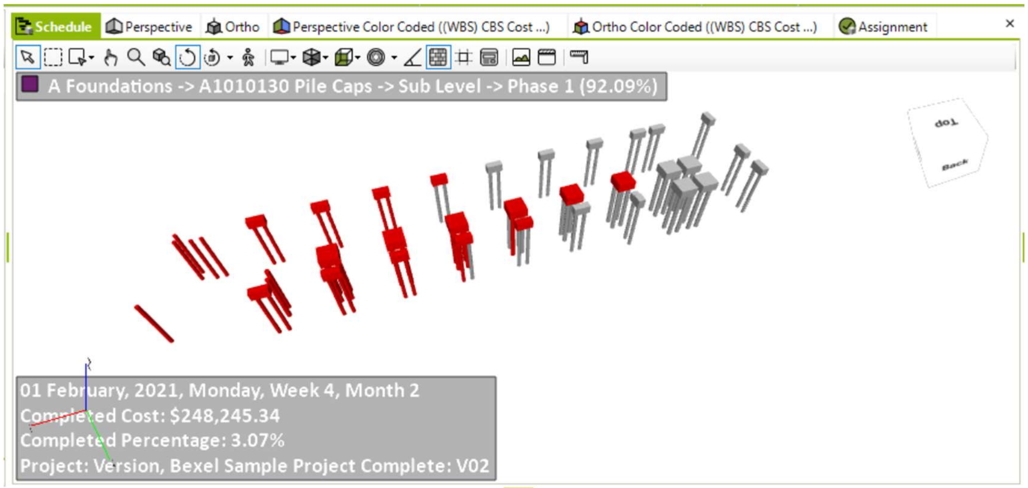

Figure 40: Elements highlighted in red to be completed as per the Look-Ahead Plan

These elements can then be selected to create a selection set of elements that needed to be completed in the upcoming week.

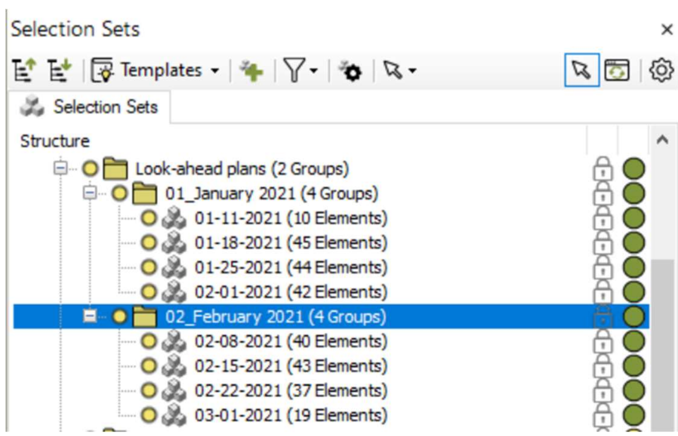

Figure 41: Selection Sets based on Weekly Look-Ahead Plans

This Selection set can then be transferred to the Site Supervisor as a BCF file which he can view these elements on any software that supports the BCF format. Once the week is complete the Site Supervisor can update the progress on the site on this BCF file and send it back to the program manager as another BCF file showing the elements that were completed during that week. The program manager then uses this to create Selection Sets for elements completed in the week and uses this selection set to update progress on the Actual Schedule.

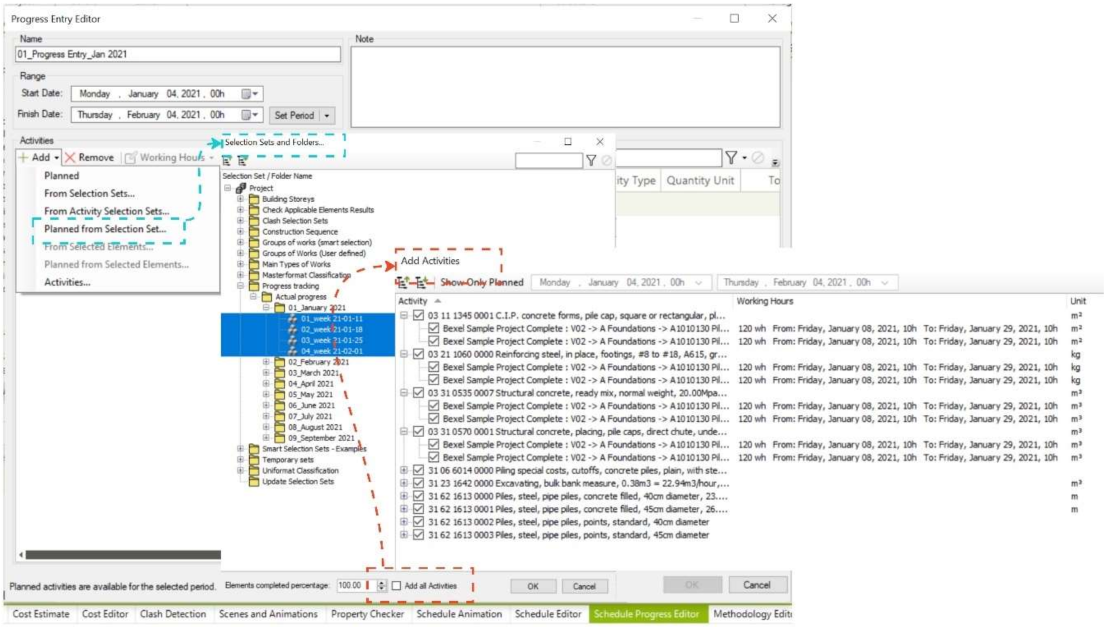

Figure 42: Method of Progress Entry in Bexel Manager

Within the Progress Editor, the actual progress of all activities related to the elements within the Selection Set can be updated separately. Also, the actual quantity of resources used and the actual working hours for each day can be updated. Once the activity data is added, update the Status Date in the “Progress Editor”. The Status Date is the date of entry of the latest progress and the activity data before this date cannot be modified anymore once it is saved.

