Integration of BIM in Risk Management during Design Phase of a Construction Project

Master thesis

International Master of Science in Construction and Real Estate Management

Joint Study Programme of Metropolia UAS and HTW Berlin

Submitted on 17.08.2018 from

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International Master of Science in Construction and Real Estate Management
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(1) Topic of the Master Thesis

Integration of Building Information Technology (BIM) in Risk Management during various phases of Project Management

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2. Supervisor ***Sunil Suwal***

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I have taken note of the subject and the deadline of the master thesis as well as the formation of the examination commission. It is known to me that I have to submit three (3) written and bound copies of the master thesis alongside a digital version as well as the additional statuary declaration at Metropolia Helsinki or HTW Berlin.

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Signature of the student

3. Release of the Master Thesis

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International Master of Science in Construction and Real Estate Management
Joint Study Programme of Metropolia Helsinki and HTW Berlin

Date 22.05.2018

Conceptual Formulation
Master Thesis for Mr. Manish Chaudhary
Student number s0557517

Topic:

Integration of Building Information Technology (BIM) in Risk Management during Design and planning phase of construction Project.

Introduction:

In recent years, awareness of and concerns about risks have risen in the Architecture, Engineering and Construction (AEC) industry with the possibility of hazard occurrence gradually rising due to increases in structural complexity, growing project sizes, as well as new and more complex construction methods. However, the current experience and mathematics-based risk management method has limited practical influence on improving the systematic risk management of a project. To mitigate against these increasing problems, Building Information Modelling (BIM) is expected to play a significant role in integrating risk management with project design, construction and maintenance.

An AEC project starts with planning and design, it may then experience a construction stage that lasts for many months, eventually coming into the period of operation that may last for many decades before demolition; different risks present themselves in each stage of the project and its lifecycle. Thus, regardless of the activity, hazard occurrence is always possible with the potential for widespread impact in varying degrees throughout the project, depending on risk type and consequence severity. According to ISO 31010:2009, risk_management is a logical and systematic method that involves a set of activities and processes for establishing the context, facilitating risk communication, identifying, analyzing, evaluating, treating risks, and recording and reporting the corresponding results properly and timely (ISO 2009). The first and most important step in the risk management process is to recognize potential risks at an early stage (Zou et al 2007). Then, through risk analysis, project participants are expected to know the possibility of occurrence and the significance level of the identified risks.

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Purpose:

The scope of a risk in the design and planning phase of a construction project consists of several issues; application of new technologies, poor project organization, budget overruns and delays to the construction schedule, etc. For this reason, all project participants must improve their ability, knowledge and experience in order to manage risks and ensure a safe, successful, and sustainable design and planning phase.

Traditional risk management methods can be divided into two main categories: qualitative analysis techniques and quantitative analysis techniques. However, it is necessary to point out that these are static and traditional methods (Alaeddini & Dogan 2011) and both types are heavily reliant on multi-disciplinary knowledge and experience (Shim et al 2012). As a result, many researchers (Zhang et al 2014, Hartmann et al 2012, and Shim et al 2012) have pointed out that the traditional risk management method can play only a limited role in the real world.

Building Information Modelling (BIM) is one of the main interest areas in the AEC industry, and is expected to play a significant role in facilitating risk management in the design, construction, and maintenance of a project.

Goals / Objectives:

- The goal of this research is to summarize the current risk management process, outline its main challenges and integrate them with BIM to improve risk management in the design and planning phase of a project.
- BIM impacts on both the external and internal risks for a construction company. These risks can be divided up into the pre-implementation, implementation and post-implementation phase. This thesis concentrates on the pre-implementation phase of a construction project.
- This thesis will produce a BIM model and conclusion of the findings.

Research Question:

What are the merits and demerits of using BIM in the Risk Management of a construction project's design and planning phase?

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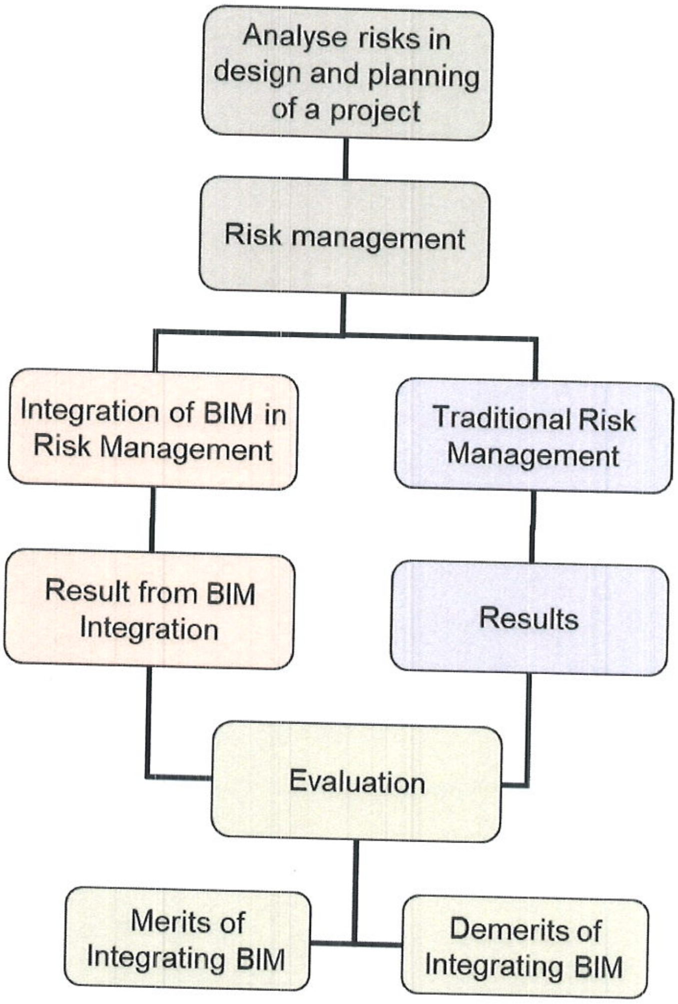
Scope & Methodology



This thesis shall be based on analysing risks during the planning and designing phases of various project case studies. Furthermore, the examined risks shall be mitigated with the use of the Building Information Model and differentiated on the basis of their qualitative or quantitative effects.

Signature of the Supervisor

Acknowledgment

The thesis was a long journey of understanding and knowledge gain. This was aimed to further research into my focus areas of Project Management and advanced technical skills. This journey had ups and downs but now after completing it, I am packed with analytical knowledge and my research data. I would like to present the same, forth.

First of all, I would like to thank my first thesis supervisor Prof. Dr.-Ing. Nicole Riediger. It would not have been better concluded without her guidance and motivation. Prof. Riediger was always there for help, whenever I ran into a trouble spot or had a question about my research or writing. She consistently allowed this paper to be my own work but steered me in the right the direction whenever she thought I needed it. Her encouraging direction and support had made this possible.

I would also like to acknowledge Mr. Sunil Suwal of the Metropolia University, Helsinki, Finland as the second reader of this thesis, and I am gratefully indebted to him for his very valuable comments on this thesis.

Experts who were involved in the endorsement and compilation for this research project, Tanay Swarupam, Prachi Sarna, Amrita Sabhapandit, were of great help. Without their passionate participation and input, the research could not have been successfully conducted. Bel Isobel, enthusiastically helped in proofreading of this document.

I am also grateful to my friends Ankit Srivastava and Amit kumar who encouraged me to start this journey with the right orientation.

Stuti, my best friend and wife, who reinforced and encouraged me throughout the journey and also participated a lot in brainstorming was a 24x7 support system.

Special thanks to my elder brother, Dr. Rajnish Chaudhary, who always motivated me for achieving the higher goals and keep moving forward.

Finally, I must express my very profound gratitude to my parents for providing me with unfailing support and continuous encouragement throughout my years of study and life. This accomplishment would not have been possible without them.

Thank you.

Author

Manish Chaudhary

Abstract

As the architects, Kieran and Timberlake make clear in this quote from their book, “Refabricating Architecture”,

"The single most devastating consequence of modernism has been the embrace of a process that segregates designers from makers: The architect has been separated from the contractor and the materials scientist has been separated from the product engineer."

by integrating design with fabrication and construction, the improvements in efficiency and predictability can be extreme. So why isn't it happening?

With the above-said note, this thesis explores the role of BIM (Building Information Modelling) in Managing and Mitigating risks that originate in a construction project during its design and planning phase. The reason and purpose of BIM methodology are elaborated with respect to the increased efficiency and productivity of building life cycle and hence how it can fundamentally replace, traditional risk assessment and management methods.

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List of Abbreviations

Analysis & Design Model	A model created with the purpose of being used in analysis and design
Application, Software, Tool	Means here Bita Tool if nothing else mentioned
BIM	Building information modelling
CAD	Computer-aided Design.
Compatible software	The Application can exchange information for support project.
Element	Predefined part that contains several objects
Integrated working method	The way of working together instead of separate towards a common solution.
Model	Graphical and mathematical presentation of the structure.
The design phase	A stage in the project where appearance and dimensions the structure is decided together with a system of the structure.
Autodesk Revit	the application is used for analysis and design of a structural system. This software is used in the case study.

1. Introduction

1.1 Background of the research

The architecture, engineering, and construction (AEC) industry consist of multiple players or stakeholders, who work together to initiate, work on it and bring a project to not only its completion but also take care of its maintenance and its smooth functioning so that the project fulfills the purpose fruitfully.

Undoubtedly there are multiple entities involved in different stages and layers. By integrating these seemingly separate entities into a single platform, architects, engineers, and contractors can work efficiently to achieve a common goal. All the stakeholders have a percentage of influence on overall feasibility and efficiency of the project.

Other than the various consultants and stakeholders involved in the project; the time, the energy and the physical resources and materials required for the project are the major players responsible for the success of the project if managed properly. Therefore, the risks coming from improper **time management and resource management also** needs to be taken care of.

Since the Building and Construction industry is a major player in making GDP's of the countries around the world, it becomes more and more crucial to plan and execute the projects with greater attention and backing. There is a lot of economics and environmental impacts involved with this industry. Building and construction industry is an integrated and interdisciplinary field of work. Other than its key elements of design and construction it is the father of small other various industries. And also, in the form of a shelter to other non-related industries.

The building design and planning consists various complex processes with various building support consultants like structural consultants, MEP consultants, landscape consultants, real estate developers etc. therefore integration among all disciplines are needed to synchronize the design and planning of the project. There should be great **communication and coordination** among all of them to achieve an effective outcome.

1.2 Research Propose

There are various stages involved in the process of project development. Starting from the design and its planning till construction and then later demolition.

The Building project is majorly divided into the following phases;

- Planning and Design Phase
- Construction Phase
- Maintenance phase and Demolition

There is a high level of risk involved in every step. All the decision taken from very minor to a major level of work design and execution affect the overall outcome of the project.

In all the three phases the multiple stakeholders and recourses face risks against the ability of the project. Once these risks are considered and design out properly, the value in the work of project phases is increased. Although, this thesis focuses in detail only on the design and planning phase of the construction project.

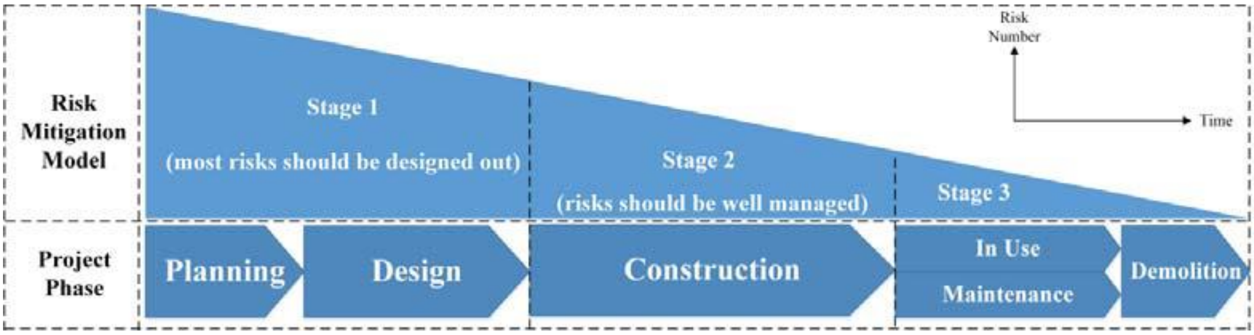


Figure 1.2-1 Risk Mitigation modal, Source: (Y. Zou, A review of risk management through BIM and BIM-related technologies 2016)

During the **design and planning phase** of a project, major changes may occur by owner or project development team, which may lead to slow down the workflow or bring that to at an initial stage. Due to this kind of situations, Architects, consultants etc. may face a major problem, which may lead to extra cost and delay in finalizing design and planning.

The scope of a risk in the design and planning phase of a construction project consists of several issues; application of new technologies, poor project organization, budget overruns and delays to the construction schedule, etc. For this reason, all project participants must improve their ability, knowledge, and experience in order to manage risks and ensure a safe, successful, and sustainable design and planning phase.

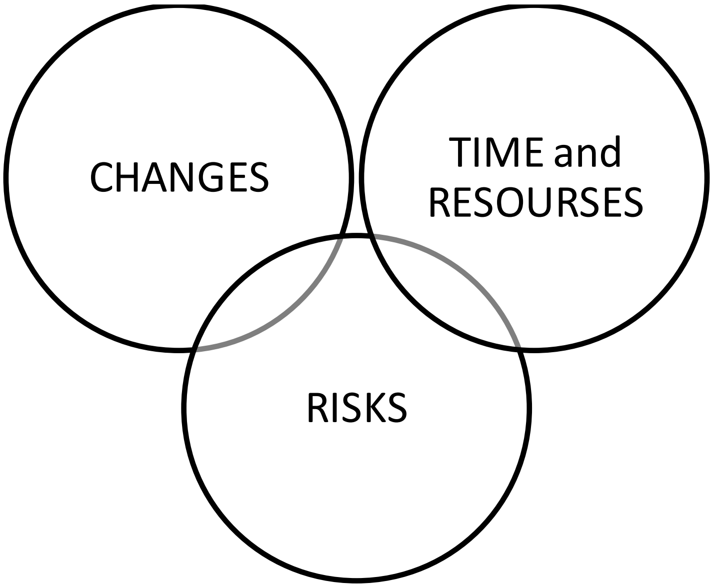


Figure 1.2-2 Graphic representation of Risk in Design and Planning of a Project

Traditional risk management methods can be divided into two main categories: qualitative analysis techniques and quantitative analysis techniques. However, it is necessary to point out that these are static and traditional methods (Alaeddini 2011) and both types are heavily reliant on multi-disciplinary knowledge and experience (Shim Shim, C.-S., Lee, K.-2012). As a result, many researchers have pointed out that the traditional risk management method can play only a limited role in the real world.

The current **risk management method** is heavily reliant on experience and knowledge, based on human cognition and there are several known challenges waiting to be dealt with. It is also very important to identify and mitigate risks at an early stage, and failure to do so may lead to further risks. In recent years, it has been observed that there is a new trend to use BIM and BIM-related technologies to facilitate risk management.

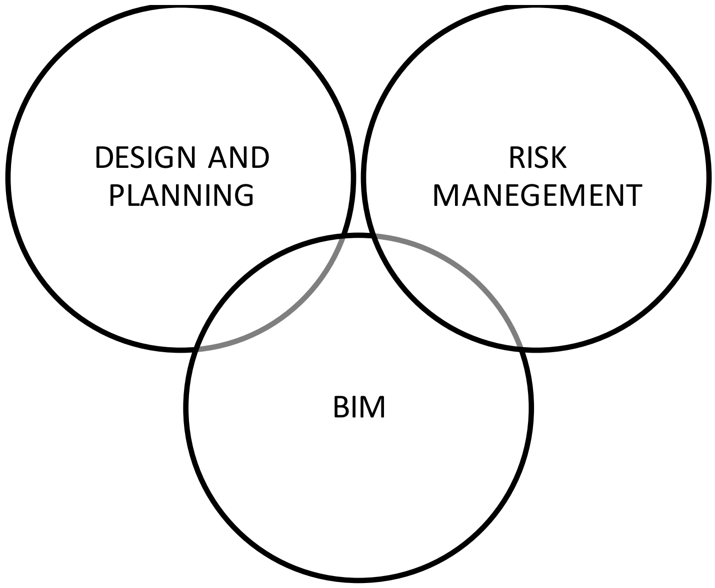


Figure 1.2-3 Graphic representation of thesis description

Building Information Modelling (BIM) is one of the main interest areas in the AEC industry and is expected to play a significant role in facilitating risk management in the design, construction, and maintenance of a project.

The purpose of the thesis is to identify and analyze the present situation and conclude the merits and demerits of using Building information modeling as a tool for a comprehensive increase in project productivity by using it control the risks involved in the project in its design and planning phase. This thesis will further add to the developing knowledge pool of BIM and its characteristics; to realize the upcoming paradigm shift in the AEC industry. The thesis aims to serve as the new developing link between BIM and risk management of a project.

1.3 Research Goals and Objective

- The goal of this research is to summarize the current risk management process, outline its main challenges and integrate them with BIM to improve risk management in the design and planning phase of a project.
- BIM can impact both the external and internal risks for a construction company. These risks can be divided up into the pre-implementation, implementation and post-implementation phase. This thesis concentrates on the pre-implementation phase of a construction project.

- This thesis lays on a reference of the BIM model produced in a BIM software to discover and state the real-time risk assessments and mitigation in the design and planning of the project.

The Objective of the thesis is to; further refine the developing link between AEC industry and use of building information models, elaborate on the deficits of the current scenario and prospects of using BIM for an altogether changed scenario of the industry.

1.4 Research Question:

How can BIM be used as a methodology to efficiently manage the risks in design and planning of a project and evaluating its merits and demerits?

1.5 Methodology

The process of the thesis is described in a diagram below to enable the reader to understand the steps and structure of the thesis. The research thesis based on the procedures of risk management that should essentially be taken care of during the design and planning of the building project. The thesis discusses in detail the concept of Risk management and building Information technology. Based on the literature study, market study this thesis tries to analyze and compare the use of BIM in Risk management over the traditional methods of risk management. The study is demonstrated using information from a building information model made in Autodesk Revit. Further, the efficiency of using BIM tools and techniques for risk management are assessed and concluded.

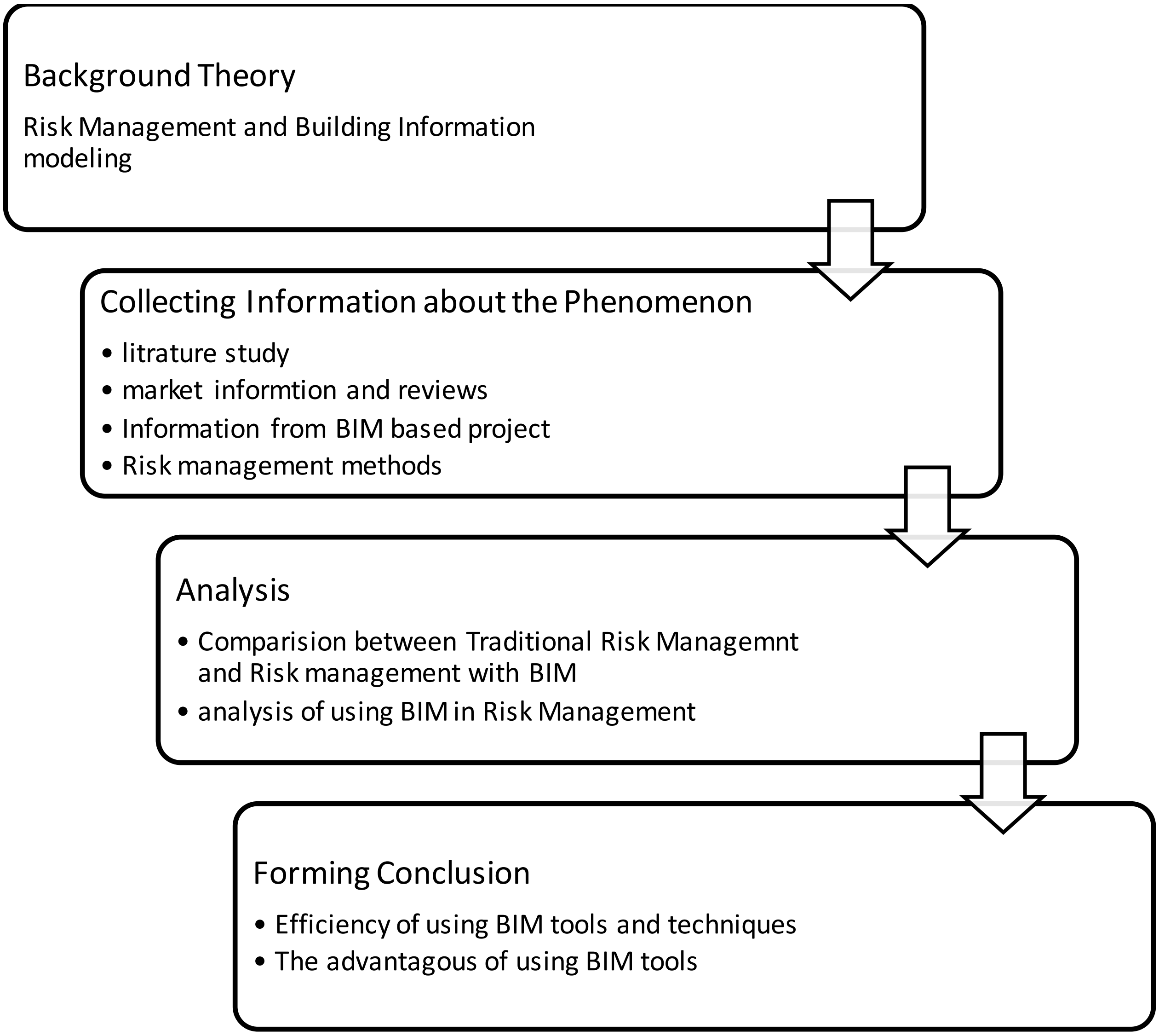


Figure 1.5-1 Methodology or Research

The methodology of the analysis is described as analyzing risks during the planning and designing phases of project case studies. Furthermore, the examined risks shall be mitigated by the use of the Building Information Model and differentiated on the basis of their qualitative or quantitative effects. Also, the merits and demerits of the BIM method will be evaluated over the traditional risk management methods

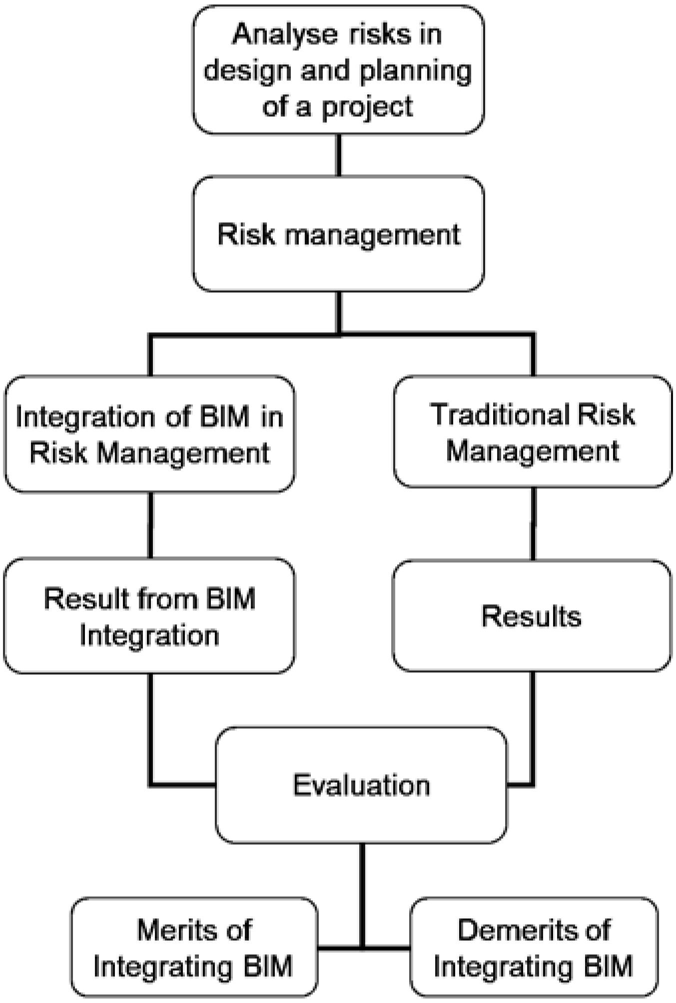


Figure 1.5-2 Structure of analysis

1.6 Research Outcome

This paper not only summarizes the general risk management process and existing deficiencies but also examines and explains the potential of BIM in the risk management implementation process. It documents a gap in implementing BIM-based risk management in the real world and how further research could help fill the gap by establishing an active 'link' so that the advantages of both a general risk management method and BIM could be combined.

The analysis is based on parameters and weighs the potential merit and demerits in the applied method. The thesis will give a clear picture and distinction between the traction risk management vs BIM-based risk management.

2. Risk Management

2.1 What is risk management?

The Risk is a chance that an undesirable event will occur and the consequences of all its possible outcomes **(Larson 2000)**. It can also be defined as something fatal and unexpected, causing tragedies or injuries. It is related to the probability of such critical events, in order to understand its impact on the project. Identification of these events and their respective consequences can be addressed by the respective project participants involved in the project. Opportunities and threats lead to risk whereas chances and hazards are related to the resultant events.

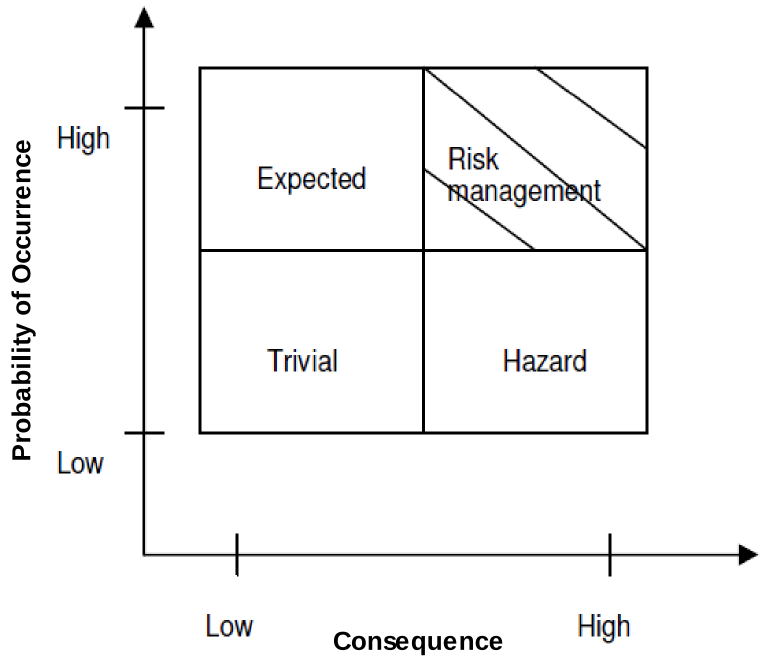


Figure 2.1-1 Events vs consequence of risks

The two main dimensions for measurement of risks are Likelihood and Consequences. These two identify the risk level. Other attributes are related to source and events. Patterns of the frequency of a risk and severity of its consequence are indicative of the need and nature of the process of its management by the project participants. An event occurring rarely and having a low impact on the project is trivial and in the least priority to be addressed to. Therefore, the intention is to identify and analyze frequently occurring effecting having an adverse effect on the project. Thus "**Risk management** is defined as the identification, evaluation, and prioritization of risks (defined in ISO

31000 as *the effect of uncertainty on objectives)* followed by coordinated and economical application of resources to minimize, monitor, and control the probability or impact of unfortunate events or to maximize the realization of opportunities" (Hubbard 2009).

2.2 The significance of Risk Management

A project is prone to critical events and hence risks in various domains. Risk can directly influence the project life cycle in term of cost, quality and time limiting the scope of the project. Risk management's objective is to assure uncertainty does not deflect the endeavor from the business goals. With the progression in time unexpected events in the project process urge need for changes in the required domain which in turn have an adverse impact on the overall cost and efficiency of the project. A project starts with a vision of need of zero change and is highly efficient in completing its targets with the estimated costs. Towards the project closure, adverse changes in the project in order to cope up with unwanted events can conclude with a highly inefficient project.

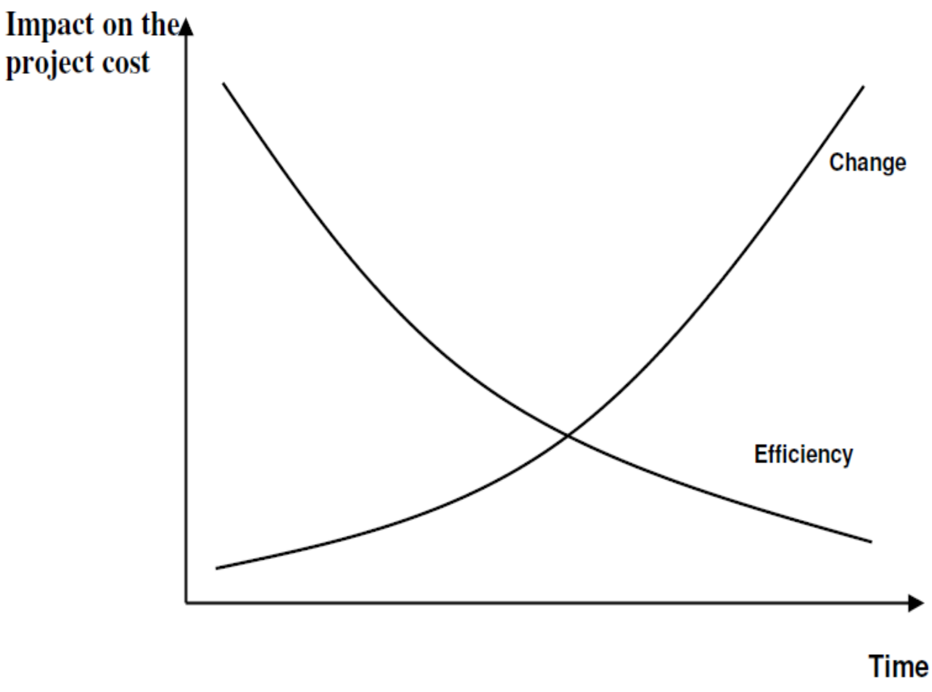


Figure 2.2-1 Relation between effectiveness and cost of change over time.

Thus, risk management involves following stages of dealing with a risk in order to reach a decision for the efficient progression of the project.

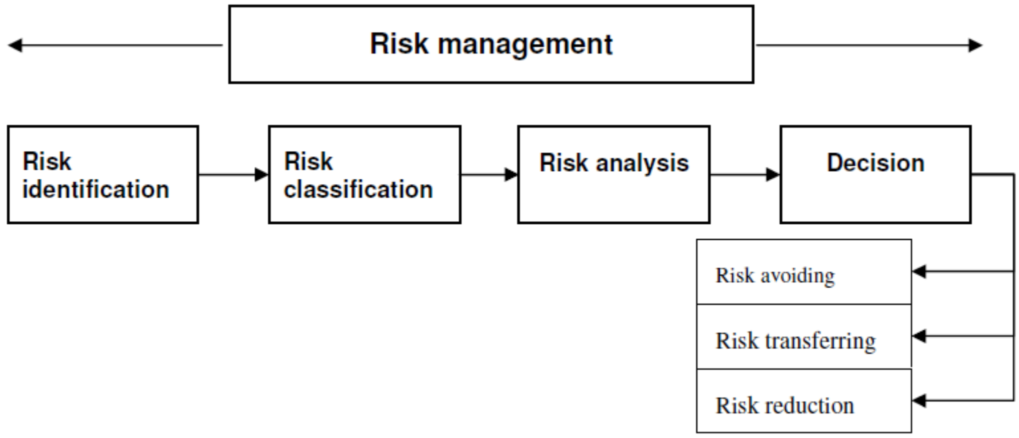


Figure 2.2-2 Risk Management

2.3 Risks during the design process of a project

The construction project is composed of various stages. From the conceptual design phase to the construction phase the project is exposed to various risks tangible and intangible ranging from economic to structural risks. (Goral 2007)

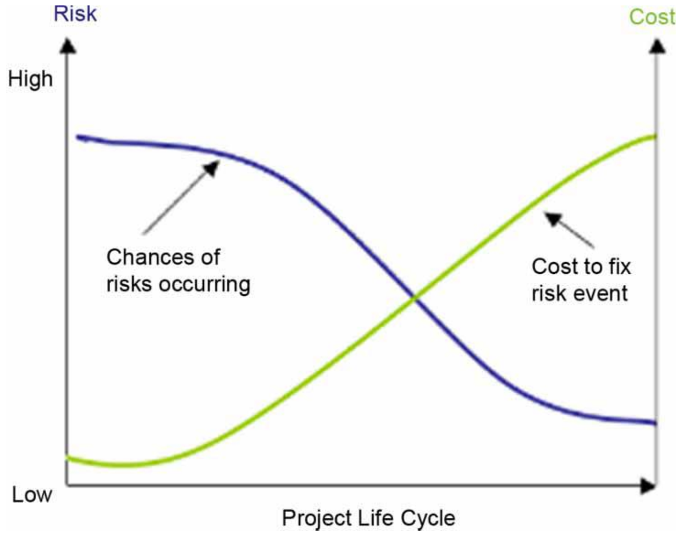


Figure 2.3-1 Risk and Cost for the Project lifecycle, Source: (Katie 2009)

The probabilities of an undesirable event to occur are extremely in the initial phase of a project due to the level of uncertainties involved in the start of any project. This makes a project extremely vulnerable to any upcoming risks in the near future. Thus, the conceptual design stage holds maximum responsibility and hence potential to secure the project from the risk in the future.

More the uncertainty greater is the possibility of risk and higher the cost to fix the event.

Thus, the early stage of a project provides with the opportunity to minimize the impact of a potential risk, if identified, assessed and addressed to in the very beginning of the project. In order to identify risks in a construction project following classification can be adopted: (Eldash 2015)

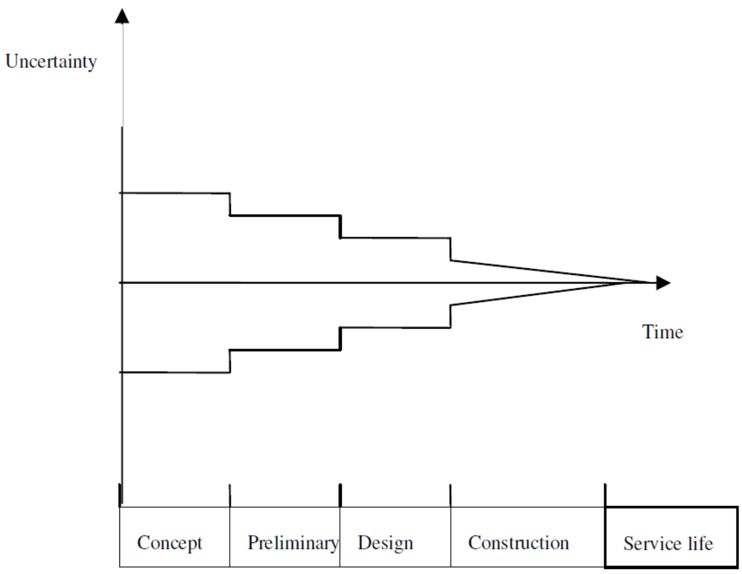


Figure 2.3-2 Level of Uncertainty in a Construction Project, Source: (Smith 2006)

Technical Risks involved in the design and planning of the project

- Design Process
    - Design errors and changes
    - Delay of design and permits
    - Innovation and new technology in design
    - Complicated Design – Insufficient details
    - Inadequate and incomplete design
    - Change in seismic criteria
    - Errors in the completion of structural/geotechnical / foundation
    - Wrong selection of materials
    - Take off data (traffic demand, water consumption demand, etc.)
    - Need for design exceptions

- Construction Risks

    - Inaccurate contract time estimates
    - Construction procedures
    - Construction occupational safety
    - Work permissions
    - Utilities
    - Late surveys, incomplete or wrong
    - Delayed deliveries and disruptions
    - Worker and site safety
    - Experimentation
    - Unsuitable equipment and materials
    - Environmental risks (such as projects close to a river, floodplain, coastal zone, high habitat sensitivity, and so on)
    - Inaccurate assumptions on technical issues in the planning stage
    - Fact sheet requirements (exception to standards

- Environmental Factors

    - Environmental analysis incomplete or wrong
    - Offsite and onsite wetlands
    - Hazardous waste, preliminary site investigation wrong
    - Lack of specialized staff (biology, anthropology archaeology, etc)

Organizational Risks

- Inexperienced staff assigned
- Losing critical staff at crucial points of the project
- Insufficient time to plan
- Unanticipated project manager workload
- Not enough time to plan
- Priorities change on existing program
- Inconsistent cost, time, scope, and quality objectives

Managerial Risks

- Lack of communication planning
- Project purpose definition, needs, objectives, costs, deliverables are poorly defined or understood
- Lack of coordination among different disciplines
- Poor organizational structure and definition of role and responsibilities
- No quality control system
- No Consultant for a specific discipline
- Unclear allocation of roles and responsibilities
- No control over staff priorities
- Too many projects
- Consultant or contractor delays
- Estimating and/or scheduling errors
- Inexperienced workforce / inadequate staff and resource availability

External Risks

- Contractual relations
    - Landowners unwilling to sell
    - Priorities change on existing program
    - Funding changes for fiscal year
    - Stakeholders request late changes
    - New stakeholders
    - Additional needs requested by stakeholders
    - New information required for permits
    - Inconsistent costs, time, scope, and quality objectives
    - Permits and licenses
- Force major factors
    - Political factors change (political interference)
    - Political climate
    - Economic instability

- Market conditions
- Exchange rate fluctuation
- Public safety regulation

- Social factors

  - Local communities pose objections
  - Changing the engineer or other consultants
  - Owner's frequent changes orders
  - Overseas consultants or contractors
  - Suitability of available risks

- Environmental factors

  - Environmental regulations change
  - Water quality issues
  - New information required for permits
  - Environmental impact statement required
  - The historic site, endangered species, or wetlands present
  - Pressure to compress the environmental schedule

  (José Cardoso Teixeira 2011)

2.4 Risk analysis in design & planning phase of a construction project

2.4.1 Risk Identification: It involves the identification of sources and reasons related to possible risks during the project. These findings can be based on previous project experiences, feedbacks from experts from the field, from documentation of database available**.**

2.4.2 Risk Classification: the reasons and sources identified in the previous stage give a basis for classification of risks specific to the field referred to in the project management. It can be based on their severity, frequency, relation with other risks, and impact on other stages of the project etc. At this stage, the specific stage and project participant responsible to deal with the respective risk is also identified.