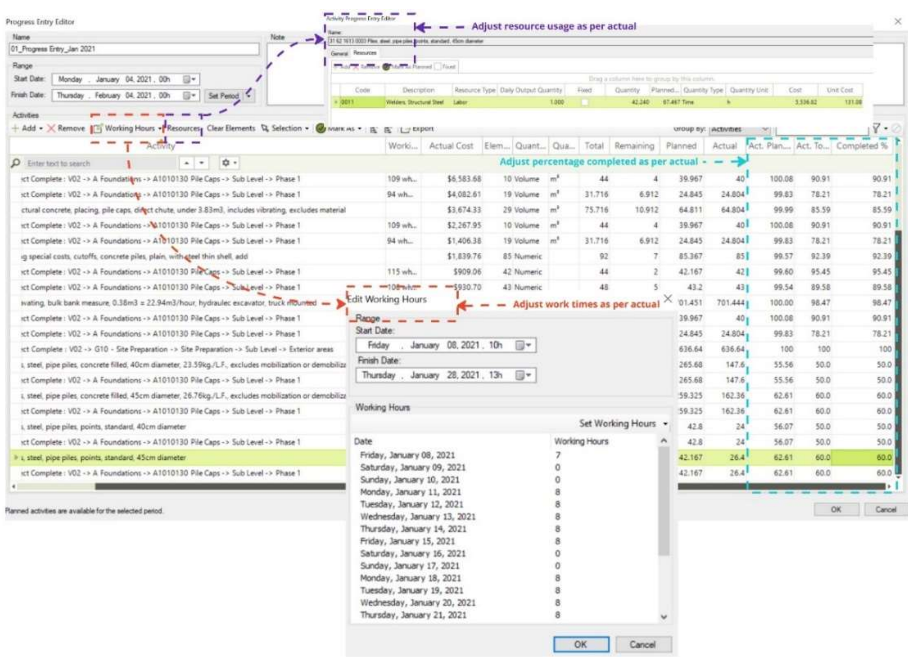

Figure 43: Editing the attributes of activities and the percentage completed as per actual in progress entry

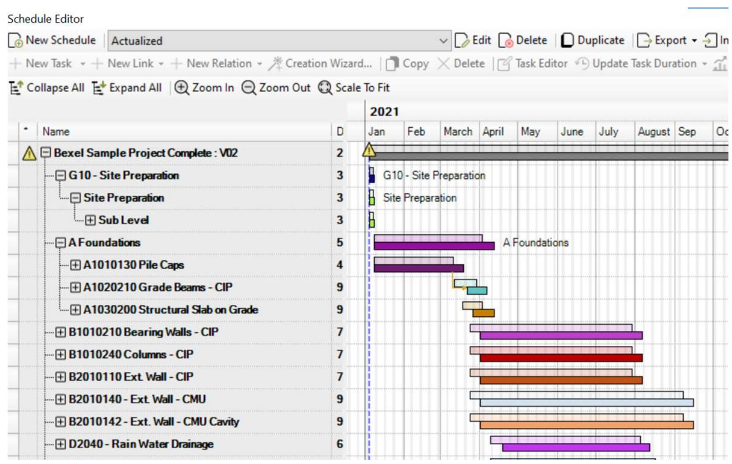

Figure 44: Updated Actual Schedule compared to the Baseline Schedule

Once the Progress entry has been saved, the Actual Schedule updates itself and can be compared with the Baseline Schedule to understand the progress of project works. Each activity can be compared and if the actual work completed is not as per the planned work, the causes for this can be identified and mitigation plans can be developed.

5.3.3 Delay Analysis

5.3.3.1 Time Slice Window Analysis

Steps involved in performing Time Slice Window Analysis are [54]:

Step 1: The analyst verifies the available updated baseline programmes to ensure that it correctly reflects the works performed in the windows of time during contract works. If such a schedule is not available, the analyst is required to develop one from the data available. The schedule should be checked to ensure that the schedule does not contain common errors like overuse of date constraints, presence of many open-ended activities, missing scope of work and out-of-sequence works etc.

Step 2: The duration of the project is divided into time slices or windows and these windows, and they are used to determine the impact of delay(s) on the baseline program within that window. The starting point for the analysis is the baseline schedule and it is usually named as W1A for the first window.

Step 3: Starting from the W1A, the delays are inserted into a copy of the baseline programme and are linked to corresponding baseline activities to estimate their impact. If the delay duration extends beyond the window, the delay is sliced at the end of the window. The effect of the delays on the critical path is studied and the impacted completion date is calculated. This date will become the prospective start for the next window.

Step 4: The programme updates from each window analysis are analysed to determine the contemporaneous or actual critical path at that time, as well as the status of any delays. This information can be used to understand the extent of critical delays that occurred during the window.

Step 5: Then the project records are investigated to identify the events that caused the delays in each of the windows. Contemporary evidence is verified to ensure that the actual progress of works was recorded correctly as these documents are most important in substantiating a claim based on delay analysis.