2.4.3 Risk Analysis: At this stage risks identified and classified are then assessed based on their occurrence, severity, the impact of their consequences on the project in terms of costs, time and efficiency. Various qualitative and quantitative methods can be used at this stage for mapping the risks.

Decision

Risk Analysis directs to the decision making in terms of how a risk should be dealt with. Risk Reduction involves a process of taking measures to propose improvements in the project in order to reduce the severity of the consequences related to the risk. Risk Avoiding is related to taking measures to eliminate the task causing the probability of occurrence of the risk. Transfer of Risk is an activity of transferring the chances of risk to other stages or project participant.

Thus, Risk management deals with regulating the project tasks in cohesion with the decision taken to address the risks as a response to the risk analyses and assessment for better efficiency of the project.

Risk Display

Various techniques are adopted for mapping and representation of the risk identified, classified and analyzed. Representation of the potential risks of a project gives a comparative understanding of the severity of the consequences of all the risks a project is vulnerable to. This helps in immediate action by the project participants in the required

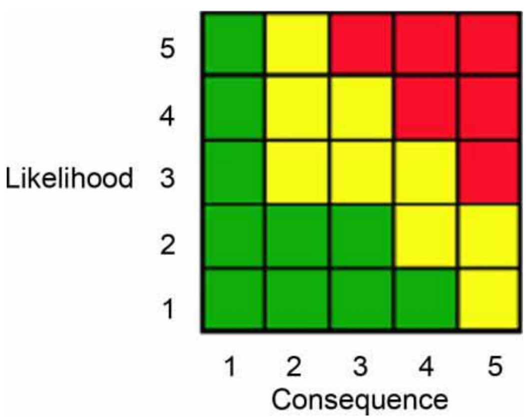


Figure 2.4-1 Risk Fever Chart Source: (Katie 2009)

domain. **Fehler! Verweisquelle konnte nicht gefunden werden. Fehler! Verweisquelle konnte nicht gefunden werden.** Shows a "risk fever chart" or a "risk grid" categorizing the risks into low (green), medium (yellow) and high (red) based on the impact of their consequences. By collecting and plotting data related likelihood and consequences of a risky event its severity can be identified and responded immediately.

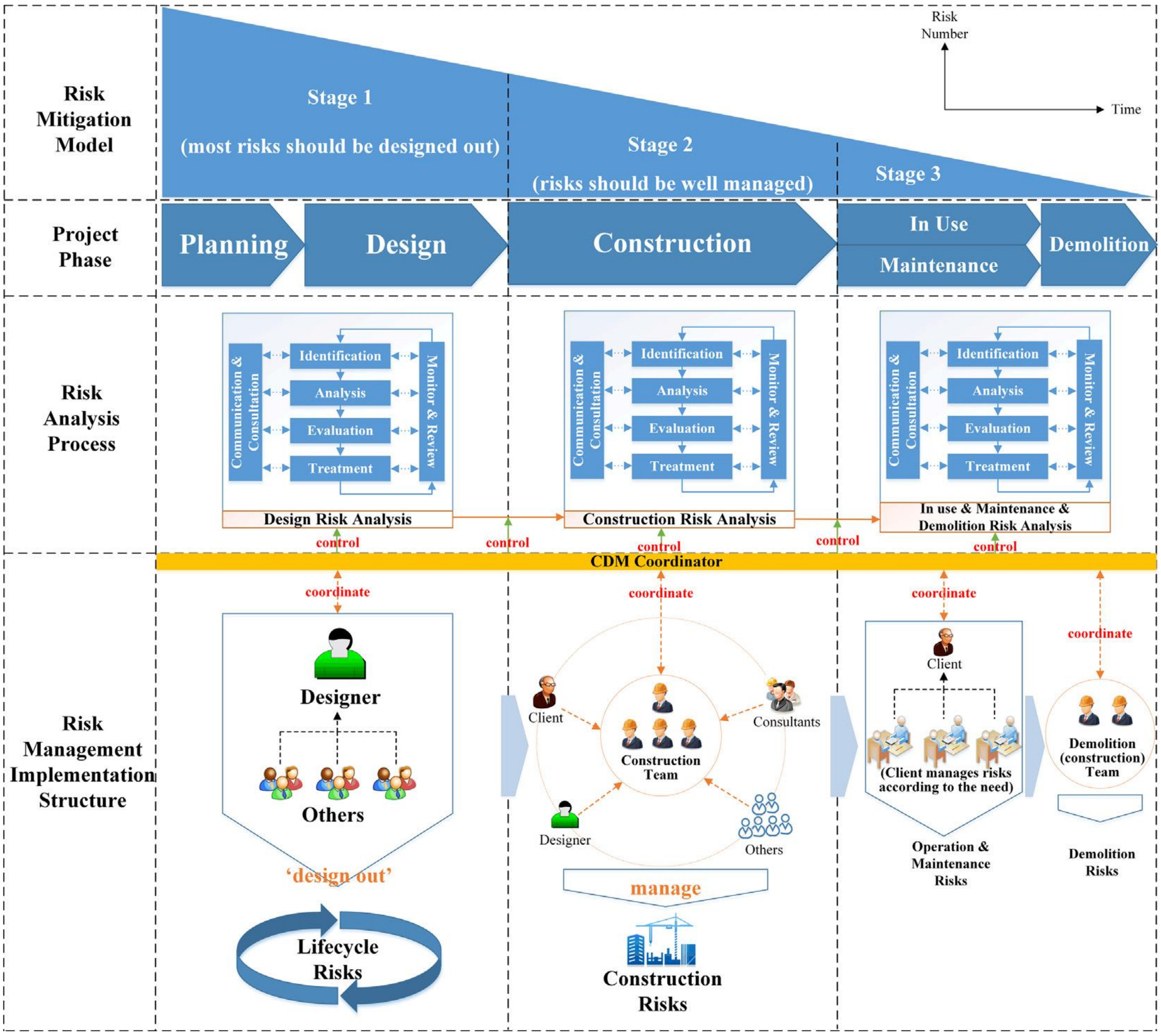


Figure 2.4-2 Risk Management Framework, Source: (Y. Zou, A review of risk management through BIM and BIM-related technologies 2016)

Errors in risk management

Involvement of various disciplines and stakeholders while management of risk is subjected to various errors in the management process itself further increasing the potential risks and its ineffective management. (Araszkiewicz 2015)

- Identification and analyses of risk as an isolated process, as a separate organizational activity in the project lifecycle
- Consequent fragmented risk management measures, conducted specifically within the department without any exchange or interdisciplinary approach with other disciplines.
- No involvement of the risk owner in the risk management process.
- Uncommon language amongst domains of risk analyses and assessment across the various disciplines of the project.
- Ineffective communication between professional and organizational entities involved in managing the sequential factors related to risk.
- Limited comprehension of methods related to risk management e.g. insurance, ignorance.

Risk management maturity level

The following set of practices as indicator of the practice of risk management process helps in assessing the level of maturity of system of risk management practiced during a project in a country. (Mario Florez n.d.) (C. &. Zou 2010)

Initial	• deifned project objectives
Repeatable	• risk management organisation wide
Managed	• regular risk management process reviews
Optimized	• risk management as mature capabilities

Table 1 Risk Management Maturity Level

3. Building Information Modeling (BIM)

3.1 Background

In AEC Industry data and its analyses have always been the key aspects of a construction project. In accordance with technological advancements with time, the modes and tools in practice are transforming drastically to cope up with the increasing specializations and hence disciplines in the industry. In such a scenario BIM has come up as an integrated tool, which works in close collaboration with all the disciplines. Thus, marking its position in the evolution of tools of AEC Industry, from Hand Drafted mode of practices to computed aided advanced systems of working.

Thumb Rule while implementing BIM in a construction project (Matejka 2014):

a) Total costs of the implementation, together with their consequences, should be lower than total benefits, together with their consequences (on the examined time period).
b) Costs during the implementation should be bearable on the operating level.

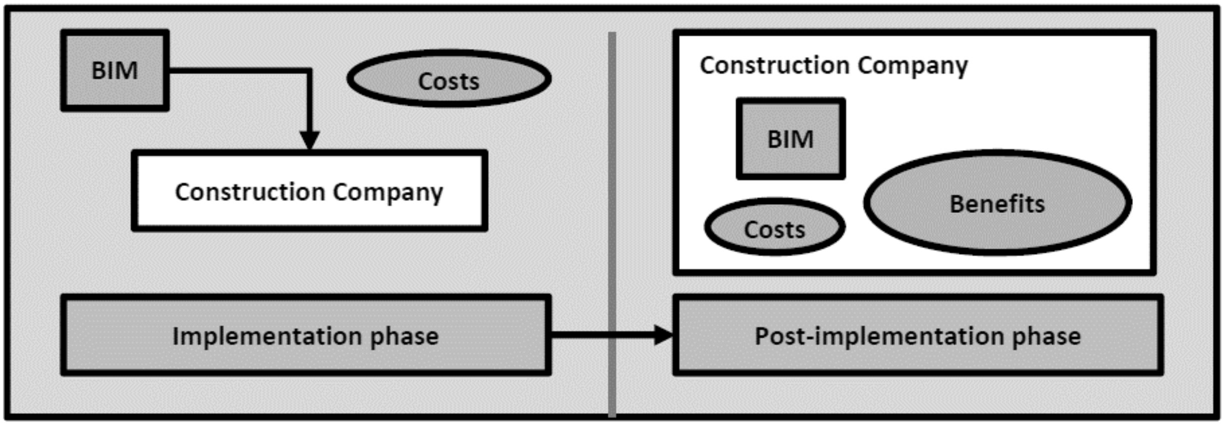


Figure 3.1-1 Implementation of BIM, Source: (Matejka 2014)

3.2 What is BIM?

The foundation of BIM system lies in the 1990's, when object – centric building product modeling was set up in the construction industry. The traditional system of practices in AEC sector followed the Design Bid Build Model, where each phase followed the former one. The architect worked as a designer, while the construction manager worked with the client. The later used to take over the project only after completion of design.

Today BIM, Building Information Modeling, as an advanced entity is referred to as a set of interacting policies, processes and technologies that generate “a methodology to manage the essential building design and project data in digital format throughout the building’s life cycle” (H 2006). Defines BIM as a set of parametric tools and processes for the creation and maintenance of an integrated collaborative database of multi-dimensional information regarding design, construction and operations of a building, with the purpose of improving collaboration between stakeholders, which reduce the time needed for documentation of the project and producing more predictable project outcomes.” (Abdulsane Fazli 2014)

It develops extensive interdependencies amongst the various fields – architectural design, structure, electrical, mechanical by pairing the project organizations technologically. The components in the model know are in constant interaction with each other, thus providing an opportunity to deal with the changes in any of the disciplines, at any point of the project life cycle.

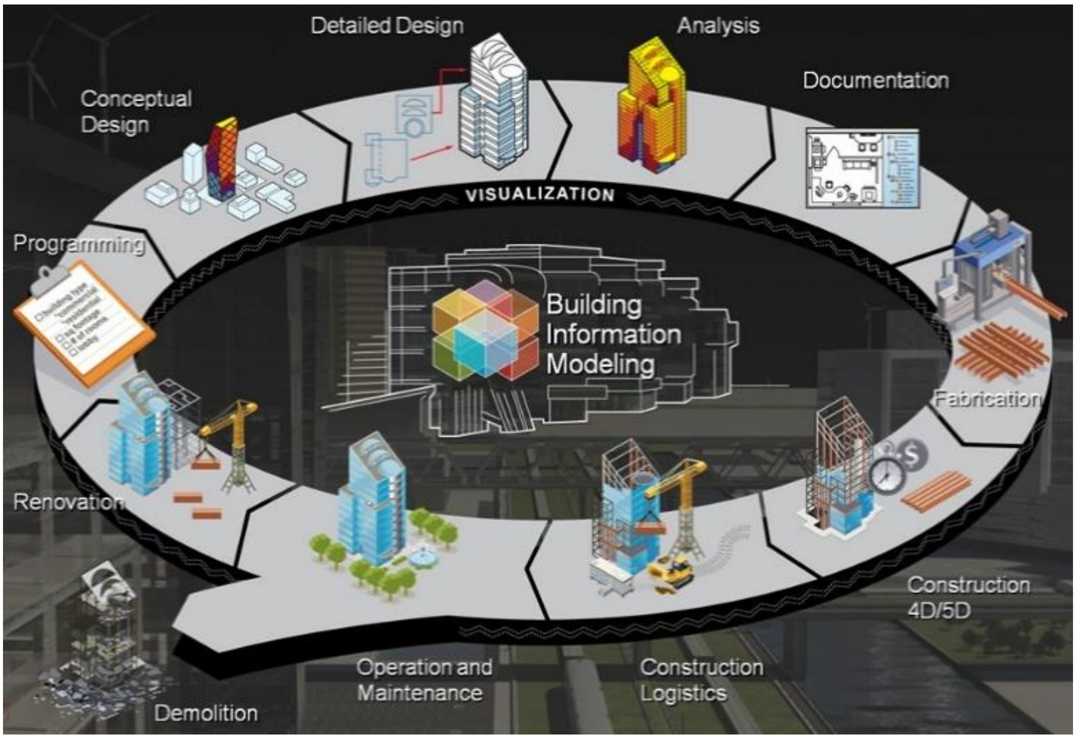


Figure 3.2-1 The BIM model, Source: (Goubau n.d.)

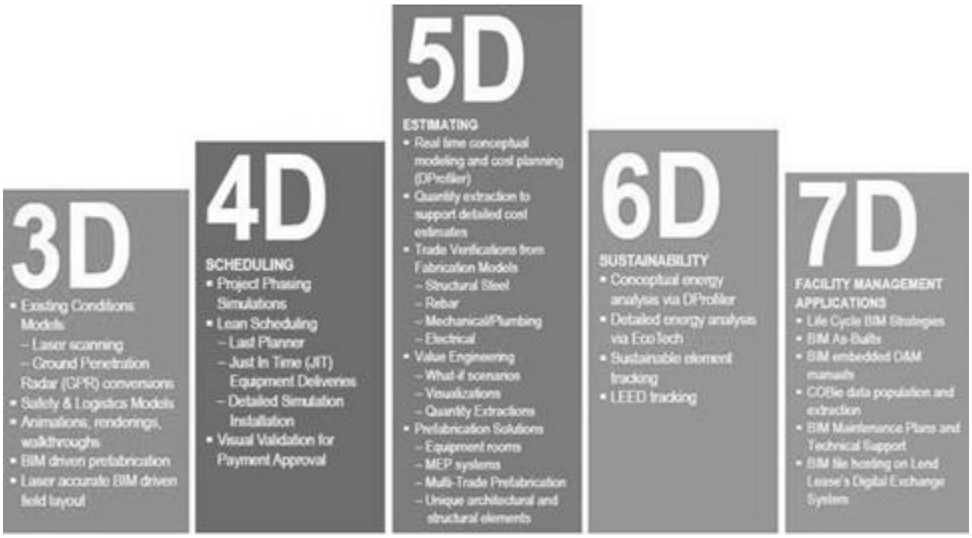


Figure 3.2-2 the 5D Model and Various Dimensions, Source: (Goubau n.d.)

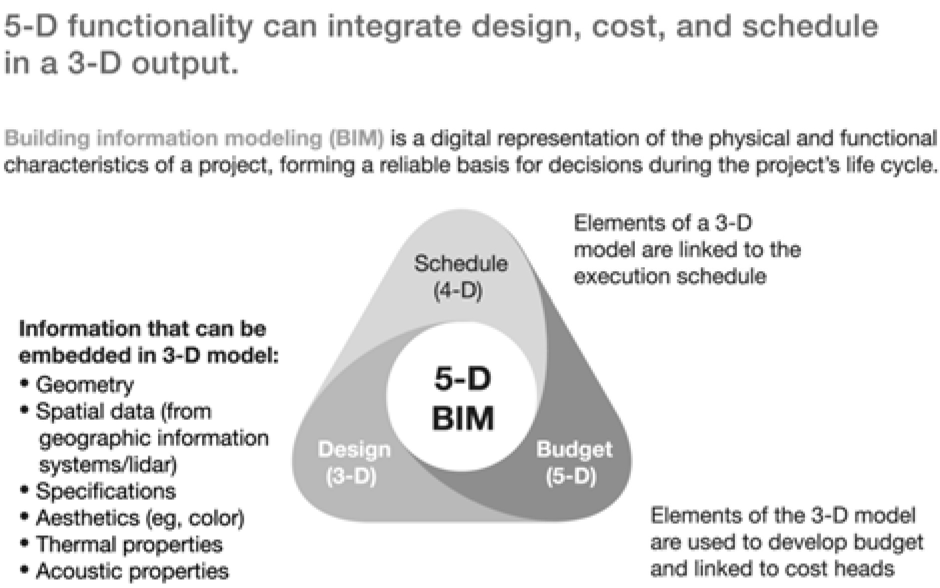


Figure 3.2-3 Dimensions of BIM, Source: (Goubau n.d.)

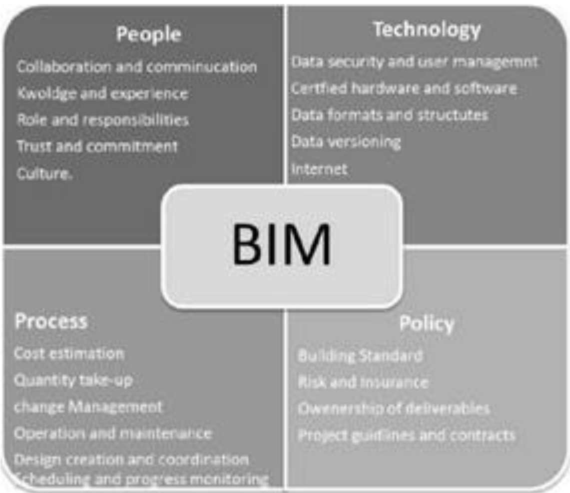


Figure 3.2-4 Integrated BIM Process, Source: (D.B. Hammad 2012)

3.3 Application of BIM in design and planning phase of a construction project

3.3.1 BIM Tools

Discussed below are the set of BIM tools based on the task in various stages of the project lifecycle of the construction project. (Matejka 2014)

- **Clash Control**
  - Integrating BIMs of various disciplines
  - Checking geometrical designs
  - Detecting and correcting errors and overlaps points of models of various disciplines during integration process

- **Analyses**
  - Energy analyses
  - Environment analyses

- **Time Estimation (4D)**
  - Linking of objects to time plan
  - Diagrammatic visualization of the schedule of the project
  - Detection of Planning errors at an early stage
  - Logical aspects optimization

- **Cost Estimation (5D)**
  - Establishing connection of objects, price lists of materials
  - Valuable and easy engineering analyses
  - Precise cost estimation at any point of the design phase
  - Understanding of financial implications of design decision

Following are the tool set of BIM applications in the various stages used by different project participant in each of the project stages:

- **Plan**
    - Existing condition modeling
    - Cost estimation
    - Phase planning
    - Site analyses

- **Design**
    - Design reviews
    - Code validation
    - LEED evaluation
    - Mechanical analysis
    - Lighting analyses
    - Structural
    - Energy analysis
    - Design authoring

- **Construction**
    - 3d control and planning
    - Digital fabrication
    - Construction system design
    - Site utilization planning

- **Operation**
    - Disaster planning
    - Space management/tracking
    - Assets management
    - Building system analysis
    - Maintenance schedule

The following table demonstrates BIM Authoring Tool set with the software and its respective manufacturer and functions in the BIM Use.

S.No.	Product Name	Manufacturer	Primary Function
1.	Revit Architecture 3D	Autodesk	Architectural Modeling and Parametric Design
2.	Revit Structure	Autodesk	3D Structural Modeling and Parametric Design
3.	Revit MEP	Autodesk	3D Detailed MEP Modeling
4.	Cad pipe Commercial Pipe	AEC Design	3D Pipe Modeling
5.	Bentley BIM Suite (MicroStation, Bentley Archietcture, Structural, Mechanical, Electrical, Generative Design)	Bentley Systems	3D Architectural, Structural, Mechanical, Electrical and Generative Components Modeling
6.	ArchiCAD	Graphic Soft	3D Architectural Modeling
7.	MEP Modeler	Graphic Soft	3D MEP Modeling
8.	RISA	RISA Technologies	Full suite of 2D and 3D Structural Design Applications
9.	Tekla Structures	Tekla	3D Detailed Structural Modeling
10.	VicoOffice	Vico	Software 5D Modeling which can be used to generate cost and schedule data
11.	PowerCivil	Bentley	Systems Site Development
12.	HydraCAD	Hydrates	3D Fire Sprinkler Design and Modeling

Figure 3.3-1 BIM Authoring Tools

3.3.2 The Application Process

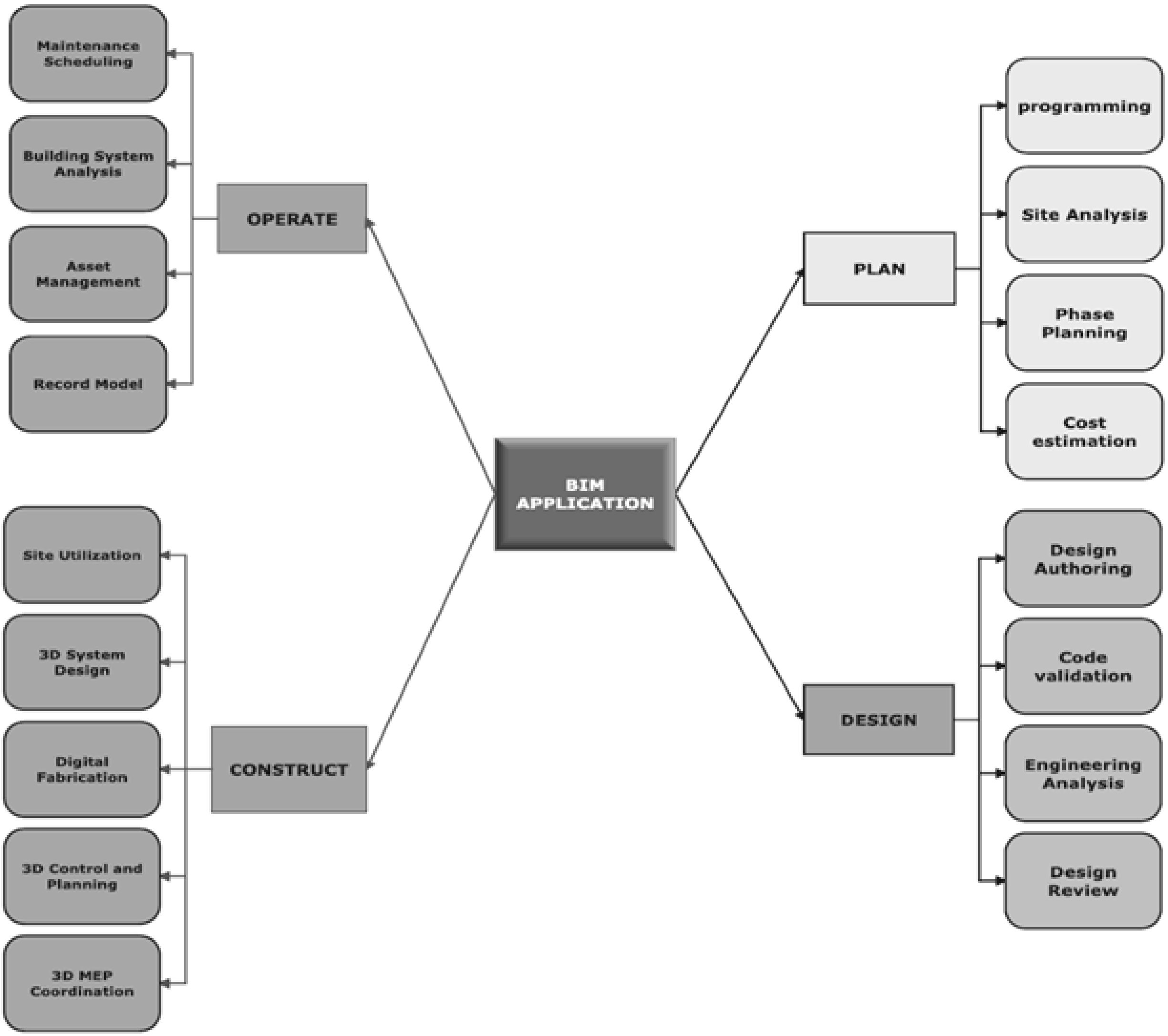


Figure 3.3-2 Application of BIM in construction lifecycle, Source: (D.B. Hammad 2012)

3.3.3 **Benefits of BIM**

Implementation of BIM model in a construction projects collectively benefits all the stakeholders – the client, the project manager, designer, contractor and labour, in various ways elaborated in the later section. For the project as a holistic entity its key benefits are the reduction of industry fragmentation, ability to control the project throughout its lifecycle, flexibility to incorporate changes and update outputs accordingly in order to avoid errors and regulation of the project team providing a well-defined mechanism to identify changes in roles and relationships in the different fields of the project. (D.B. Hammad 2012)

Figure 3.3-3 Benefits of BIM, Source: (Goubau n.d.)

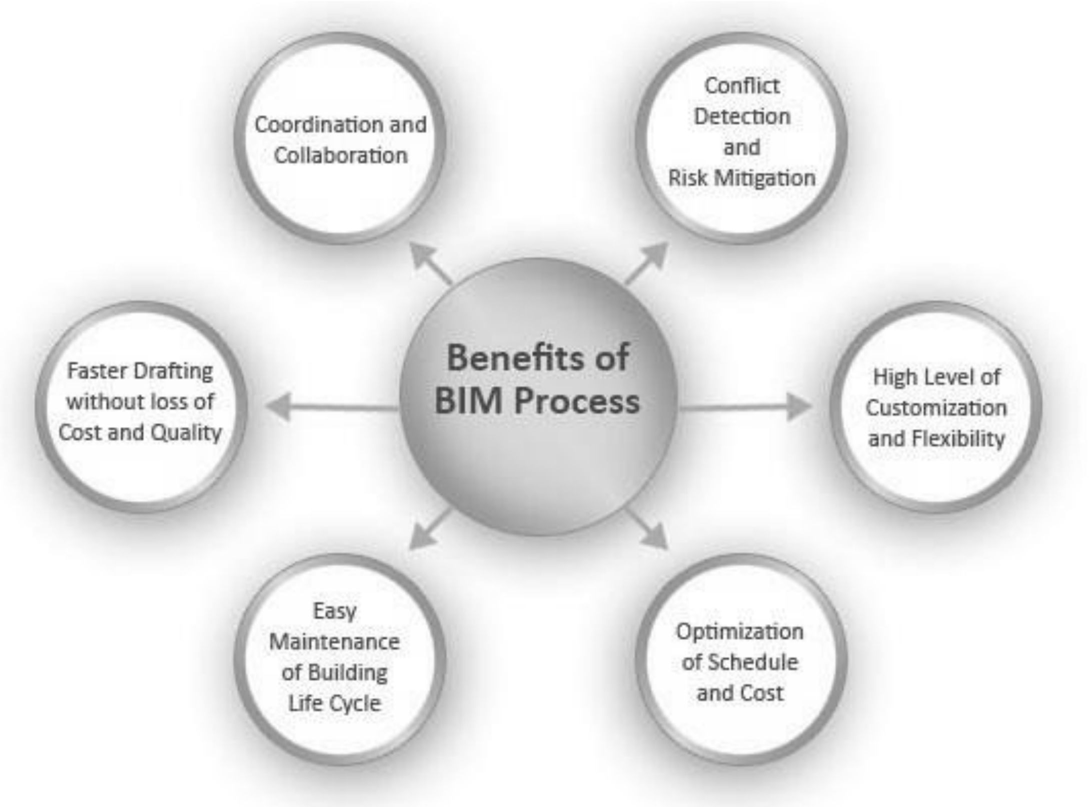


Figure 3.3-4 Benefits of BIM, Source: (Goubau n.d.)

- Cost Estimation & Optimization
- Higher Quality of the delivered product
- Increased Efficiency of the implementation process
- The faster process, reducing project delivery time
- The safer process, preserving the human resource
- Low Wastage, preserving energy and material resources
- Better Management amongst the related industries
- Fewer Errors in process implementation
- Higher Productivity of the input resources
- Threats Mitigation related
- Competitive Advantage amongst the industries involved
- Significantly facilitate the collaboration, communication, and cooperation for both within and between organizations
- Risk identification and assessment
- Risk Management measures and implementation tools (D.B. Hammad 2012)

3.3.4 Maturity Level of BIM Practice

Various authors gave theories related to the intensity of utilization (Succar 2009)

Pre BIM Status	•Risk avoidance and shedding
Object Based Stage	•Single - disciplinary models
Model Based Stage	•Active collaboration
Network Based Stage	•Collaboration across lifecycle projects
IPD	•Sustainable version of BIM technologies

Figure 3.3-5 BIM Use Maturity Level

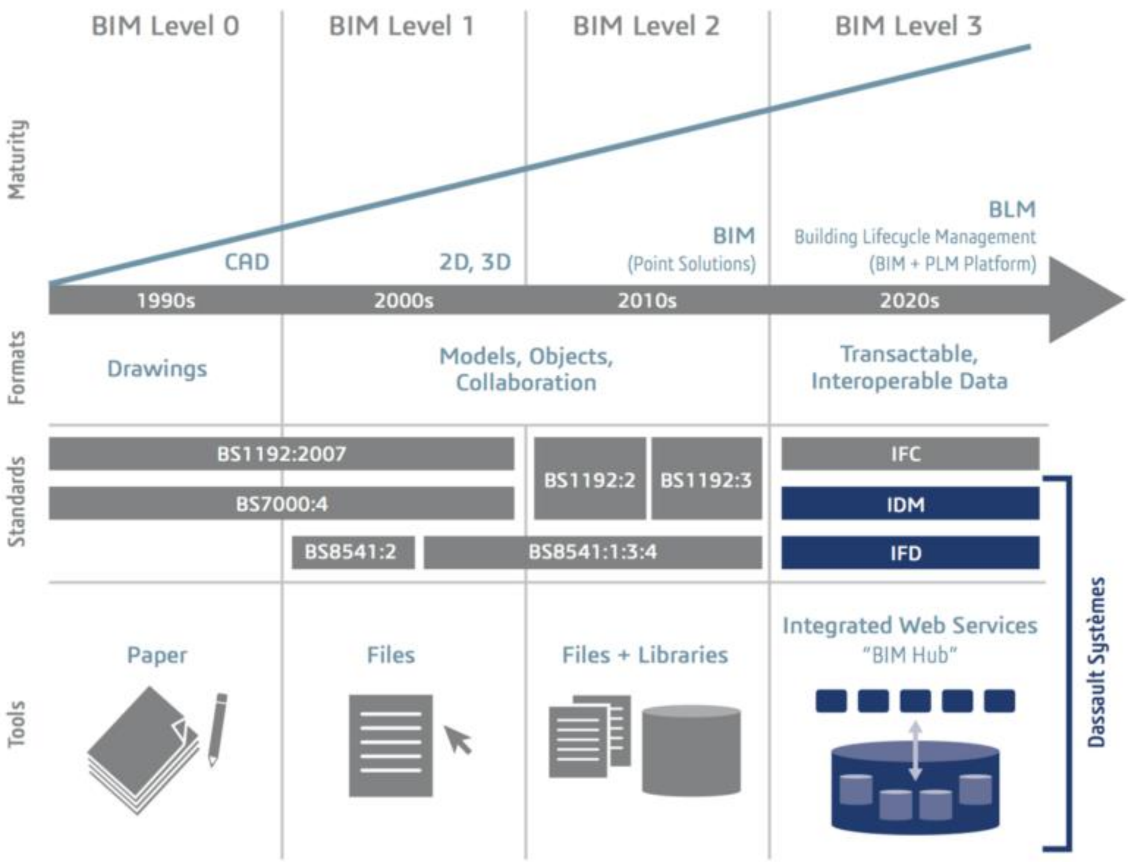


Figure 3.3-6 The BIM maturity model, Source: (Richards n.d.)

a) Level 0 BIM is indicative of minimum digitalized and completely isolated data of the construction project

b) Level 1 BIM involves utilization of 3D CAD for concept work and 2D CAD for drafting the proposed design of the project for approval and other required information

c) Level 2 BIM is subjected to collaborative working by various disciplines with 3D CAD modeling within their respective disciplines. Information is not shared amongst the disciplines in case of this level.

d) Level 3 BIM is indicative of the extensive collaborative working of the different disciplines related to project. In these the information is shared and centralized for all, thus making the model open to all parties involved in the project.

3.3.5 **Limitations**

The main barriers found in the process of implementation of BIM is its initial cost of acquiring the software, training personnel, technical support and the cultural change of modifying the standard manual process that has been used traditionally.
Another significant limitation is the process of data input, which is through human resources manually by different individuals at different points of time for the varying disciplines. Thus, the manual feeding increases the probability of multiplication of initial minute errors with the progression of the project.

4. BIM in risk management

The increasing technological advancements, specialized knowledge base and their respective implementation in the AEC (Architecture Engineering & Construction) sector all across the globe is raising concerns for the management of increased risks in the project life cycle. Traditional approaches towards risk management are based on experience, intuition and multi-disciplinary knowledge. These approaches tend to adapt qualitative measures and lack scientific attempts to predict, analyze and manage risks. Also, the expertise of each domain is aware of risks and its management related to its specific domain of interest, therefore, is ignorant of the probable overlaps and gaps amongst risks related to different stages and fields of the project life cycle.

BIM, on the other hands, with its 4D data-centric quantitative approach provides scope to analyze the project at every stage in every domain with precision and in an integrated manner. Thus, in the larger domain of project management, integration of BIM and BIM related technologies in risk management processes is capable of providing with opportunities for effective risk management.

The interdisciplinary integrated approach of the BIM model is the key feature of effective risk management in the project life cycle of a construction project. BIM and BIM related tools also allow incorporation of change if any which facilitates the process of updating risk and its management. Thus, two processes demand parallel integration at every stage and every domain of the project life cycle so as to achieve desired results effectively.

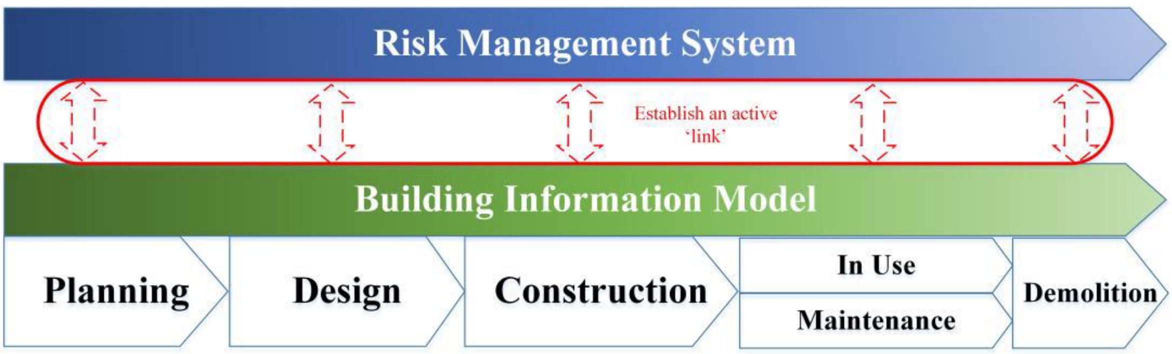


Figure 4-1 Establishment of an 'active' link between BIM and Risk Management System, Source: (Yang, BIM-based Risk Management: Challenges and Oppurtunities 2015)

4.1 BIM Tools in Design and Planning

The key aspect of the BIM and BIM related tools used in risk management is their Interoperability within the project life cycle. These tools enable to identify the potential risk clashes or gaps in the different stages of the project life cycle. (Y. Zou, A review of risk management through BIM and BIM-related technologies 2016)

4.1.1 **Knowledge-Based Systems**

Knowledge-Based systems focus on methods of management of learnings from the ongoing project. Each project generates valuable experience and knowledge which can provide the basis for effective risk management for future projects. But management of the learnings from the experience and their availability for implications in other projects is the key feature of these systems. Following are the methods proposed by professionals across the globe:

a) Total Safety assists professionals to extract information from the knowledge-based database regarding safety so as to identify the high levels of risks in the project lifecycle. It functions within the ICT tool module.
b) ToolSHeD supports the integration of the assessment of safety risks and the design process. It focuses on the structuring of understandings comprehended from industry standards, guidelines, codes and other information sources and implementing these learnings in risk assessing process in complicated stages of the building construction project.
c) BIMKSM (BIM-BASED Knowledge Sharing Management) system: this system enables the sharing of the knowledge gathered during the project lifecycle for implementation in the future projects for effective risk management. The facility of sharing of the gained knowledge is enhanced by developing a framework for dissemination and classification of the data.

4.1.2 **Automatic Rule Checking**

It is an object-centric design analyses system using a computer application. It encodes rules and classifications by analysis such that the models can be checked against the machine-read policies claiming results e.g. “pass” for safe projects, “fail” in case of scope of potential risks, “warning” in case of high-risk levels or unknown in case the model doesn’t match the data stored. The system of automatic rule checking can be developed in three directions:

a) Compliance with building design codes: this deals with minimum construction standards for building and infrastructure projects.
b) Safety checking of the construction project is essential for human safety at the site. For this purpose, the rule checking process simulates the construction process and mitigates risk related to on-site work e.g. fall protection, occupational safety, health hazards
c) Special requirements for checking which refers to the theme-based checking of the project e.g. issues related to circulation, space requirements, site considerations etc.

4.1.3 **Reactive IT Based systems:**

Reactive IT Based systems are essentially implemented for management of risks related to safety in the AEC industry. The goal of the system is to detect health and safety risks in time and take preventive measures before the hazard occurs. This goal is aimed for through collaborative measures with BIM tools and BIM related technologies. Various technologies related to reactive IT-based systems of safety management are discussed as follows:

a) **Database Technology**

Database technology involves stocking of valuable knowledge, collect information and then critically extract the required information based on the project and its stage. For example, multiple cases of bridge failure were identified and the electronic database was generated to analyze risk distribution and risk causing factors, such that the findings are available for reference for risk mitigation measures for future projects. The database and analyses thus collected can be used to guide clients to evaluate competences of the project in the different domain for the future. This can help to enhance the proficiency of the project by enabling remote access, fast data collection and effective communication.

b) **Virtual Reality**

As the name suggests is a mode of simulating the project in a three-dimensional form virtually such that its stages of development and specific fields can be regulated as per required demonstration. This virtual demonstrative technique can help be helpful in making the site workers aware of the factors related to potential risks in the project. Various dangerous scenarios can be demonstrated such that workers can be trained for safety measures related to respective scenarios and safety operations on site can be regulated.

c) **4D CAD**

4D CAD tool integrates the information related to 4d construction scheduling with the 3D model so as to identify the probable risks, regulate risks and modify the construction schedule accordingly. For safety risk management the 4D CAD model is established by collecting design data and construction process of the project and the related activities so as to conduct a risk analysis of the project based on this model. To integrated safety risk management and construction management in case of working at height risk, rule-based algorithms were established and visualized and interpreted in the 4D model. The rule-based algorithms helped to detect potential risks automatically and project the required initiatives to deal with the identified risk.

d) **GIS: Geographic Information Systems**

This system is a collection of information related to the environment of the project at a very macro-scale. This technology can be integrated into the support system model to map, regulate and mitigate risks. GIS system outreaches the domain of various components of 3D modeling untouched by tools of BIM and 4D CAD – editing of 3D components, updating and generation of tools, geospatial analysis, and topographical modeling. Integration of BIM use and GIS can further enhance the assessment and mitigation of risks in various stages of the construction project.