5.3.3.2 Workflow in Bexel Manager for Delay Analysis

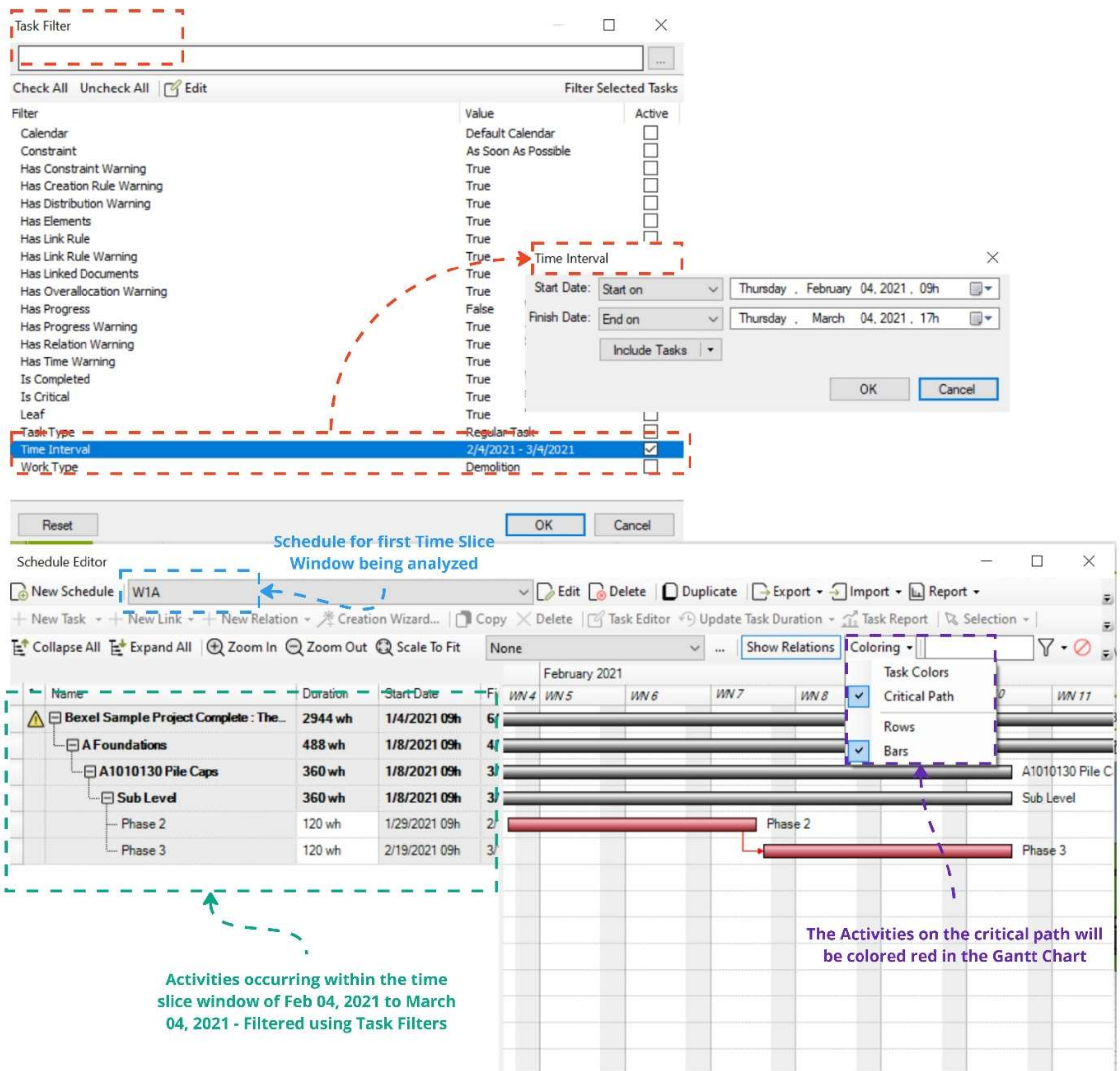

Figure 45: Time Slice Window Analysis – Task Filtering

The first step is to create a copy of the baseline schedule for delay analysis. Collect all available delay information and identify the time periods in which they occurred. Then, divide the schedule into time slices. For the purpose of this discussion, each of the time slice is considered to be one month long.

Considering that 'Delay01_Severe Rains' occurred in the month of February from February 10, 2021, to February 13, 2021, and it took 2 more working days to clear the site of the debris which is marked as 'Delay02_Clearing Site' and prepare the site. Before adding this delay to the schedule, the tasks that occurred within the Time Slice Window under consideration are filtered using Task Filters and the Critical Path is highlighted in red in Bexel Manager.

The delays are then added as tasks in the schedule and it is visible that the rains occurred while Phase 2 of Pile caps were planned to be constructed. 2 sub-activities are added within the 'Phase 2' activity, and these are linked to the delay activities as predecessors and successors. For visualization purposes, the elements under 'Phase 2' activity were divided and assigned to the sub-activities.

The Delay01_Severe Rain Activity was added as a task with a constraint of "Must Start on" of Feb 10, 2021, and activity attached to the first set of elements was linked as predecessor to this activity and the Delay02_Clearing Site was linked as the successor activity. The 'W1A' schedule is then compared with the Baseline Schedule to identify the effect of this delay on the completion date of the project.

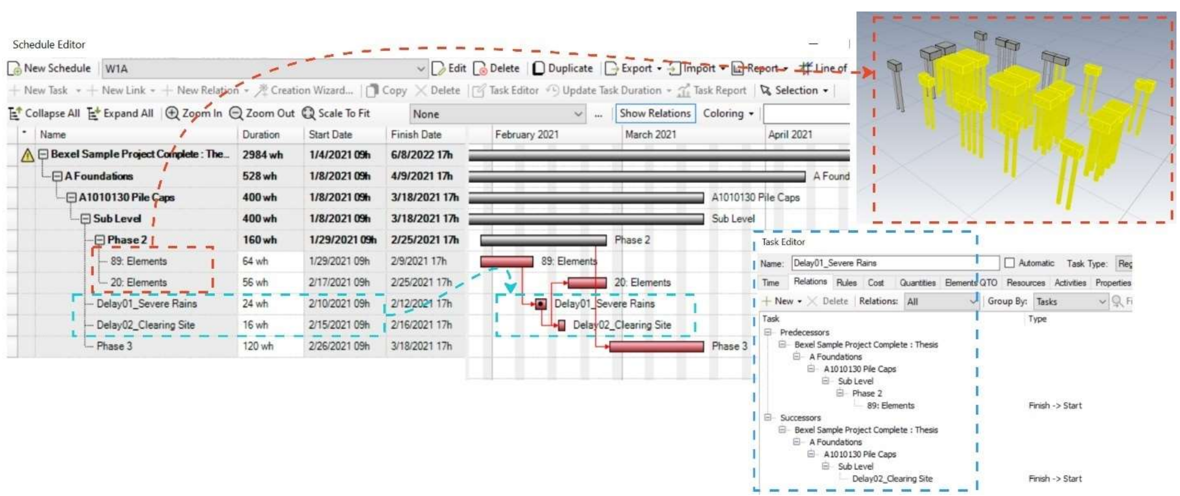

Figure 46: Time Slice Window Analysis – Assigning Delays

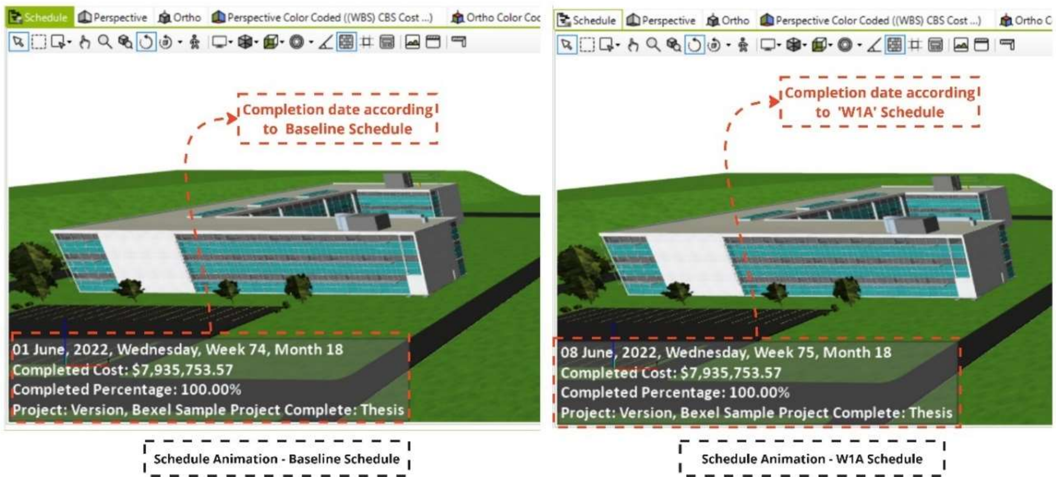

Figure 47: Visual Comparison of Baseline Schedule and W1A Schedule

5.3.4 Claim Documentation

5.3.4.1 Steps Involved in Preparing a Claim

Step 1: Identify the delay instances that occurred during the project and consider each event separately to identify the effects of each of them on the project completion time. Identify the party who is contractually responsible for that specific kind of delay.