Example of the utilization of the integrated model is identification and optimization of the location of tower cranes on site for effective demand and supply of the materials wherever required.

4.1.4 **Proactive IT Based Safety Systems**

These systems address the constantly changing dynamics of the project at every stage unlike the above discussed tools of the reactive IT-based systems, as discussed earlier. As the later with the project in its static change and is insensitive to the sudden alteration faced by a project at any stage. Thus, the proactive IT-based systems play a significant role in responding to the immediate changes by updating the data and its respective measures related to risks.

It tracks the hazard areas, in case of unplanned changes, collects data from the site and responds immediately by giving warning
This system creates a virtual environment, in which positions of static and mobile objects can be tracked; the respective data from the actual world in actual time is then collected and analyzed by rule-based algorithms such that information related to potential hazards is floated in real time so that effective measures can be taken immediately.
Different models have adopted to accomplish proactive IT-based systems. Some were based on theoretical approach while others completed driven by technology. The theory-based measures adapted human-centric assistance model to avoid obstacles in a risk-prone area. It used 3D workspace model, rule-based algorithms, sparse point cloud approach etc. for the proper functioning of the model. The technology-centric approach used modes like radio frequency wave spectrum technology, remote sensing, actuating technology, global positioning systems, and ultra-wideband as proactive systems. The radio frequency wave spectrum technology would warn workers about the existence of blind spots for the operators of the machine. The significant aspect of the sensors warning about the potential risks is its mobility with the worker on site. The important instruments in this regard are helmets, hats, shoes – the personal protective equipment (PPE).

4.2 Application of BIM in risk management

In order to manage risks by exploiting BIM uses, a framework needs to be established for effective implementation of the process. This framework identifies the attributes related to risk and BIM uses in a construction project lifecycle individually as two separate entities. Then appropriate BIM uses respective to potential risks are identified. The correlation thus established provides with guidelines to manage risks using these information models in various stages of a construction project. Discussed below are the steps adopted as part of the framework for the application of BIM Use in Risk management process in a project - Framework for mapping BIM Use and Risk (Veerasak n.d.)

Detail Setting

The first step of the framework demands identification of attributes related to potential risks and its respective BIM use for the project to set up a detailed database for the mitigation initiatives for dealing with the risk. Cataloging system is used for presentation of the attributes with tags as – risk factors, the frequency of the risk event, vulnerable elements of the projects, ownership of risk etc. The catalog is subjected to modification based on the user and the project type. The following tables demonstrate the tentative Risk Catalogue and BIM Uses catalog for any project.

Risk Code	Type	Risk Center	Risk Event	Risk Factor	Simplified Risk Factor
R.1.02.06.01	Internal	Constructio n	Construct-ability	Incomplete design review	Inspection
R.1.02.06.02				Overlooked conflicting items	Drawing insufficiency
R.1.02.06.03				Clashes with engineering system	Drawing insufficiency
R.1.02.06.04				Owners are unsure if contractor's method statement are accurate	Client
R.2.05.01.01	External	Political/ Legal	Site access/ right of way issues	Unidentified right of way issues	Right-of-way
R.2.05.01.02				Lack of knowledge on local regulations	Inspection
R.2.05.01.03				Contractor's rights-of-way due to particular method of construction	Method of construction

Figure 4.2-1 Risk Catalogue, Source: (Veerasak n.d.)

Code	BIM Use	Description	Expected Benefit	Relevant References
BU1	Existing Conditions Modeling	This BIM use is used to develop a model based on the existing conditions of a site, facility, or specific area within a facility. There are various ways of developing this model such as laser scanning and conventional surveying techniques.	Efficient and accurate existing conditions documentation Enhanced visualization of existing conditions Future modeling benefits for retrofitting	CICRP (2011) Jung et al. (2014) Volk et al. (2014) Lee et al. (2015b)
BU5	Site Analysis	A BIM use wherein GIS tools are utilized along with the BIM software. This is usually performed to determine the optimal site location for a project. Site data collection is done prior to selection of site.	Efficient evaluation of an existing or potential site in relation to the development program Increase energy efficiency Improvement on hazard related and environmental issues Cost-savings on utility demand and demolition	CICRP (2011) Kumar & Shaikh (2013) Zimmerman (2000)

Figure 4.2-2 BIM Use Catalogue, Source: (Veerasak n.d.)

Table 3. BIM use catalogue (information, information source, tool, model, and outcomes)

Code	BIM Use	Requirements				Out-comes
		Information	Info Source	Tool	Model	
BU1	Existing Conditions Modeling	Actual existing conditions gathered through (1) contact or (2) non-contact technique Photos of the site Floor plans As-built drawings/model	Owner	BIM modeling software Laser scanning point cloud manipulation software 3D Laser scan Surveying equipment	N/A	Laser scan model Existing conditions model
BU5	Site Analysis	Site information (Slope, road proximity, land use/cover, land value, geological information, utility distribution, planning and zoning ordinance, etc.)	Owner, Engineer	Design authoring software GIS software		Site analysis model

Figure 4.2-3 BIM Use Catalogue, Source: (Veerasak n.d.)

Risk Investigation

After generating the two catalogs as individual entities, it is important to comprehend the relation between the two. The risk and BIM Use catalogs are reviewed critically to identify the common relations. Few filters can be used to make the relation establishing accurate. Thus, BIM Use suitable for a specific risk is identified.

Analyses of BIM

Based on learning from the third step a third catalog is generated, which is an integrated risk and BIM use catalog indicative of BIM Use suggested in case of a particular risk. The relation established is essentially based on the attributes identifies in the first step – risk factors and the BIM use purposes. For this purpose, BIM Use classified as project life cycle and BIM uses purpose classification. The following table shows the establishment of an integrated table thus arrived at.

Risk Event	Risk Center	Risk Factor	Simplified Risk Factor	Primary Purpose	Purpose
Constructability	Constructability	Incomplete design review	Inspection	Gather	Monitor
		Overlooked conflicting items	Drawing insufficiency	Analyze	Coordinate
		Clashes with engineering system	Drawing insufficiency	Analyze	Coordinate
		Owners are unsure if contractor's method statement are accurate	Client	Communicate Communicate	Document Visualize

Figure 4.2-4 Risk-BIM Use Catalogue, Source: (Veerasak n.d.)

Filtering BIM Use

As discussed earlier certain filter can be used while cataloging the risk-BIM use catalog. Applying filter to identify appropriate BIM use for effective risk management is very important to avoid errors in the risk mitigation process. For factors are used for the filtration process.

a) BIM Use purpose: It chooses the modeling use based on the factors related to risk.
b) Project lifecycle: It selects the appropriate BIM use to be applied at two significant stages of the risk management process: before and during the incident of hazard.
c) Elements: It identifies the common elements of the BIM use and the potential.
d) Discipline: It looks into the domain and stage of the potential risks to be dealt with.

The above-discussed filters need to be applied in order of discussion so as to minimize the number of BIM Uses associated with the specific potential risk leading to the set of ideal BIM uses. After the filtration process, ideal BIM use is recommended as per the risk identifies. The results, after completion of all above discussed steps, also declare the domain responsible for the application of the identified BIM use, thus allocating the risk.

Risk BIM Use Matrix

This matrix is generated as the final output of the framework. In this matrix, uses of BIM are classified based on the stage of occurrence of an event in the project life cycle process as follows:

a) The preconstruction phase (PC)
b) The construction phase (C)
c) The preconstruction and construction phases (PC+C)
d) The construction and post-construction phases (C+OM)
e) The post-construction phase (OM)

For example, in Table 5 the risk related to constructability is mapped to be associated with 12 BIM uses after filtration. To state a few, BU1 (Existing Conditions Modelling), BU3 (Visualization), and BU4 (Database Information Management) can be executed to cope up with constructability risk throughout the project life cycle.

Table 5. Mapping possible BIM uses for managing the constructability risk

RISK \ BIM USE	BU1	BU2	BU3	BU4	BU5	BU6	BU7	BU8	BU9	BU10	BU11	BU12	BU13	BU14	BU15	BU16	BU17	BU18	BU19	BU20	BU21	BU22	BU23	BU24	BU25	BU26	BU27	BU28	BU29	BU30
	ALL				PC											PC+C			C						C+OM	OM				
Delay in design	•		•			•											•	•												
Unable to get approvals	•		•	•											•		•	•												
Difficulty in choosing proposals	•		•												•		•	•												
Changes in quantity/scope of work	•	•	•												•		•	•			•			•						
Design changes	•		•		•	•								•	•		•	•			•			•						
Exceptionally inclement weather		•								•	•	•	•																	
Desiciencies in specifications and drawings			•			•								•				•												
Coordination with suppliers and subcontractors	•		•	•		•											•	•		•	•	•		•						
Bureaucratic problems				•																										
Constructability	•		•	•			•								•	•	•	•		•	•		•	•						
Lack of value management/engineering	•	•	•												•		•	•			•	•	•	•						
Unforeseen site conditions			•				•								•	•	•	•				•		•						
Site access/right of way			•				•	•									•	•				•								
Inadequate quality of work and need for correction						•	•	•	•														•	•						
Difficulties/delay in availability of materials, equipment and labor						•											•			•										
Safety/Accidents	•		•		•		•							•	•		•	•			•	•	•	•						
Inconsistent design and construction work	•		•	•											•		•	•		•			•	•						
Difficulty in inspection for progress payments		•																•												
Inconsistent warranty information and as-built drawing				•													•			•			•	•	•		•	•	•	•
Difficulty in property management and maintenance	•		•	•											•		•	•	•		•	•		•	•	•	•	•		

Notes:

ALL: Throughout project lifecycle PC: preconstruction phase C: construction phase OM: post construction

Figure 4.2-5 Mapping BIM Use for Constructability Risk, Source: (Veerasak n.d.)

Guideline for BIM Use Implementation

The above discussed steps showcase a comprehensive integrated approach towards risk management in close collaboration with BIM uses, but fail to demonstrate how to implement the identified use in the complex project life cycle. The following table demonstrates implementation of BIM uses in the preconstruction and construction phase of the project, through the above discussed example of managing constructability risk. In every stage three risk related category needs to deal with while implementing the BIM use, they are, Risk Identification, Risk Response and Risk Monitor.

Table 6. Guideline on implementing BIM uses for the constructability risk

Constructability Risk (pre-construction phase and construction phase)	Risk Identification	Risk Response	Risk Monitor
Existing Conditions Modeling			Along with visualization, this BIM use can automatically gather actual locations and geometry which would help monitor clashes that were identified before construction.
Visualization	The parametric modeling capability of BIM can show actual representations, which can determine clashes during modeling process.	After clash detection, project members can visualize the actual clashes happening in the digital models which would subsequently occur in construction if not responded.	
Database Information Management		Clash detection processes can document and inform project participants of their engineering systems having problems.	
Design Reviews	The design review would help stakeholders identify design errors, which would cause problems in the future.		
Options Analysis		After design review and 3D coordination, various options on how to respond on the clashes can be chosen to provide optimal solution to the problem.	
3D Coordination	This BIM use can identify overlooked conflicting systems prior to construction of the facility.	Clashes with engineering systems can be assigned to respective stakeholders in charge of the modeling of the involved element.	Repetitive conduction of clash detection would help the project team continuously monitor the facility elements upon addition of new elements.

Figure 4.2-6 Guideline for Implementing BIM Use, Source: (Veerasak n.d.)

4.3 The Benefits of BIM in Risk Management

BIM-based Risk Management Functionality	Benefits for risk management
3D Visualisation	Facilitating early risk identification and risk communication
Clash detection	Automation of detecting physical conflicts in model
4D construction scheduling/ planning	Improving construction management level by facilitating early risk communication and risk identification
5D cost estimation or cash flow modeling	Planning, controlling and managing budget and cost reasonably
Construction progress tracking	Quality, safety, time and budget management level can be improved
Safety management	Personnel safety hazards reduced
Space management	The consideration of space distribution and management in design can be improved
Quality control	Construction quality is improved
Structural analysis	Structural safety is improved
Operation & maintenance (O&M), facilities management (FM)	Management level is improved and risks are reduced
Urban planning and design	Land-use planning, design and management can be facilitated by integrating planning and design of urban space and AEC projects

Figure 4.3-1 Application of BIM-based Risk Management in the project planning, Source (M M Mering 2017)

5. Comparison between Traditional Method and BIM Method

This chapter discusses and compares the traditional and BIM methods involved in Project Risks Events. It draws comparisons using examples of Technical Risks Events, Managerial Risks Events, and External Risks Events. The first part of this chapter contains examples which show how using BIM in the design and planning phase of the project may reduce the probability of risk events, and how it can also reduce the risk identification, analysis and response time. The second part of the discussion explores the comparisons drawn between the traditional and BIM methods within the parameters of cost, time, error chance, communication, and response time.

5.1 The Overall Process

The design and planning phase of a project starts with vague ideas and the conceptual sketches. The sketches are then further developed using computer-aided design (CAD) in 2D as basic drawings. To explain the complete design and planning of the project, many separate drawings need to be made to explain elevations, sections, and plans. Even these drawings are sometimes not enough. During the design process and development, if there are any changes then all the individual drawings must be changed. When making these changes to the individual drawings there is a high risk of error and it is also very time-consuming. Consequently, when making these changes, the traditional method process is very error-prone, resulting in the poor documentation.

This CAD documents consist of graphical entities, such as; circles, lines, arches, hatches, texts, etc. These entities are also individual in that they are not related to one another, for example, a wall is made of two separate parallel lines with a given distance between them representing the wall thickness. This image of the wall does not contain any information about its materials, thickness or other parameters and specifications.

With time, use of BIM in the AEC industry will become increasingly important. In the future, it will be an essential tool for the AEC industry; designers, planners, MEP consultants, structural engineers, Project and Construction management, among many others working with the tool, will enjoy using it once they have gained some experience and witnessed the benefits for sustaining and meeting market requirements.

When the simulation uses BIM instead of CAD software, the process is very different, we cannot use the same controlling and surveying methods with CAD and BIM. CAD, Computer Aided Design, as the name suggests, replaces the pen with a computer mouse. Drawings made with CAD are similar to old-style paper drawings in that they are independent of each other. So, design changes need to be followed up carefully and changes must be made manually on each CAD drawing. Of course, CAD reference files will make CAD more usable and much faster than original paper drawing. Even so, BIM is a huge leap compared to the step from paper to CAD. (Dzambazova 2010)

On the other hand, the BIM model serves as a central database, where all information assembles in one location, cross-linking data among associated objects. BIM allows project teams to make error-free changes at any time; this process is less laborious, automatically checking for errors during the design and documentation process. This more streamlined process offers the opportunity to spend more time on design and on other major architectural problems rather than correcting all the drawings after a change has been made as would be the case with CAD. All documents within the BIM model are interdependent and intelligence sharing. A change anywhere in the BIM model is propagated throughout all relevant views and documents for the project. This allows the design team to deliver better work faster, because it means that their creation of the key project is deliverable, such as visualizations and regulatory approval documents, which require less time and effort. Again, the BIM application has an intelligent understating of the fact that the objects created here are practical objects. For example, if one draws a door on the BIM application, it will generate all the properties that a real door has, including material properties.

Since in the BIM model, all data is stored in a single centralized file, managing data from all disciplines becomes easier than with the traditional 2D CAD file. The BIM model also helps to manage changes from any of the disciplines; if there is a change made somewhere, it will automatically update all related drawings, such as floor plans, sections, elevations, views, BIM even updates their quantities and schedules. This results in fast updates without errors or delay. In this way, BIM helps with the analysis of risk faster and reduces the risk response time, in turn improving risk management.

The BIM model contains more than just architectural data, it even contains other disciplines' data as well. This helps in energy simulations to control energy consumption. BIM is not only a 3D model, it also contains many other pieces of information which are not visible but can be seen in reports and schedules. Different objects and elements have their own quantity report providing some of the most useful data and information that the BIM model offers. This saves the time otherwise spent calculating things separately.

The collaboration of the project with other disciplines and project members using traditional 2D CAD program is very challenging and risky. Alternatively, BIM programs are designed in such a way so as to collaborate many disciplines together on a single platform.