Step 2: Verify how the delay affected the critical path of the project at the time that the delay occurred.

Step 3: Consider all available facts and evidence that affect the issue being studied.

Step 4: Perform delay analysis as described in the section ‘Delay Analysis’ in this thesis.

Step 5: Identify all the documents available to support the analysis and attach them to the claim.

5.3.4.2 Protocols for Bexel Manager for Maintaining Documentation

a. Trigger Event: Acts of God/Weather

Reported by	**Site Supervisor**
Report to	Project Controller
Report approval by	Project Manager

Required Documentation

Documents	**When to report?**	**Who should report?**
Works completed right before the event occurred must be marked in the issued look-ahead plans	Immediately after the start of the event	Site Supervisor
The works affected by the event must be marked in the issued look-ahead plan	Immediately after the end of the event	Site Supervisor

Weather report/report related to the event	Immediately after the end of the event	Site Supervisor
Report on residual impact of the event and the works affected by it	Immediately after the end of the event	Site Supervisor
Geo-tagged photographs of the identified impact with dates	Immediately after the end of the event	Site Supervisor
Changes to planned schedule	Immediately after the start of the event	Project Controller
Updated look-ahead plans	Immediately after the start of the event	Project Controller

Action Plan

Step 1: When the trigger event occurs, the Site supervisor must identify and mark the works that were completed and those that were not completed based on the look-ahead plans provided to them and send them to the Project Controller.

Step 2: After receiving the updated look-ahead plans with elements completed before the start of the event, the Project Controller must update the progress in the actual schedule of the project in Bexel Manager.

Step 3: The Project Controller must identify alternate works that can be completed during the time, if any, and update the schedule and document the reasons for schedule change. Issue updated look-ahead plan to Site Supervisor using Bexel Manager.

Step 4: After the end of the event, the Site Supervisor must record the impact of the event photographically and report the impact on the planned work and assign this to the Project Controller using Bexel CDE.

Step 5: The documents must then be approved by the Project Manager, and they must be linked to the activities that were delayed.

Step 6: The Information Manager then shares the documents in the respective information container following the file naming conventions specified in the EIR.

Step 7: For an on-going delay event, the documents can be updated using the Bexel Docs platform. Bexel Docs can be used to manage and update documents, link documents to BIM elements or groups of elements, filter documents based on element selection and to explore the version history of documents, all of which are vital for the easy retrieval of information corresponding to a delay and to validate the legitimacy of the documents.

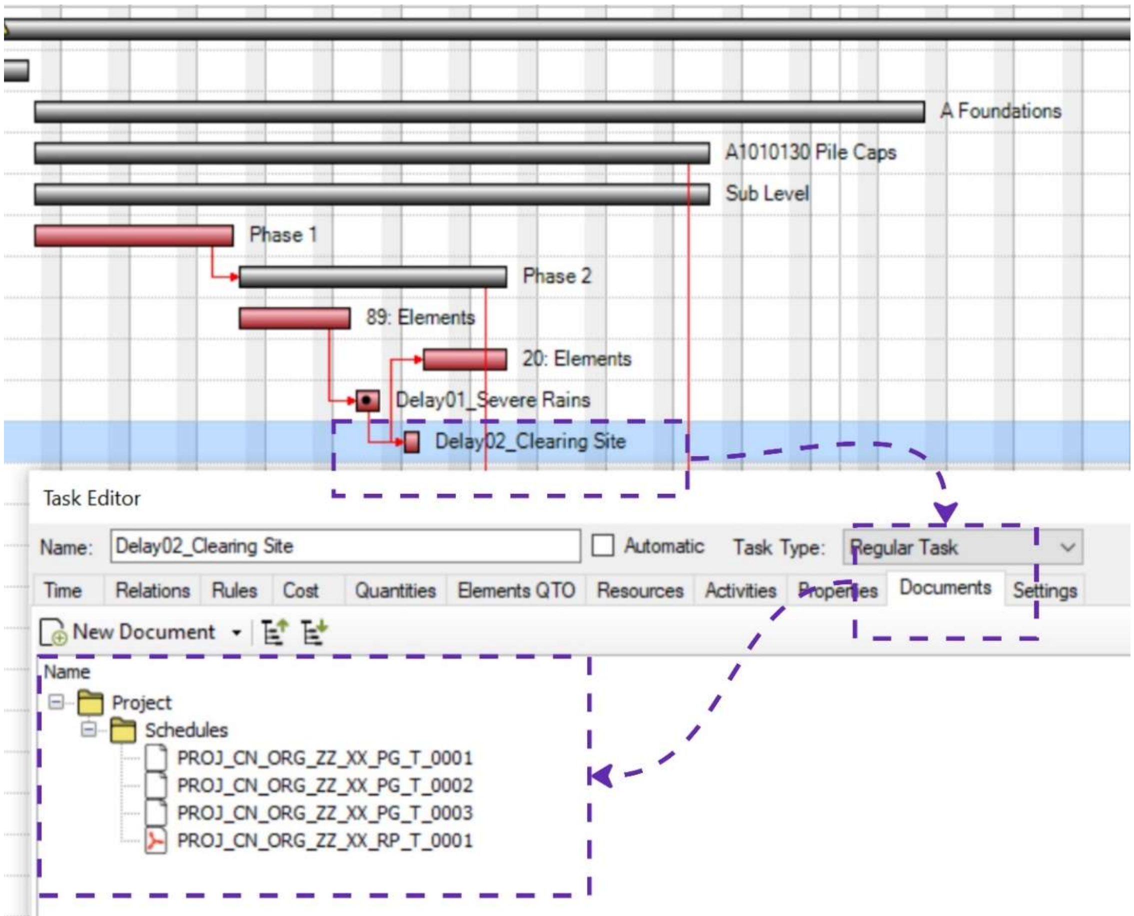

Figure 48: Attaching documents to the delay activity within the Task Editor

Within Bexel Manager, for Claim documentation, all the available documents related to the delay event can be attached to the Delay Activity within the Task Editor.

b. Trigger Event: Defect Repair

Reported by	**Employer's Representative**
Report to	Project Engineer
Report approval by	Project Manager

Action Plan (Using BCF Format)

Step 1: Immediately after the site inspections, if any defects are found, the Employer's Representative/Engineer must raise an issue using the BCF format and assign it to the Project Engineer. The issue must contain information related to the type of issue, comments on the type of defect and the required rectification, priority and location, status of the issue and the viewpoint which shows the affected elements. The Project Engineer should be notified of the issue.

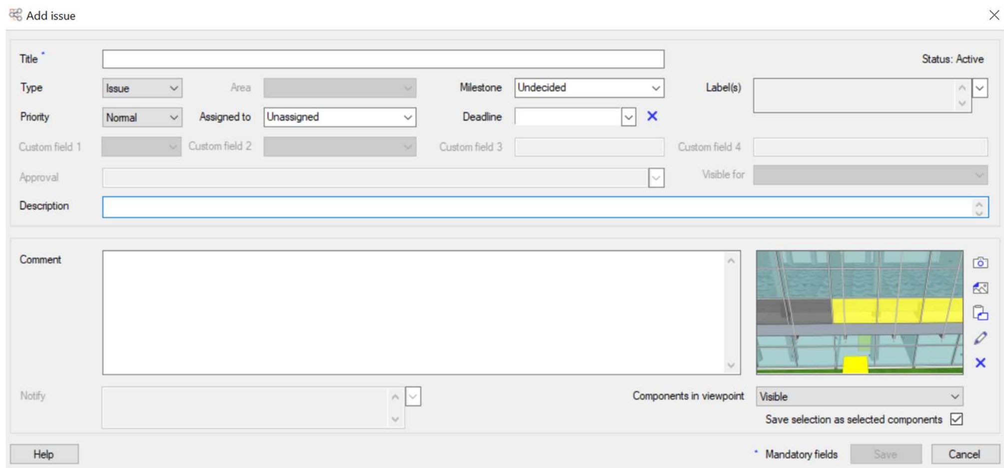

Figure 49: Creating an Issue using BCF Manager in Bexel Manager

Step 2: The Project Engineer can then identify the responsible personnel or subcontractor and assign the issue to them. The Project Controller and the Project Manager must be notified of the issue.

Step 3: The Project Controller must identify the tasks/activities that would be affected by the issue and assign the issue to the Project Manager with comments on the affected events and request for instructions on updating the schedule.

Step 4: Once the action plan for correction of defects has been identified, the Project Manager can assign the issue to Project Controller for updating the schedule. The file names of documentation approving the schedule changes should be added in the comments and the Information Manager must be notified about updating the status of the documents.

Step 5: The Project controller then updates the schedule and attaches the corresponding documentation to the BIM elements in the model.

5.4 EIR Template Creation

In case an extension of time and/or additional costs claim occurs under the Appointment, the 'Information protocol to support BS EN ISO 19650-2 the delivery phase of assets' obligates both the Appointing Party and the Appointed Party “to provide information and assistance as the Information Particulars requires them to provide”. This implies that the parties are only obligated to comply only as far as mandated by Information Particulars and therefore care must be taken to identify and include the types of documentation that would be required to identify, quantify, and substantiate claims along with the timeline they should be provided in (which is as per the dispute resolution clauses of the respective contracts).

5.4.1 Commercial Requirements

Commercial Requirements provides insight into the purpose of the project, the deliverables required and the points in the project when they are required, the key questions that needs to be addressed in the response to the EIR and the provide information regarding the shared data for use on the project.

General project information is common for all EIR created within the project. It contains details regarding the location of the project, budget, type of asset, the contract type, plan of work etc. It is useful for all the stakeholders to have a common understanding of the project and the general requirements and conditions.

Shared resources could include information exchange requirements like the OIR, PIR and AIR, other organizational process assets like reporting formats, historical information, templates, policies and procedures and enterprise environmental factors like resource availability, commercial databases, and software licenses. This section also indicated the permitted uses of the shared resources to avoid their misuse. These documents enhance collaboration on the project and adherence to the standards of the organization.

BIM uses are defined based on the information requirements and the purpose for which the information will be used. Defining BIM uses is vital in deciding the hardware and software requirements, the level of detail to be included in the models, project formats, training requirements and for assigning responsibility.

Key decision points could include contractually binding timescales mentioned in the agreement between parties, the project milestones, deadlines for each stage of the project or other points in time where an informed decision needs to be made. They play a vital role in obtaining the benefits of BIM, since it provides the project team members with a timeline for delivery of information and clarity on the level of definition required at each of these points. The dates for deliverables are decided after considering the time required for them to be verified.

Response to the EIR defines the key questions that must be answered and the deliverables that should be submitted in response to the EIR. It can be used to request specifically for BIM competency assessments, delivery plans for the BIM deliverables, risk assessment and risk management plans, responsibility matrix amongst others. Explicitly stating the requirements in the EIR provides the lead appointed party guidance towards what information should be mandatorily included in the response. Since Information Requirements as per CIC BIM protocol refers to both EIR and BEP, clarity in producing both these documents is vital.

5.4.2 Management Requirements

Management requirements describes the BIM processes to be adopted on a project and could include sections describing the project standards, roles and responsibilities of individuals involved in the project, plan of work, security, coordination and collaboration processes, compliance plans and delivery strategy for asset information.

5.4.2.1 Project Standards

Project standards define the standards that should be followed on the project to improve collaboration between project team members and to ensure that the work aligns with industry standards. Different countries follow different standards, and they should be identified and clearly mentioned in the EIR along with the version number that is to be used on the project. If any of the standards are revised or new standards applicable to the project are released during the project, the effects of the change on the project must be studied and the appointing party or his representative must approve the change before it can be used on the project.

5.4.2.2 Roles and Responsibilities

Role of each project member, the name of the person associated with the role and their contact information must be identified within the EIR to ensure seamless communication. The tasks that need to be completed at each stage of the project must be identified in the EIR and the roles responsible for ensuring the accurate completion of each of the tasks are tabulated in the responsibility matrix.

5.4.2.3 File Naming Conventions

Defining the naming convention in the initial stages of the project is vital to improve searchability, transparency and consistency of project files. It reduces the time and budget spent in identifying and reconfiguring the files by each party. For a naming convention to be effective there must be a collaborative agreement between the parties while establishing the naming conventions and the defined codes below can be extended as the project progresses but must be approved by the responsible person before it becomes accepted for use in the project CDE. ISO 19650-2:2018 provides detailed guidelines on conventions to be used in naming files and these can be adapted to suit the project needs and described in the EIR for the information of all the parties involved.