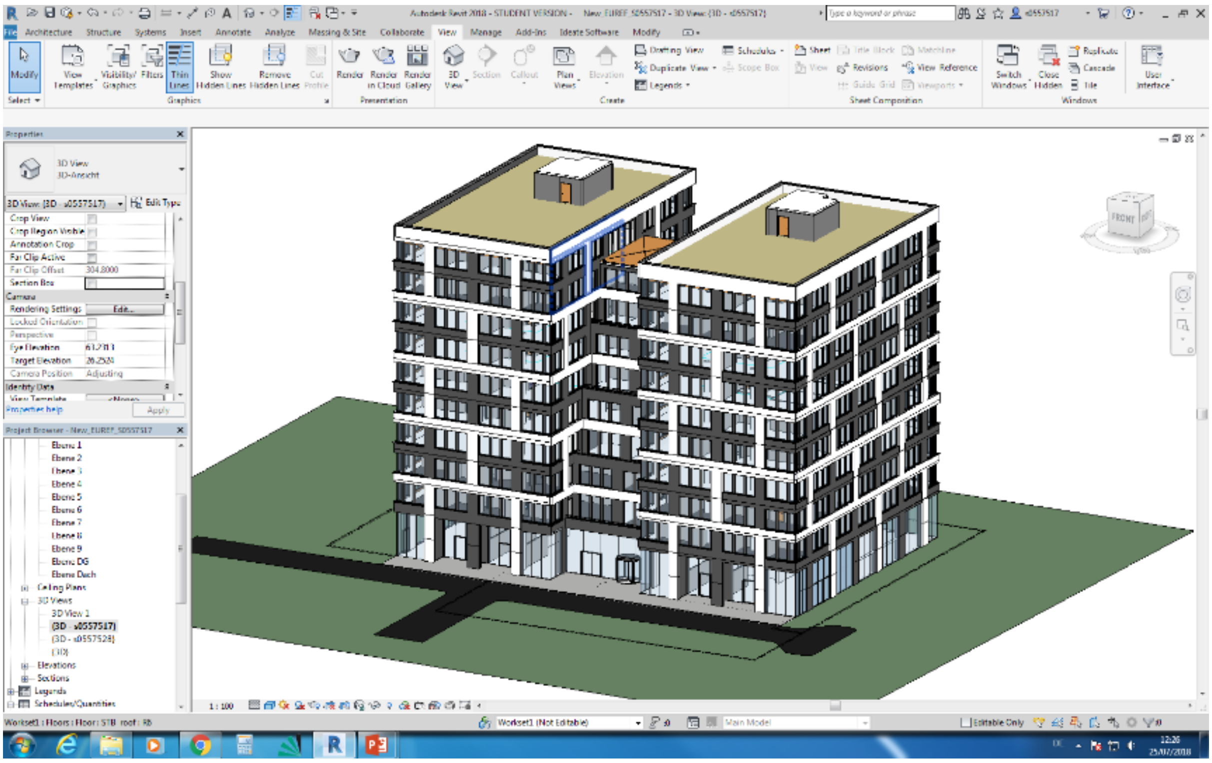
5.2 Particular comparison

5.2.1 Technical Risks Events

A. Design Errors and Changes

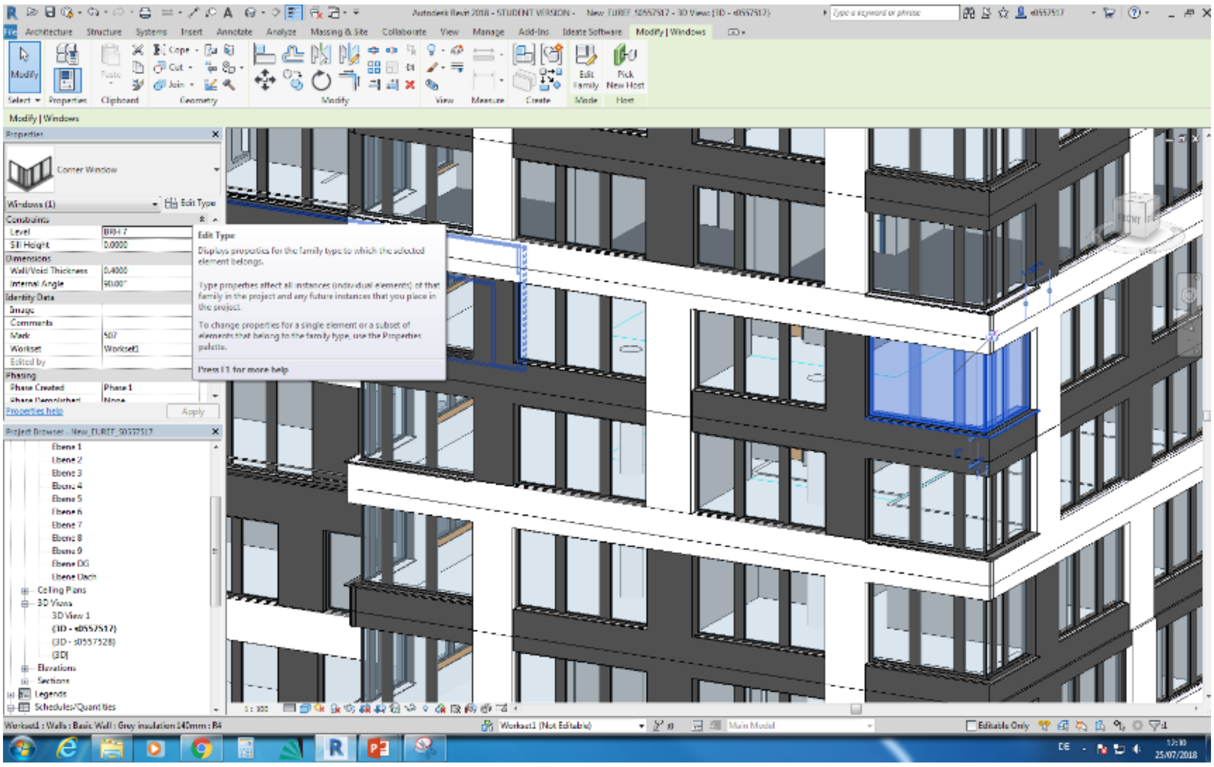
In Technical Risk events, one of the most common risks is the ‘Design Errors and Changes’ event risk. To explain how BIM can minimize this risk event more effectively, the author has produced a BIM-based Revit model; the following section will explain it by use of examples.

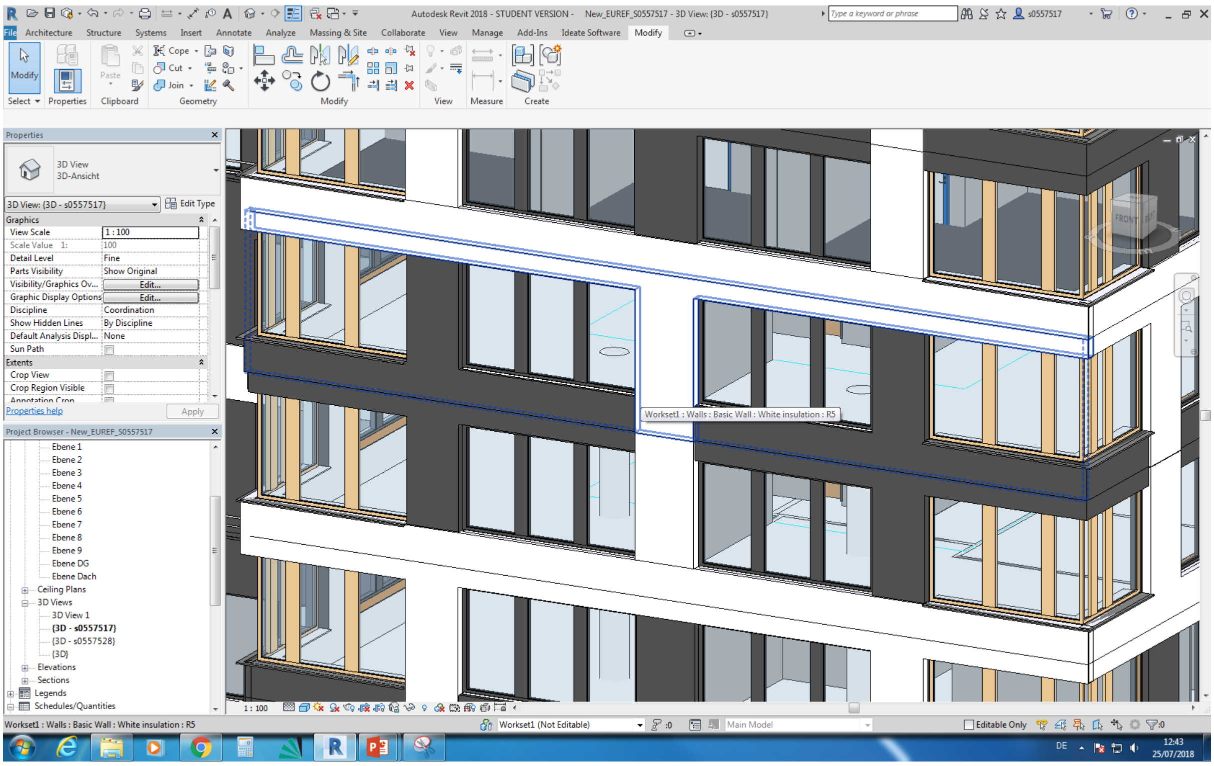
In this illustration we can see a multistory office building in 3D view, this is the Revit model. This paper will look at what happens when a parameter must be changed due to client demand or as per the architect’s new design. In this example, the parameter in question is the material of all the corner windows.

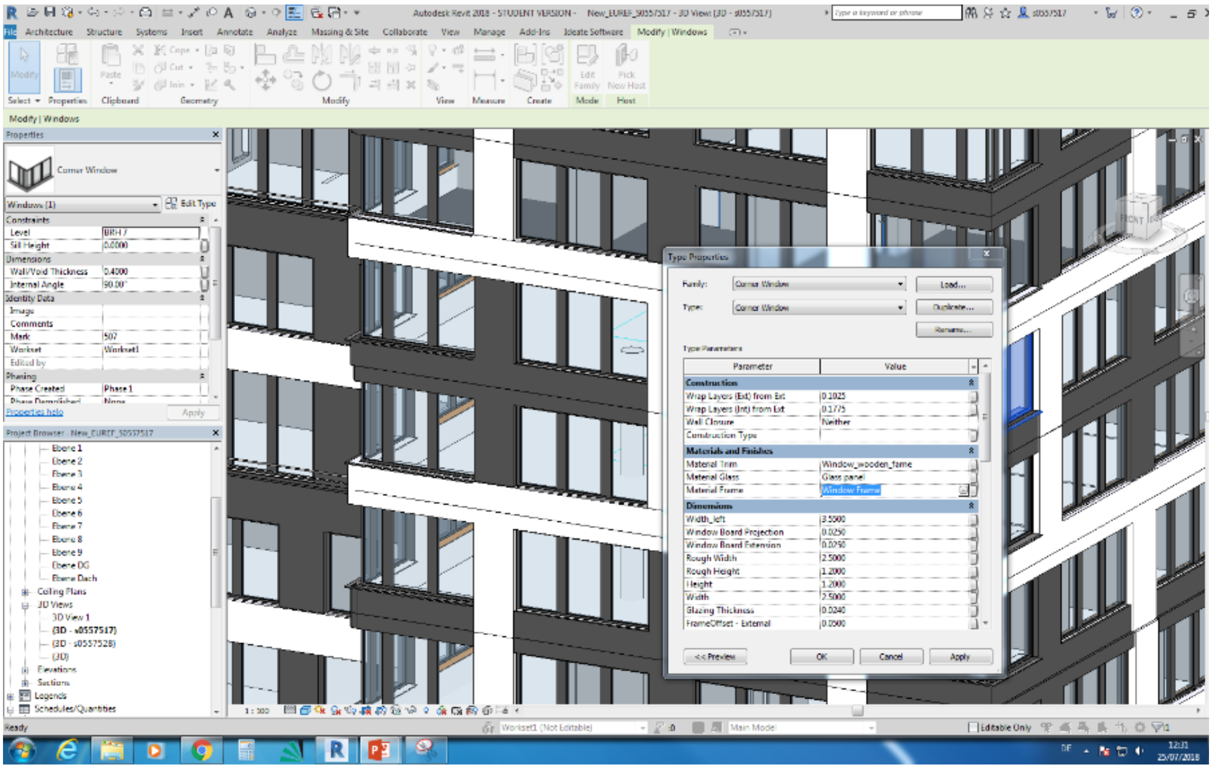


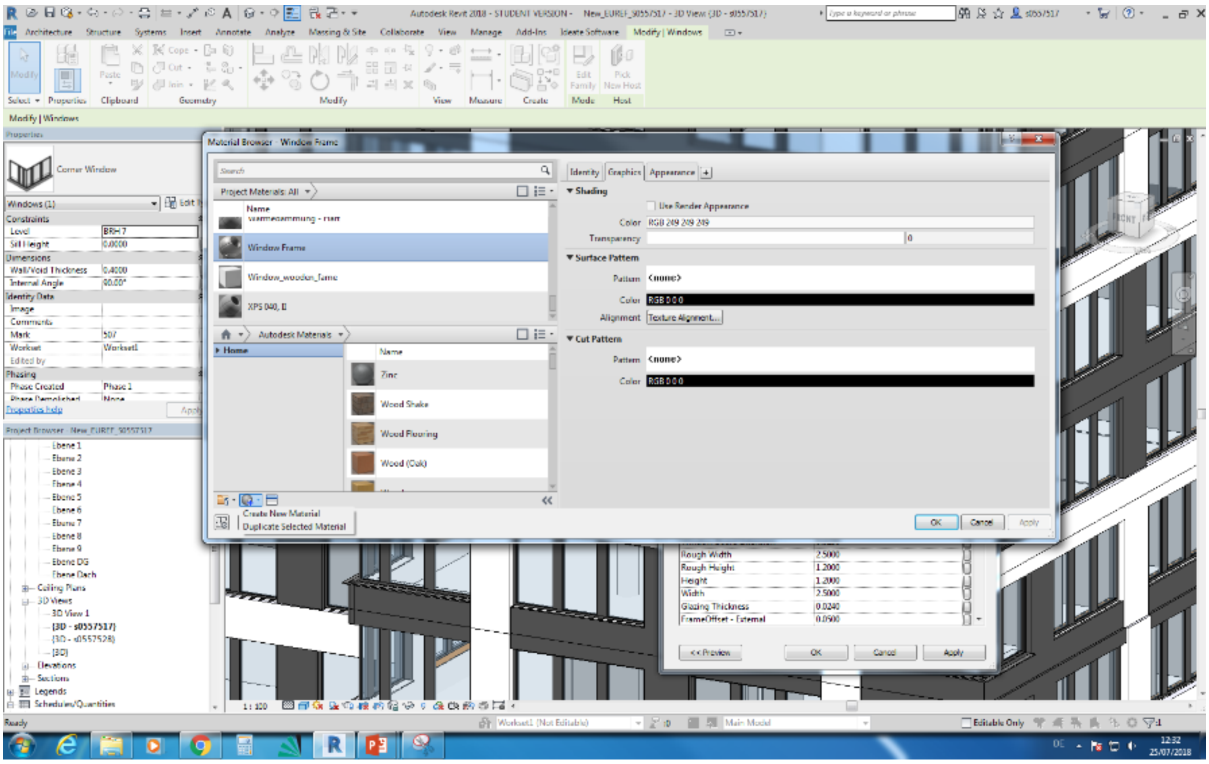
In traditional 2D CAD drawings, we need to individually change the corner windows in all the documents, including the elevation, sections, views, and plans. However, here in BIM, only the corner window family must be changed, the program automatically reflects and updates this change throughout the model and model documents.

The following illustration demonstrates how this feature works.









The above example shows only how BIM helps to reduce the manual effort involved in updating all drawings and documents for the design project. This, in turn, helps to minimize the risk events related to project design changes.

Another risk that can occur during the design and planning phase of a project is related to the energy consumption of a project during its life cycle. This risk is much more dependent on the building design. Energy consumption can be reduced with an appropriate design approach and with the use of energy efficient materials and fixtures.

To reduce design risk, BIM-based programs help to conduct energy simulations from the very beginning up until finalization of the design phase of the project, providing us with a detailed report as well as suggestions and recommendations for design changes. This helps architects and other stakeholders to minimize the energy consumption for the life cycle of the building. This option, provided in Revit, is a reliable, fast and scalable program helping to improve building performance.

For this research project, the author simulated the above Revit model to explain how BIM can help architects and other stakeholders to make changes with the help of a simulation study and its results.

The author used Revit's in-built 'Insight' program for energy optimization. This option is provided under the analyze tab.

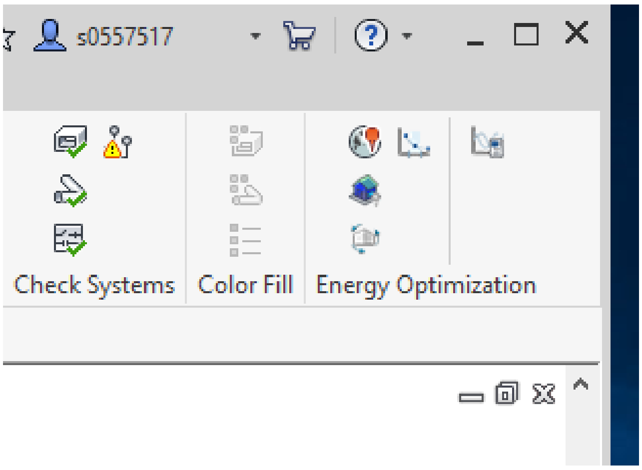
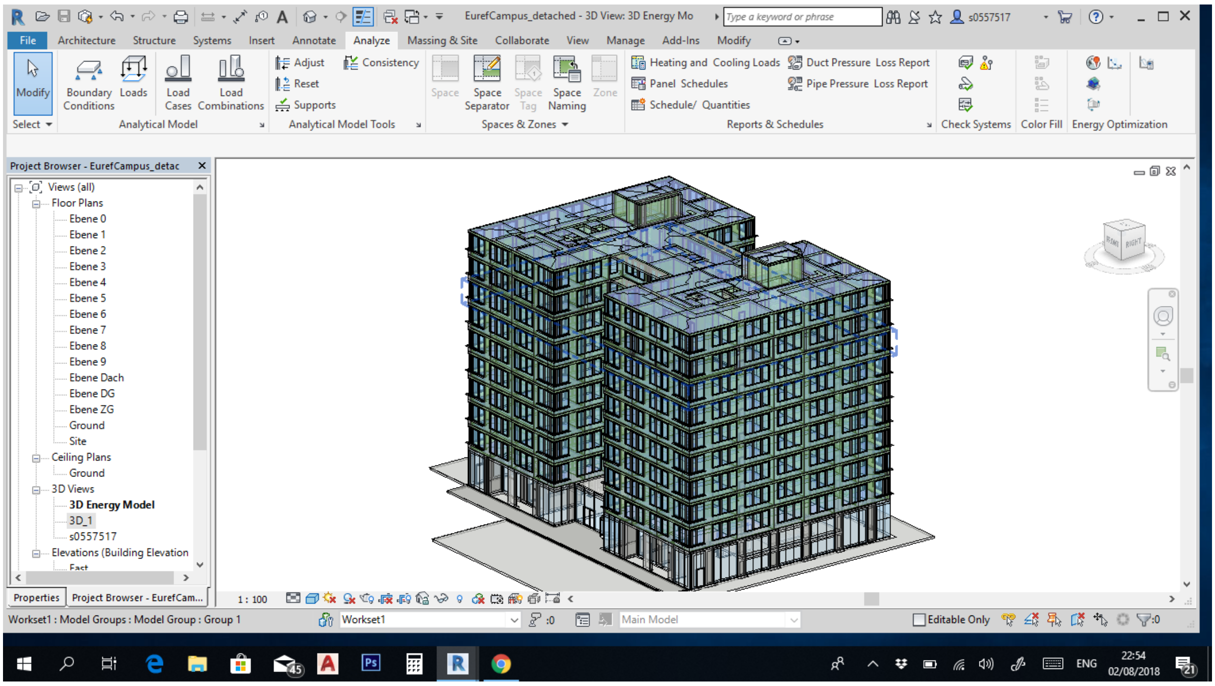


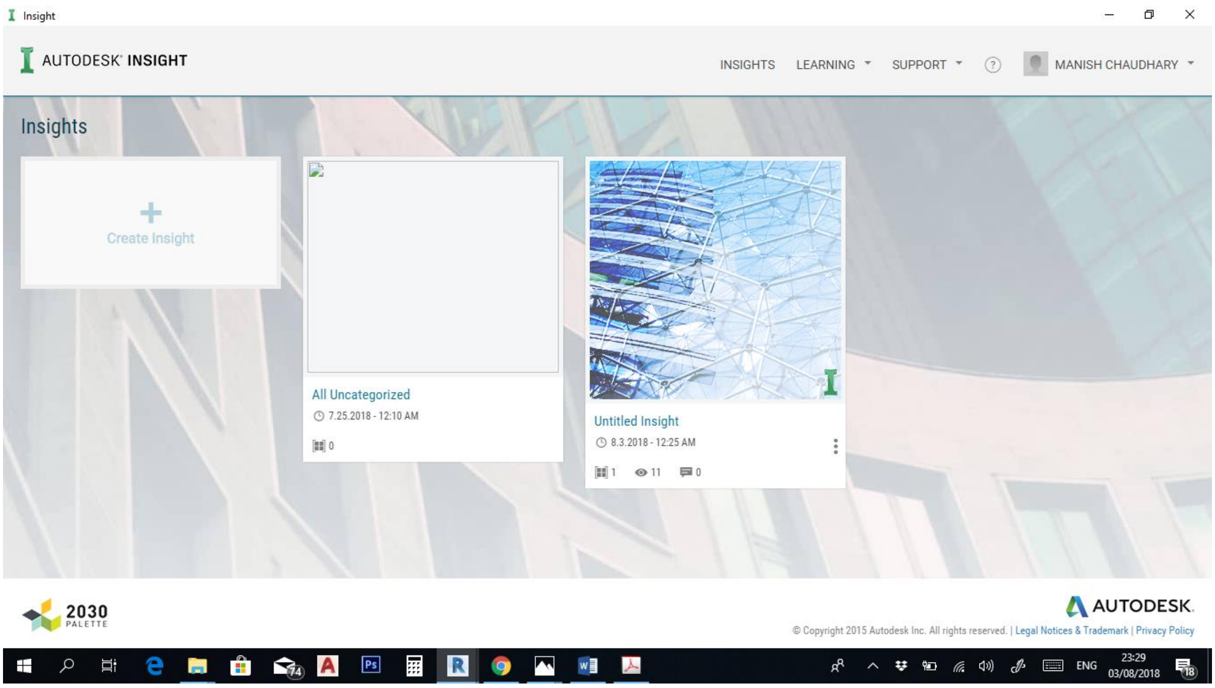
Figure 5.2-1 Revit interface showing Energy Analysis options