ISO 19650-2:2018 also sets out metadata requirements for files within the CDE and they include a classification code, status code and revision code. Additionally, metadata related to security could also be used to enable the responsible person to assign accessibility rights for project team members. ISO 19560-2:2018 stipulates that these metadata should not be appended to the name of the Information

Container. Use of metadata improves various filters to be applied during searches and enhances CDE connectivity.

- *Classification Codes*: This field helps to identify and describe the information container and the contents within by using a reference dictionary like Uniclass. The assignment of metadata must also be based on the requirements for transfer of information containers between different CDE solutions used on the project. It is vital that no information that is previously conveyed in the naming of the information container or other attached metadata be duplicated when using the classification code.
- *Revision Codes*: This field enables tracking of changes that occurred between revisions and thus in creating an audit trail and is useful in identifying the versions and revisions shared to other project team members. Revision control is performed at each stage of the CDE process from Work in progress to Shared to Published. Two types of prefixes are prescribed by 1SO 19650-2 to indicate whether an Information Container is preliminary (non-contractual) or contractual.
- *Status Codes:* This indicates the permitted use of the information container and by extension, the purposes for which the information must not be used. It indicates whether the information container is suitable for review and comment or for information only or for construction. It improves the reliability of the information and removes liability in case the data contained is misused. Suggested codes for status codes adapted from CDBB EIR guidance[55] are attached in the appendix.
- *Security Codes:* This can be used to control access to information containers by various project team members and provide viewing and editing rights to them, depending on the security requirements of the project, thereby preventing unauthorized access and modification of the contents within. Suggested codes for security codes adapted from CDBB EIR guidance[55] are attached in the appendix.

5.4.2.4 Acceptance Criteria

Information containers can exist in various states depending on its stage of development. The information container must be reviewed and approved by the responsible party before its state can be changed within the CDE. Describing the criteria for the review and approval process within the EIR provides the project team members with clarity on requirements to be fulfilled for the information to be approved for a status change to Shared or Published. In case of legal disputes, it also provides the legal practitioners with information on the considerations and conditions that resulted in the approval of any document. ISO 19650-4:2022 provides a list of items the individual responsible for status change and approval could consider verifying before approving the status change.

Rules defined as acceptance criteria must include verification of:

- Delivery of required information
- Syntax, case, and spelling of file naming
- Metadata
- Definition of prescribed values or ranges

Explicitly describing the acceptance criteria within the EIR ensures that they remain consistent even if the responsible individual is replaced during the project.

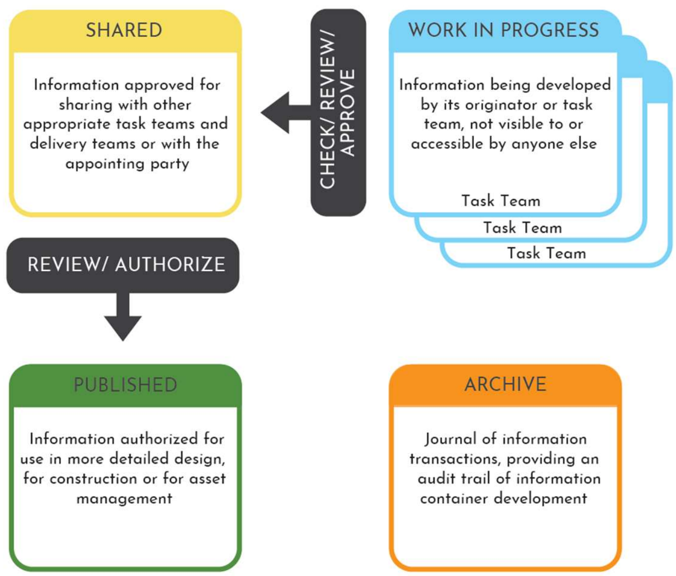

Figure 50: States of Information Containers within the CDE [56]

5.4.3 Technical Requirements

Technical requirements include details about the coordinates of the project, the hardware and software requirements, the versions of software, training requirements, the formats for deliverables and the level of information requirement for deliverables for fulfilling the purposes of the information.

5.4.3.1 Project Coordinates

Project coordinates are defined within the EIR so that all the models will have the same point of coordination and orientation. This is important for federation of models, clash detection and spatial coordination to avoid potential rework.

5.4.3.2 Hardware and Software Requirements

To ensure interoperability between the software used by the appointing party and the appointed party(s), it is essential for the appointing party to specify the software they intend to use on the project and the versions of these software and stipulate that the appointed party procure software that are compatible for use on the project. The native file formats required by the appointing party to utilise the information model as well the record copy formats must be specified under Project Formats. This is especially important since Information protocol states that the unless the project team member fails to fulfil obligations set out under the agreement or protocol, the project team member does not warrant that "*any software used to prepare the Specified Information or any software format in which the Specified Information is shared, published or otherwise issued in accordance with this Protocol and the Agreement, is compatible with any software or software format used by or on behalf of the Employer, the Employer's Information Manager or any Other Project Team Member in connection with the Project*"

5.4.3.3 Level of Information Need

The information requirements should be specific enough to avoid any assumptions being made by the provider, which will ultimately improve the quality of the information delivered. The specifier should avoid requesting unnecessary information, as this can lead to data overload and decreased productivity. They must only define the information required to fulfil their tasks or those performed on their behalf.

Information requirements are communicated in two parts: high-level requirements and detailed requirements. To define the high-level requirements, it is necessary to first identify the purpose for which the information is required. Then these high-level requirements can be elaborated upon to include the form, format and content to form the detailed requirements. Content can then be split into content summary and content breakdown which includes both the geometrical and alphanumerical information. Information deliverables can be structured or unstructured. Structured information is information that is organized in a specific way with pre-defined relations between one another. It is machine readable and can be queried to extract specific information. Databases, spreadsheets, XML documents and models are examples of structured information. Unstructured Information cannot be queried and needs human interaction to interpret the data. Examples of unstructured information include photos, emails, drawings, videos, and reports. Requirements for structured information include geometrical information, alphanumerical information, and documentation. Explicitly defining what should be included can help to ensure that information is managed effectively, data accuracy is maintained, and file sizes are kept under control.

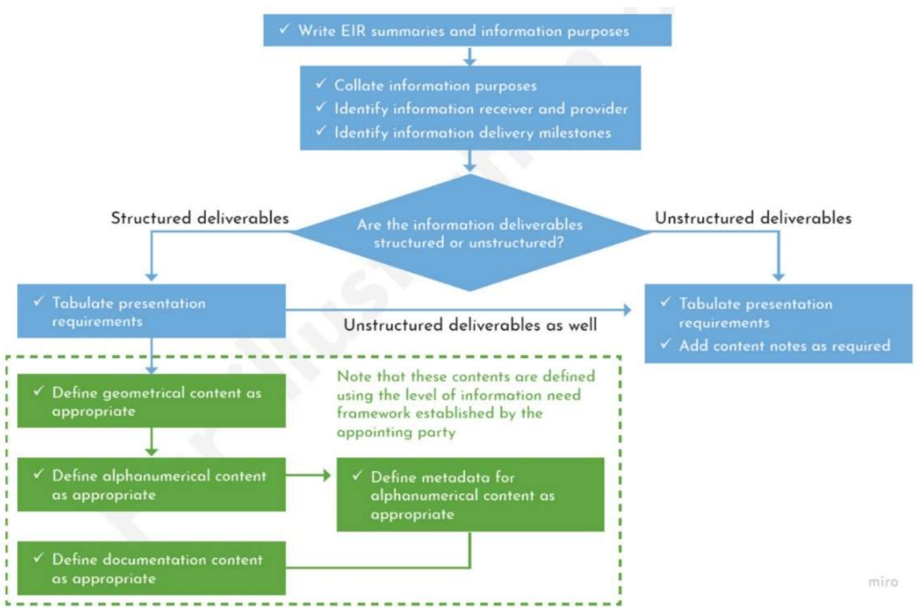

Figure 51: Process for creating EIR [57]

The OIR of the organization would specify "Effective Claim Management" as one of the goals for using BIM on the project. Based on this requirement PIR specifies the requirement for "Progress Monitoring Information" to be provided to the "Information Manager" to the appointing party by the "Main Contractor" on specified information delivery milestones. Based on this, the content to be requested using the EIR is identified and listed as structured information requirements and unstructured information requirements. A sample for requesting this information has been developed using guidance from UK BIM Framework and is attached in the appendix.

5.4.4 Importance of sections of EIR for Claim Management

Table 3: Importance of sections of EIR for Claim Management

EIR Section	Description	Stage of Claim Management
General Project Information	Provides information on who the EIR is addressed to and BIM Protocol in use.	Pursuing claims Claim Resolution
List of shared resources	Provides information regarding the resources that have been shared between the parties involved, the permitted use of the information and the security requirement for each of the documents.	Claim Prevention Claim Mitigation Pursuing claims Claim Resolution

	The shared resources include organizational process assets which are used as basis for estimating cost and time for the project. It also informs the parties involved in handling the claims about the security they should maintain with these shared resources.	
Project Coordinates	Beneficial in understanding the federation of models and it is essential for creating forensic investigation models and animations to be presented in courts.	Claim Prevention
Project Standards	Provides understanding of the BIM standards in use on the project. Many statements in EIR and BEP refer to project standards.	Claim Prevention Claim Mitigation Pursuing claims Claim Resolution
Project Formats	Provides information on accepted formats of deliverables.	Claim Prevention
Software Platforms and versions	To avoid claims related to interoperability of software used my employer and the project team.	Claim Prevention
CDE Requirements	Clearly indicates the technical requirements and the party responsible for maintaining the CDE.	Claim Prevention Claim Mitigation
File Naming Conventions	Describes the organization that created the information, the creator's role, and the format of the information. It reduces the time spent in searching for information.	Claim Prevention Claim Mitigation Pursuing claims Claim Resolution
Metadata Requirements for Information Containers	Indicates the status, classification, and security requirements of the information container. This information is necessary to understand how the information can be used, prevent misuse, improve reliability, ensure everyone is using the same version, protect data from unauthorized access, and improve legal validity.	Claim Prevention Claim Mitigation Pursuing claims Claim Resolution

Acceptance Criteria for Information containers	Provides clear understanding of the criteria for accepting information created and for changing the status of information from Work-in-Progress to Shared to Published.	Claim Prevention Claim Mitigation Pursuing claims Claim Resolution
Roles	Provides personal details of the job roles mentioned in the responsibility matrix.	Claim Prevention Claim Mitigation
Responsibility Matrix	Provides information on the personnel responsible for each task on the project. This information can help to resolve issues related to liability and ownership rights to some extent.	Claim Prevention Claim Mitigation Pursuing claims Claim Resolution
BIM Uses description	A clear description of the uses for the BIM models is essential for ensuring that all parties involved have a shared understanding of the information. Avoiding the use of umbrella terms and providing clear definitions can help to improve understanding and avoid confusion.	Claim Prevention Pursuing claims
Level of Information Need	Provides information on who will use the information, who will provide the information, and how the information will be used. It also allows the information specifier to describe specific requirements for the information that are not typically included when creating information.	Claim Prevention Claim Mitigation Pursuing claims Claim Resolution
Information delivery milestones	Provides information on when the deliverables are required to make key decisions on the project and to meet contractual project milestones.	Claim Prevention

6 CONCLUSION

Delays are ubiquitous in construction industry. It is rare for a project to be completed on time and within budget. Delays can be caused by a variety of factors, including weather, changes in scope, and material or equipment problems. Delays are so common that they have their own classifications and terminology. However, filing a delay claim can be challenging, as delay analysts often face difficulties in retrieving information and presenting their findings. Claims can be rejected due to a lack of contemporaneous records, inconsistencies in the information presented, or each party referring to a different version of the same document.

The types of contemporaneous records required by the courts to substantiate delay claims are generally created on site on a regular basis. However, these records may not be sufficient to prove the claim if they do not meet certain conditions, such as being prepared contemporaneously, being accurate, and being complete. From the literature review, it was concluded that standard contracts typically do not specify the types of contemporaneous records that need to be maintained or their content, leaving it to the contractor to determine what records are necessary to support their claim.

The thesis found that the EIR can be used to require the preparation of project records to meet legal requirements for these documents. In BIM projects, EIR is used to define the level of information needed to meet each purpose in detail. The EIR clearly states the geometrical, alphanumerical, and documentation requirements for meeting the purposes of information stated in the EIR, PIR and OIR**.** It can also be used to specify key delivery dates for each deliverable. However, it was first necessary to understand the issues and provisions within contracts regarding the use of BIM data for legal purposes.

For this purpose**,** the current provisions for incorporating BIM in commonly used standard forms of contract were identified. The BIM Protocols were then studied alongside the contracts to determine whether any modifications were necessary to incorporate the protocol into the contract, as well as to identify any additional obligations that the protocol placed on the Appointing Party and the Appointed Party. A study of standard forms of contract found that CIOB's – TCM15 and PPC2000 were the best suited for BIM projects in their original form. It also found that JCT and NEC suites have provisions for use of BIM Protocols along with their standard contracts and they have released practice to align terminology and provide clarification on conflicting clauses within the protocols and the standard contracts.