To start the simulation, geographical information must be provided about the project, for this example, a building located in Berlin, Germany, has been used. The program itself extracts the information it requires for energy analysis for each geographical location, this information includes the climate, weather, sun path, daylighting, and wind. After providing this geographical information, the energy analytical model must be created from the main model as illustrated below:



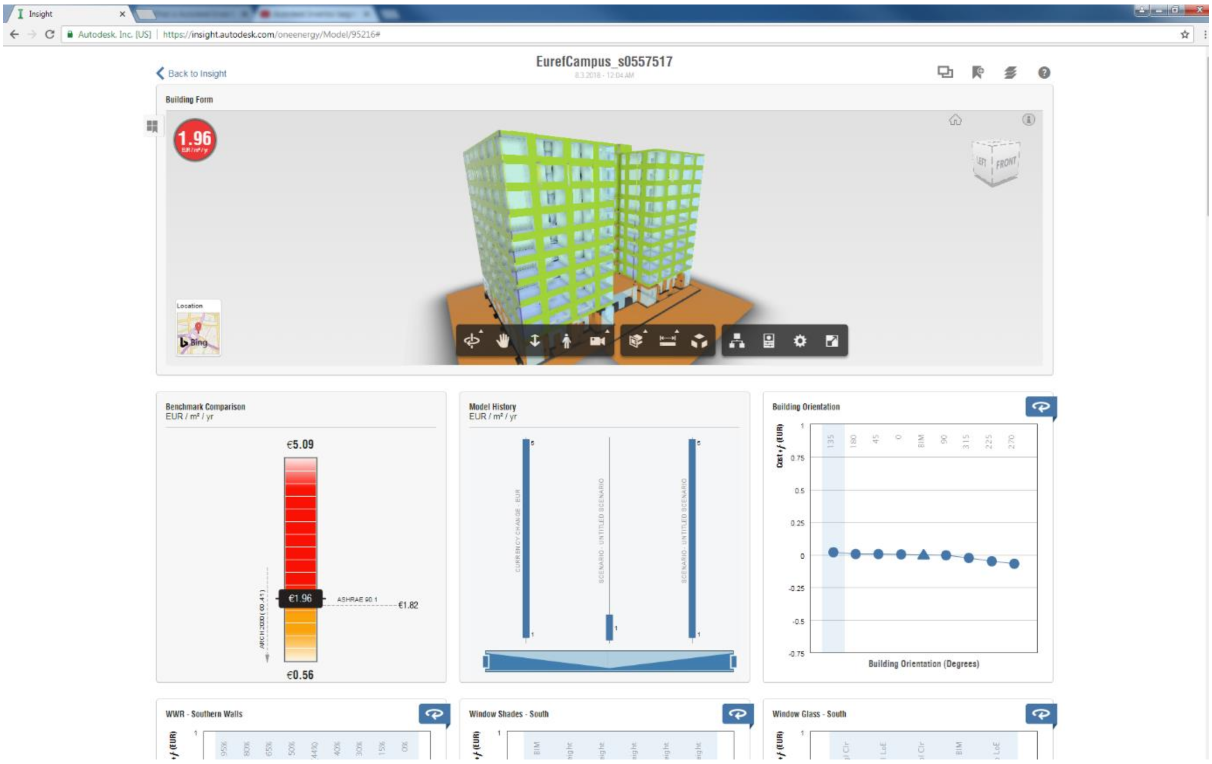
After generating the energy model, one must click on the ‘optimize’ option to start the online energy simulation, this redirects to the Autodesk Insight page.

To use these cloud-based services one needs an Autodesk subscription.

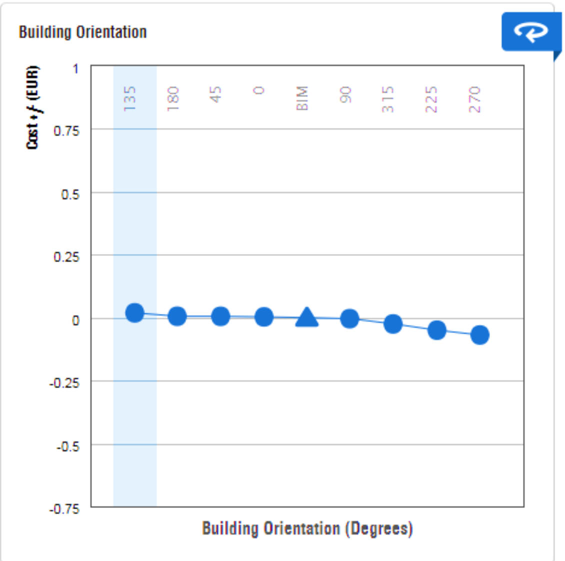


Here Autodesk Insight starts to analyze the model on its cloud. This takes varying amounts of time according to the building area and data on materials used materials among other parameters. Each piece of information relating to the analysis is also provided on the user's e-mail ID.

On completion of the analysis, the following information is given:



In this study, it is shown that the total energy cost for running the building throughout the year is 1.96 Euro/m^2 . As indicated in red, the energy consumption is very high.



Information is also given on the building orientation. Here it is shown that this building is at 135^0, which increases the energy consumption by just over zero. However, if we change the orientation of the building to 270^0, the energy consumption costs reduce.

WWR - Southern Walls

Window-Wall-Ratio (glazing area / gross wall area) interacts with window properties to impact daylighting, heating & cooling.

Current Setting:
95% - 0%

Window Shades - South

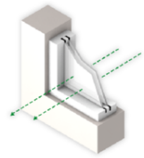
Shades can reduce HVAC energy use. The impact depends on other factors, such as window size and solar heat gain properties.

Current Setting:
BIM - 2/3 Win Height

Window Glass - South

Glass properties control the amount of daylight, heat transfer & solar heat gain into the building, along with other factors.

Current Setting:
Sgl Clr - Trp LoE



WWR - Northern Walls

Window-Wall-Ratio (glazing area / gross wall area) interacts with window properties to impact daylighting, heating & cooling.

Current Setting:
95% - 0%

Window Shades - North

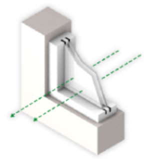
Shades can reduce HVAC energy use. The impact depends on other factors, such as window size and solar heat gain properties.

Current Setting:
BIM - 2/3 Win Height

Window Glass - North

Glass properties control the amount of daylight, heat transfer & solar heat gain into the building, along with other factors.

Current Setting:
Dbl Clr - Trp LoE



WWR - Western Walls

Window-Wall-Ratio (glazing area / gross wall area) interacts with window properties to impact daylighting, heating & cooling.

Current Setting:
95% - 0%

Window Shades - West

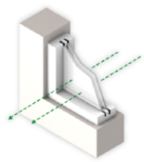
Shades can reduce HVAC energy use. The impact depends on other factors, such as window size and solar heat gain properties.

Current Setting:
BIM - 2/3 Win Height

Window Glass - West

Glass properties control the amount of daylight, heat transfer & solar heat gain into the building, along with other factors.

Current Setting:
Sgl Clr - Trp LoE



WWR - Eastern Walls

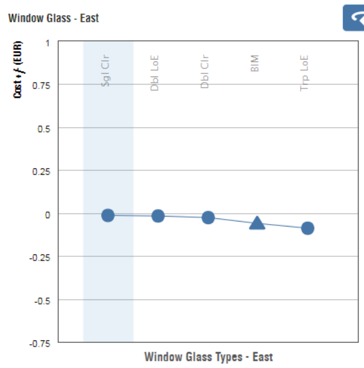
Window-Wall-Ratio (glazing area / gross wall area) interacts with window properties to impact daylighting, heating & cooling.

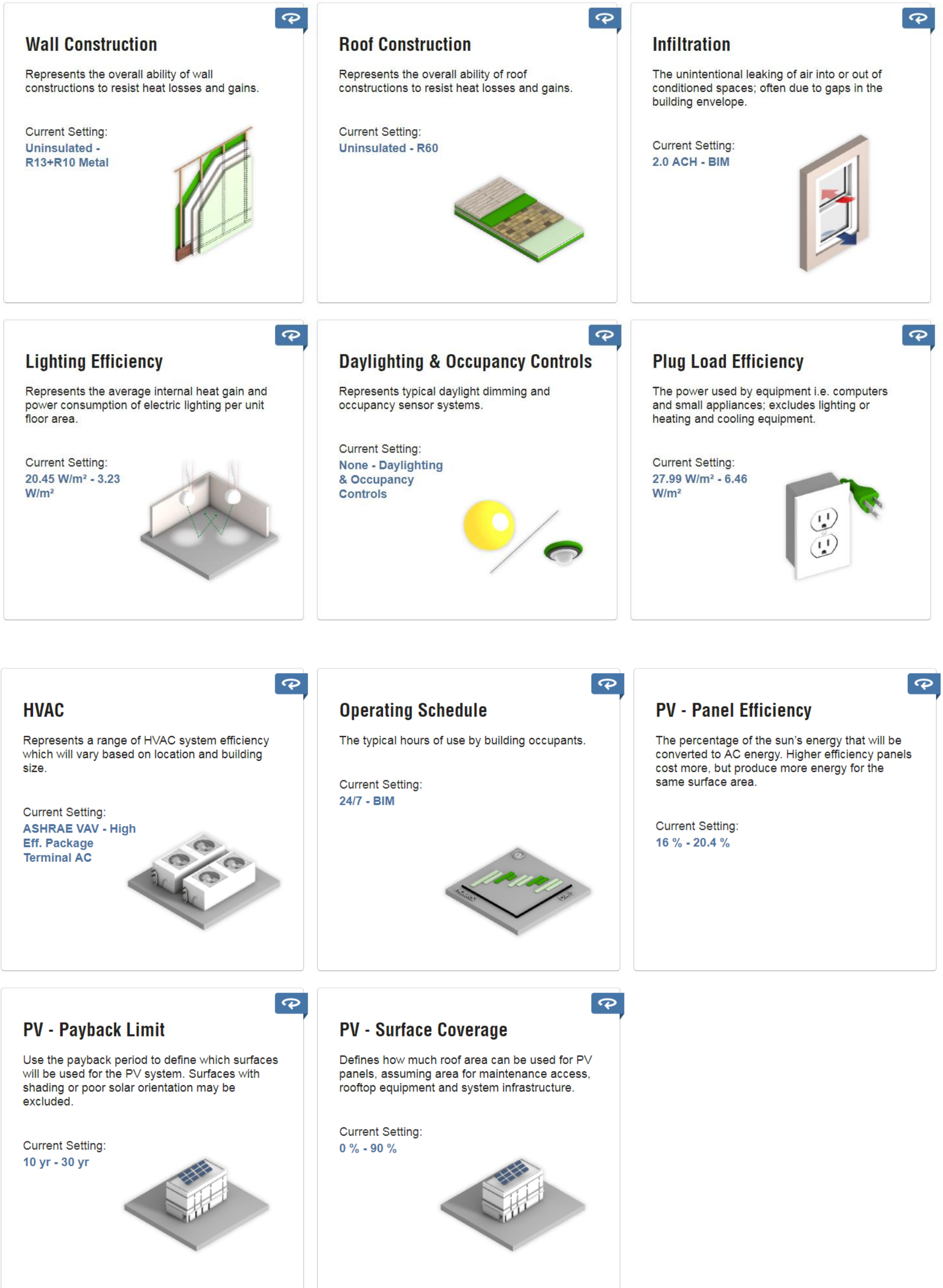
Current Setting:
95% - 0%

Window Shades - East

Shades can reduce HVAC energy use. The impact depends on other factors, such as window size and solar heat gain properties.

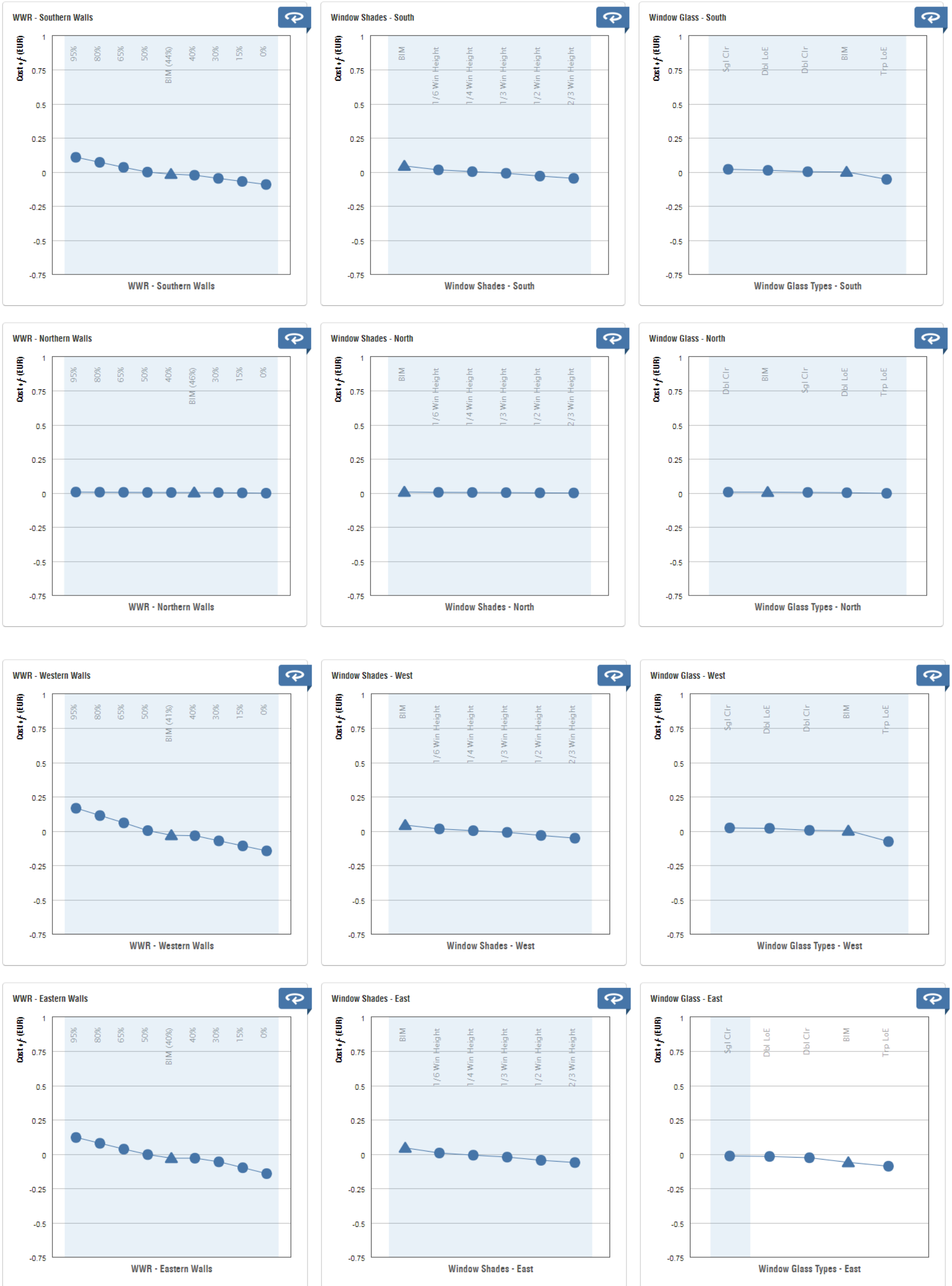
Current Setting:
BIM - 2/3 Win Height

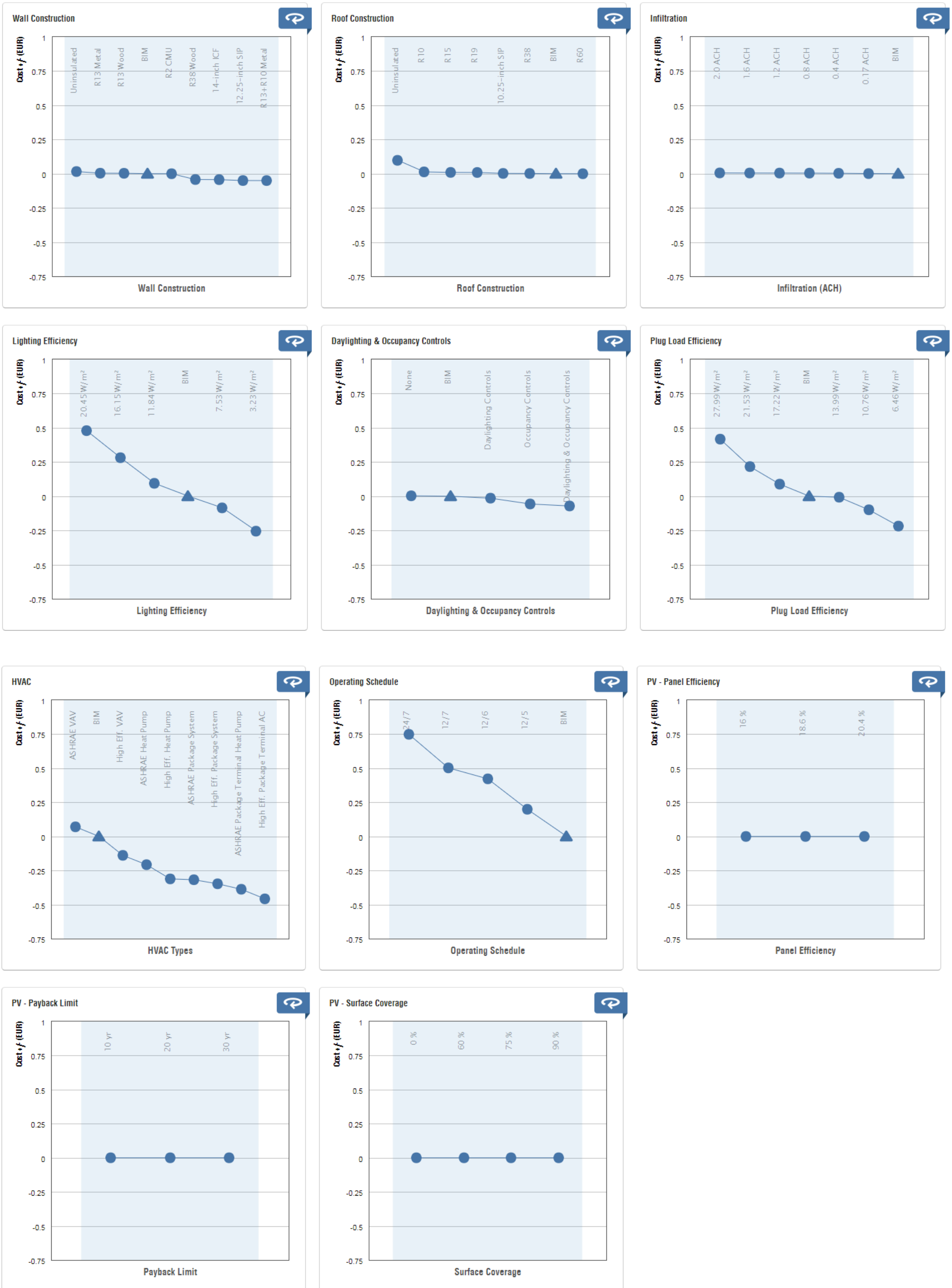




Listed above are the results of the analysis along with suggestions for specific energy optimization approaches.