The CIC BIM Protocol and Information Protocol were both carefully studied to understand the obligations, responsibilities and rights of the Appointing Party and the Appointed Party imposed by the protocols. This was essential in comprehending how the protocols sought to address some of the legal obstacles to BIM use, as well as the significance of information requirements documents, and the information conveyed through them to tenderers and appointed parties. 'Table 3: Importance of sections of EIR for Claim Management' was created to provide an overview of the importance of each section of the EIR for various stages of claim management, based on the legal obstacles identified and the contractual provisions for creating information on a BIM project.

Use of Bexel Manager for Claims management and Forensic delay analysis

4D models and simulations can be used by delay analysts to communicate findings to other stakeholders clearly and the use of CDE can help address the issues related to retrieving information and inconsistencies in presented information. By following the processes outlined in ISO 19650, which specifies the workflow for creating, sharing, and publishing information in a CDE, each party can be confident that they are using the latest and most accurate information. This can help to improve the efficiency and effectiveness of collaboration and reduce the risk of referring wrong information.

Integrating 4D and 5D models can help project teams better forecast funding requirements, identify risks, improve resource planning, and optimize the project schedule. It can also be used to easily compare the cost requirements for different project schedules, and to avoid delays caused by lack of funding. An integrated 4D-5D model can be used to analyse the effect of a delay on the project budget by showing how the delay affects the timing and cost of activities. It gives the analyst a clear understanding of the cost allocated to each activity associated with a model element.

Claim management process involves four phases: claim prevention, claim mitigation, pursing claims, and claim resolution. Bexel Manager can be useful in all these stages.

Visualizing schedules before they are finalized can help all stakeholders understand the proposed work sequence and provide suggestions and insights that can be incorporated into the project schedule. This can also be used to show alternative construction sequences, such as what would happen if some of the identified risks occurred. Bexel Manager's integrated 4D-5D model can clearly show the impact of each scenario without the need to recalculate costs, which saves time and allows stakeholders to make informed decisions about which construction scenarios to approve.

Bexel Manager can be used to visually communicate to each subcontractor and supervisor the work that needs to be completed in a particular time frame. This helps them coordinate their work and resources, which can help to reduce interference and issues on site. It also gives them a clear understanding of what is expected. Progress monitoring is simplified by creating selection sets of elements within look-ahead plans for the site supervisor and communicating it to them using the Bexel Manager native format or BCF format. The supervisor can then update the selection set with the work completed in a particular time frame and send them back to the project controller. The project controller can use this information to update the progress of work, labour productivity, earned value management, and project KPIs. This information can be used to identify problems earlier, create plans to mitigate delays, and file claim notices if necessary. The contracts require that the contractor file a claim notice within a specific time frame after the delay is identified or should have been identified. If the contractor fails to do so, they will forfeit their right to claim.

Bexel Manager can be used to create visualizations of the impact of delays, based on the chosen delay analysis methodology. Bexel CDE and Bexel Docs can be used to manage documentation and view document history, which is essential to ensure the reliability of the documentation. The documentation within Bexel Docs can be linked to BIM elements or schedule tasks and filtered by element selection. This is helpful for retrieving information and contemporaneous records related to delays.

Identified issues and suggestions: Currently, a script provided by Bexel is used to create side-by-side visualizations. However, it would be more beneficial if this could be configured within the model viewer itself. This would give the modeler more control over the visualizations that are created. It would also be beneficial to be able to identify and visualize near-critical paths as delays on these paths could easily make the tasks on the path critical.

Scope for Future Work

Although it may seem tedious at first to collect information requirements for all types of claims that could occur during a project, once developed, this information can be used for all projects within an organization with minimal changes.

More studies need to be conducted on both the technical and contractual dimensions of this issue. On the technical side, there is a need to identify the documentation requirements for each type of claim and include them in the EIR. Additionally, research is needed on how to automate reporting and how to use IFC classes to manage claims.

On the contractual side, currently, there are very few publicly available case laws related to BIM projects. As more case laws become available, they need to be studied to identify the issues pointed out by the court when using information from BIM models and CDE. Equipped with this information, contracts and protocols must be further studied to improve the robustness of contract clauses for BIM projects.

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8 APPENDIX

A. EIR Template for 4D and 5D Model Creation

EIR Reference No.	AAAA-AAAA-0000
Issued on	dd-mm-yyyy

A.1. BIM Uses

BIM Uses		Purpose for information
Author 5D Model	3D models with cost information	Progress quantification and issuing payments
		Quantification of delays and damages
		Claim Management
Author 4D Model	3D models with the added dimension of time	Visual communication to stakeholders
		Procurement planning
		Progress tracking
		Delay identification and quantification
		Claim Management

A.2. Level of Information Need

Information Requirements for Claims Notification

Structured Information				
Item	**Content Summary (based on Uniclass 2015)**	**Format**	**Milestone No.**	**Description**
1	PM_40: Design & Approvals Information			
1.1	PM_40_60_01: 4D Programme Federated Model (Baseline)	IFC	1	Schedule and resource linked 3D Model
1.2	PM_40_60_01: 4D Programme Federated Model (Updated)	IFC	2	Schedule and resource linked 3D Model updated at pre-set intervals
1.3	PM_XX_XX_XX: Look-ahead plans	BCF	2	
1.4	PM_40_30_63: Photorealistic Visualization Model	mp4	2, 4	

Unstructured Information					
Item	**Content Summary (based on Uniclass 2015)**	**Format**	**Mile-stone No.**	**Description**	**Content Comments**
2	**PM_40: Design & Approvals Information**				
2.1	PM_40_30_77: Schedule of Works	PDF	2		
2.2	PM_40_60_28: Document Numbering System	PDF	1		
3	**PM_55: Contract Information**				
3.1	PM_55_17: Contract Notice	PDF	3		
4	**PM_60: Construction Management Information**				
4.1	PM_60_10_95: Work Area Information	PDF	2, 3, 4		
4.2	PM_60_20_15: Completion Work Information	PDF	2, 3, 4		
4.3	PM_60_30_66: Progress Report	PDF	2, 4		
4.5	PM_60_40_55:Meeting Minutes	PDF	4		Should contain details regarding the date, agenda, participants, and decisions taken during the meeting
4.6	PM_60_40_58: Progress Photographs	JPEG	4		Should contain the date which the photograph was taken and must be geo-tagged
4.7	PM_60_50_23: Cost Estimate	PDF	4		
4.8	PM_60_60_70: Site Records	PDF	2, 4		

A.3. Information Delivery Milestones

Milestone No.	Key Decision Points	Dates
1	Pre-mobilization	
2	Monthly progress meetings	
3	Claim Notification	
4	Detailed Claim submission	