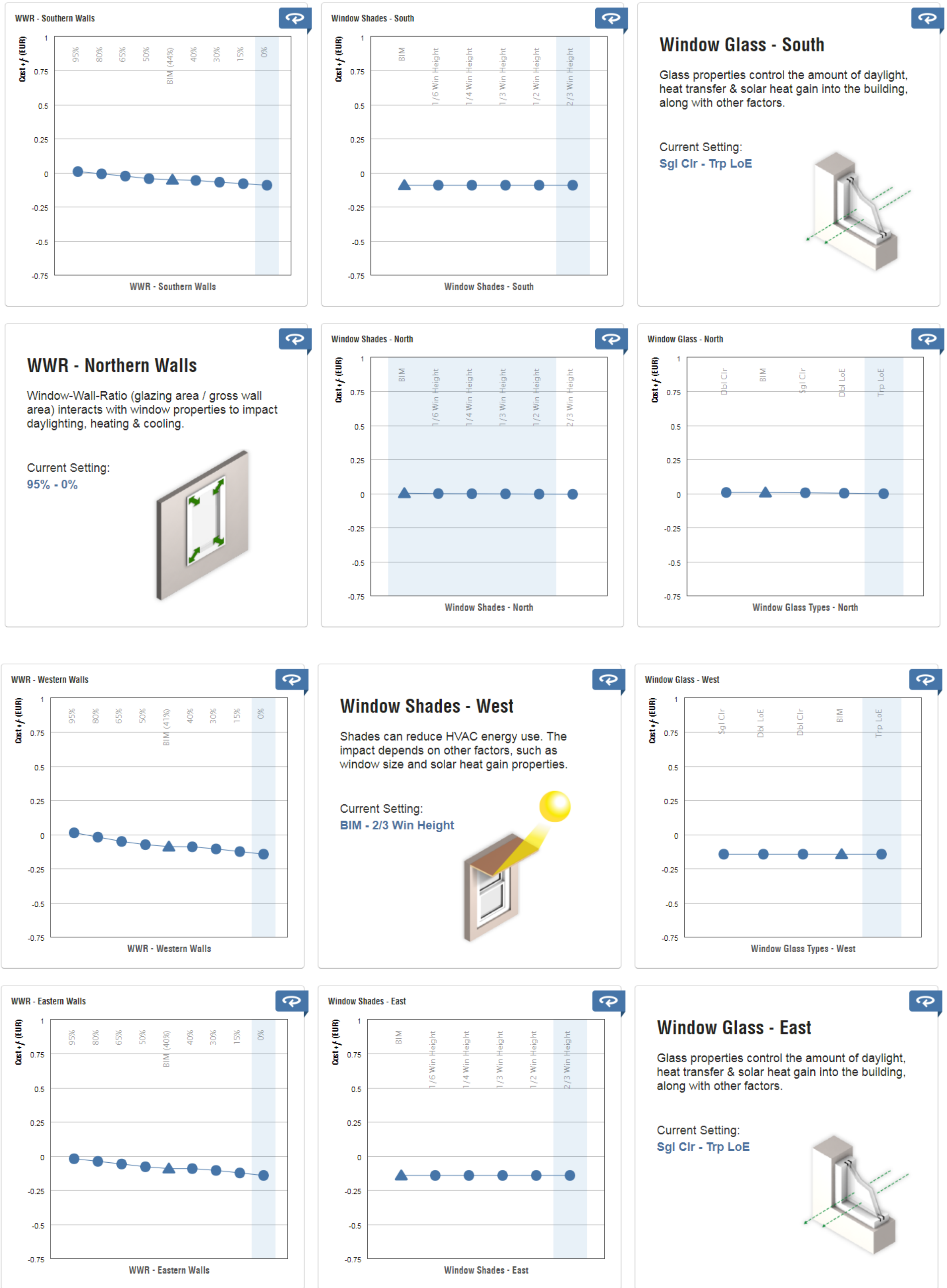
For the example building the results are shown below:

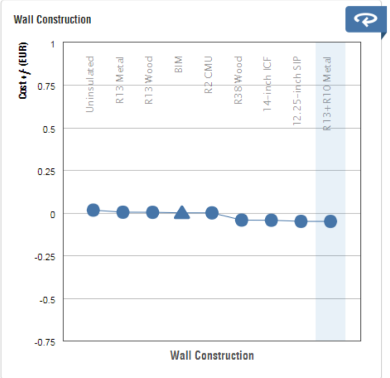




Here we can see the results for all of the different parameters and approaches. The triangle point shows the specific result for the building while the circular dots show other possibilities which can be used to improve the building performance.

Once these results and recommendations have been attained, a better overview is achieved of the parameters that can be changed in order to improve the building performance.

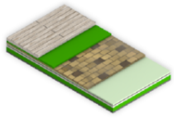




Roof Construction

Represents the overall ability of roof constructions to resist heat losses and gains.

Current Setting:
Uninsulated - R60



Infiltration

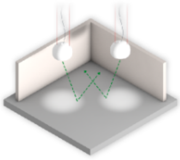
The unintentional leaking of air into or out of conditioned spaces; often due to gaps in the building envelope.

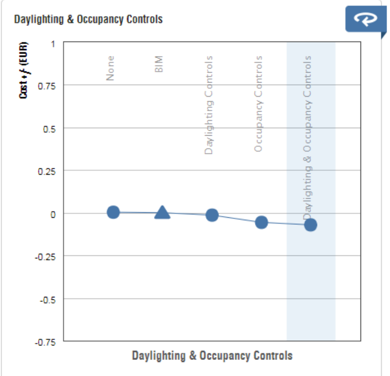
Current Setting:
2.0 ACH - BIM

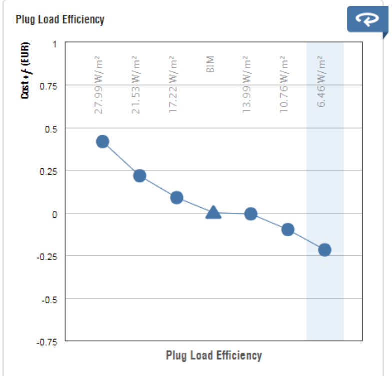
Lighting Efficiency

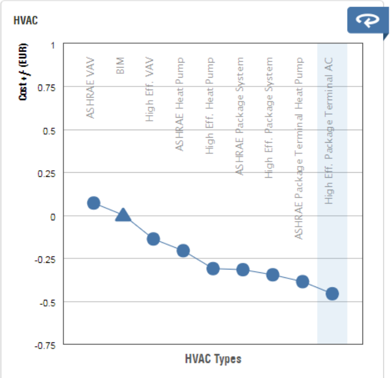
Represents the average internal heat gain and power consumption of electric lighting per unit floor area.

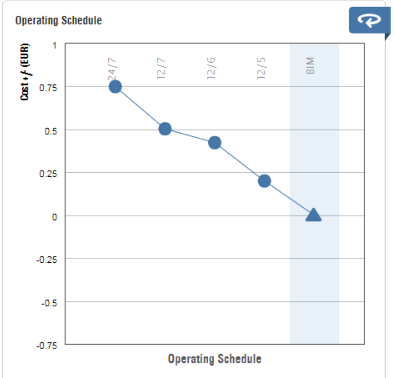
Current Setting:
20.45 W/m² - 3.23 W/m²











PV - Panel Efficiency

The percentage of the sun's energy that will be converted to AC energy. Higher efficiency panels cost more, but produce more energy for the same surface area.

Current Setting:
16 % - 20.4 %

PV - Payback Limit

Use the payback period to define which surfaces will be used for the PV system. Surfaces with shading or poor solar orientation may be excluded.

Current Setting:
10 yr - 30 yr

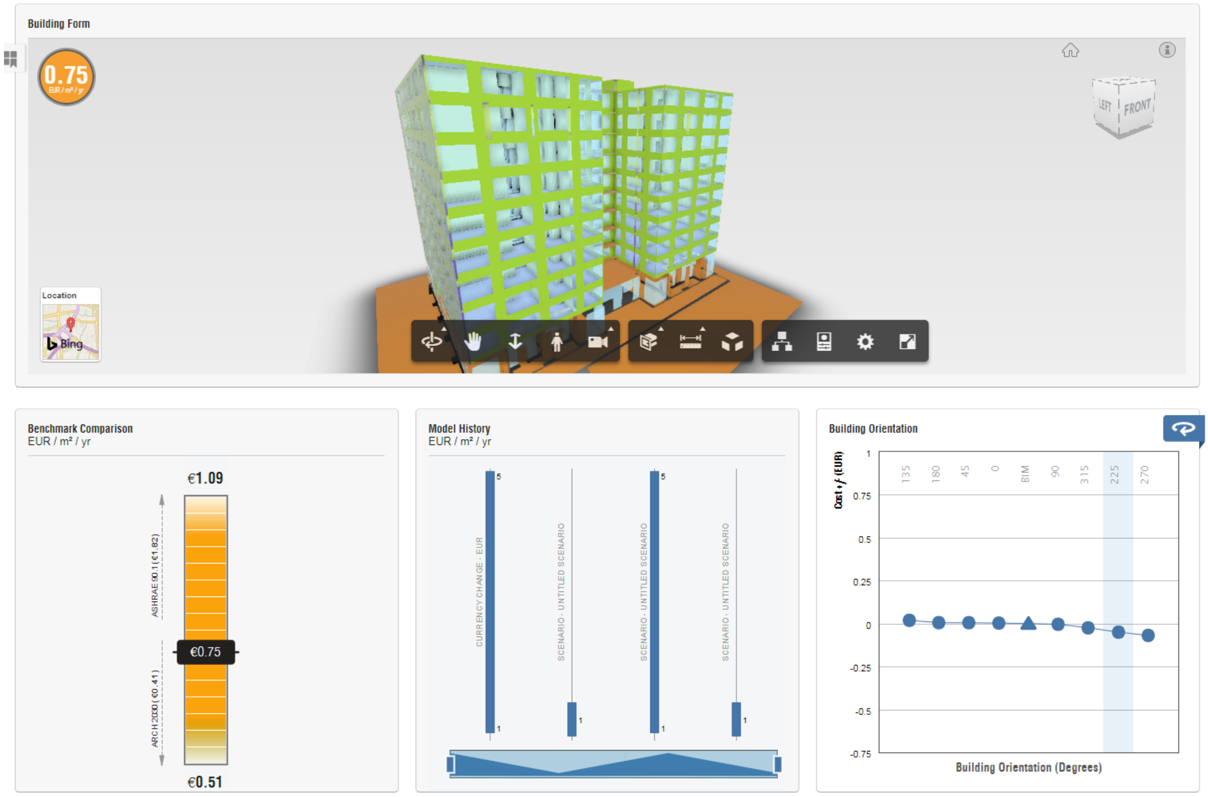
PV - Surface Coverage

Defines how much roof area can be used for PV panels, assuming area for maintenance access, rooftop equipment and system infrastructure.

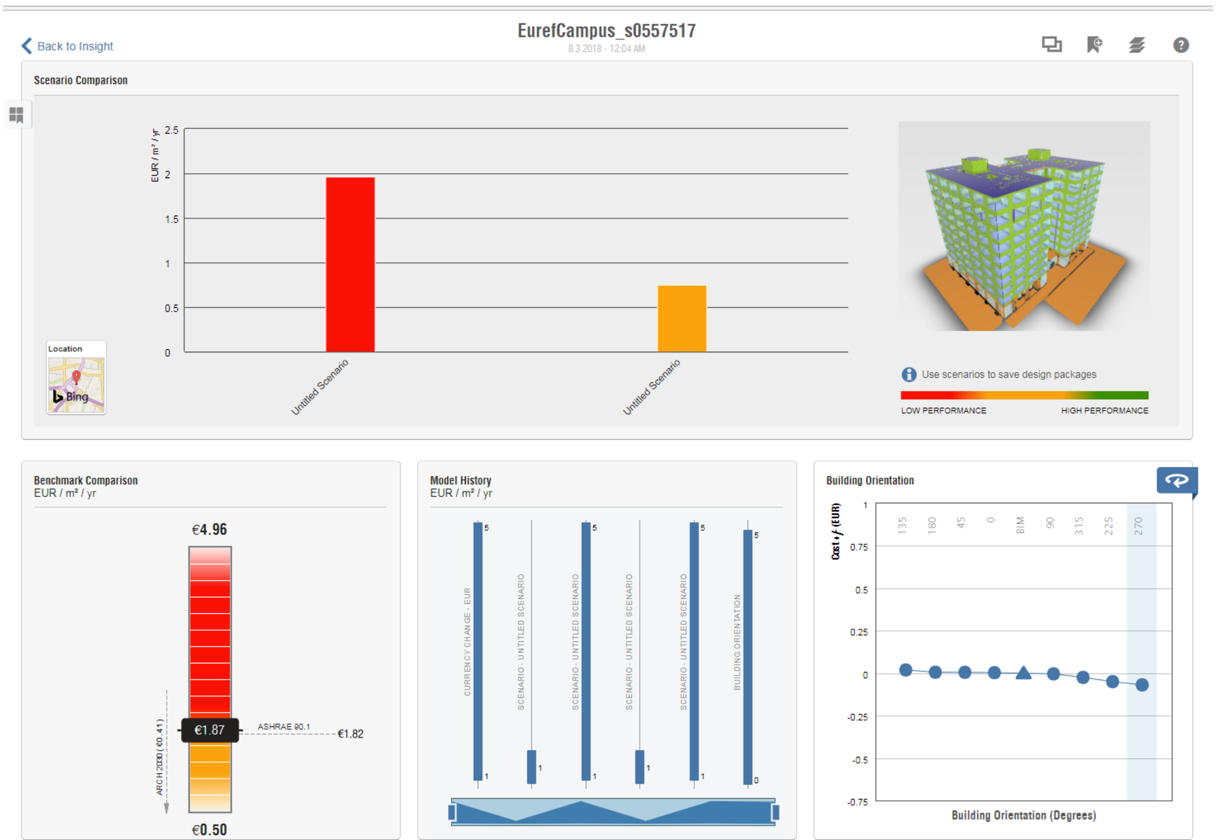
Current Setting:
0 % - 90 %

It is not necessary to make changes to all the parameters. In the above pictures, where there are no graphs there are no suggested changes to the primary design.

This option shows that the energy cost per year is 0.75 Euro/m^2 after making the above changes to the parameters, less than half of that of the primary result.



With the use of this program, it is also possible to compare all possible options.



Here we can see that the color of the result turned from red to orange, indicating that the building performance has improved after the suggested changes have been implemented.

This kind of simulation can be implemented from the first sketch of the conceptual design, giving a basic result about building and façade orientation, wall to window ratio, and shades etc., once the initial results and recommendations have been attained, they can be analyzed in further detail. By following these steps we can improve on our building design and planning from the very beginning of a project, preventing the need for major changes in the design finalization phase.

Comparatively, when using the traditional method, buildings are designed using a site survey, analysis of said site survey, a few architectural concepts related to reducing energy consumption, and the architect or designer’s experience. These designs are not always reliable and accurate in terms of optimizing energy, a major risk event for a project.

As shown above, we can benefit greatly from the improvements offered by BIM for Risk management during the design and planning phase of a project. (Hartmann 2008)

B. Delay of design and permits

To overcome obstacles presented by the delay of design and permits, ICT has been applied in the AEC industry to manage risks, e.g. BIM, 4D CAD, and Virtual Reality (VR). For instance, construction safety risk planning and identification is an issue addressed by 3D/4D visualization (Hartmann 2008). BIM could help automatically detect physical spatial clashes (Chiu 2011) and specific requirements of building codes could be interpreted to machine-read rules and checked automatically in Industry Foundation Classes (IFC) information models (C. L. Eastman 2009). Li, Chan, and Skit more presented a proactive monitoring system using Global Positioning System (GPS) in combination with Radio Frequency Identification (RFID) to improve the safety of blind lifting of mobile/tower cranes (Li, H., Chan, G., Skitmore, M., 2013). There are two possible explanations for the increasing interest and adoption of BIM for risk management. The first is that, as the industry has benefited from salient technical advantages of BIM and other digital technologies, a natural consequent is to investigate their possibilities in risk management. These new techniques could not only provide new design tools and management methods (C. T. Eastman 2011), but significantly facilitate the collaboration, communication, and cooperation for both within and between organizations (Dossick, C.S and Neff 2011), essential requirements for managing risks successfully. The second reason comes from a strong thrust from government policymakers who have realized the importance of integrating ICT with risk management. Strong evidence for this comes in the form of a new version of CDM regulations that will cover ICT tools such as BIM after 2015 (Joyce 2014), thereby replacing the older version that was introduced in the UK initially in 1996 to improving safety and risk management.

5.2.2 **Managerial Risks Events**

A. Lack of Communication in the planning and design phase

In managerial risk events, lack of communication is one of the biggest risk events for a project. Active communication during a project, although very common in developed countries, is not as prevalent in developed countries. The main cause of this problem is lack, as well as inappropriate tools for communication.

When using the traditional method, e-mails and meetings are the only ways for the project workers to communicate. These are not effective forms of communication and may lead delay of the project.

In addition, a BIM-based collaboration and communication environment could naturally facilitate the early risk identification and mitigation (Dossick, C.S and Neff 2011) BIM programs are designed so as to make communication easy among all the stakeholders related to the project. (Yang, Kiviniemi and W. Jones 2015)

Again, using the BIM program Revit as an example, it will be shown how BIM would make communication on projects easier and faster in the AEC industry.

Due to limitations to program access these illustrations are taken from Revit help tutorials.

In Revit, a communicator option is available along with an editing request option. This communicator works with Autodesk 360 sign in to provide contextual communication when working with more than one discipline in any one project on a central model. This option is only available for Revit service subscribers.

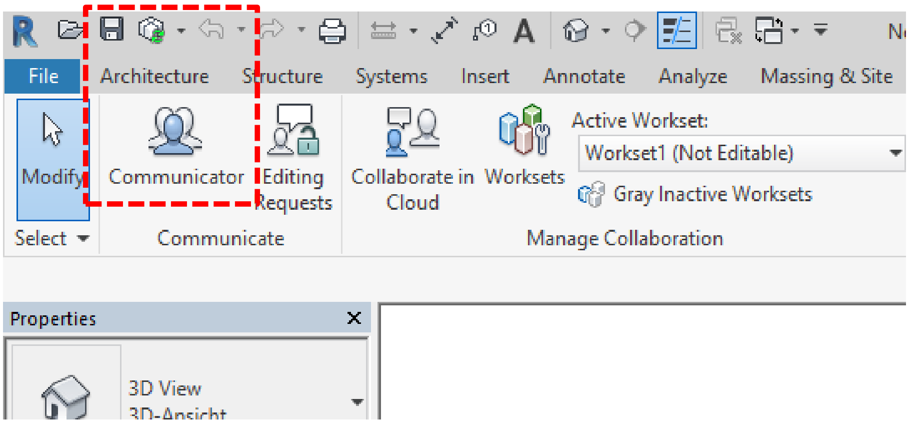


Figure 5.2-2 Revit interface showing Communicate window

The following images illustrate the important options available with Revit communicator.

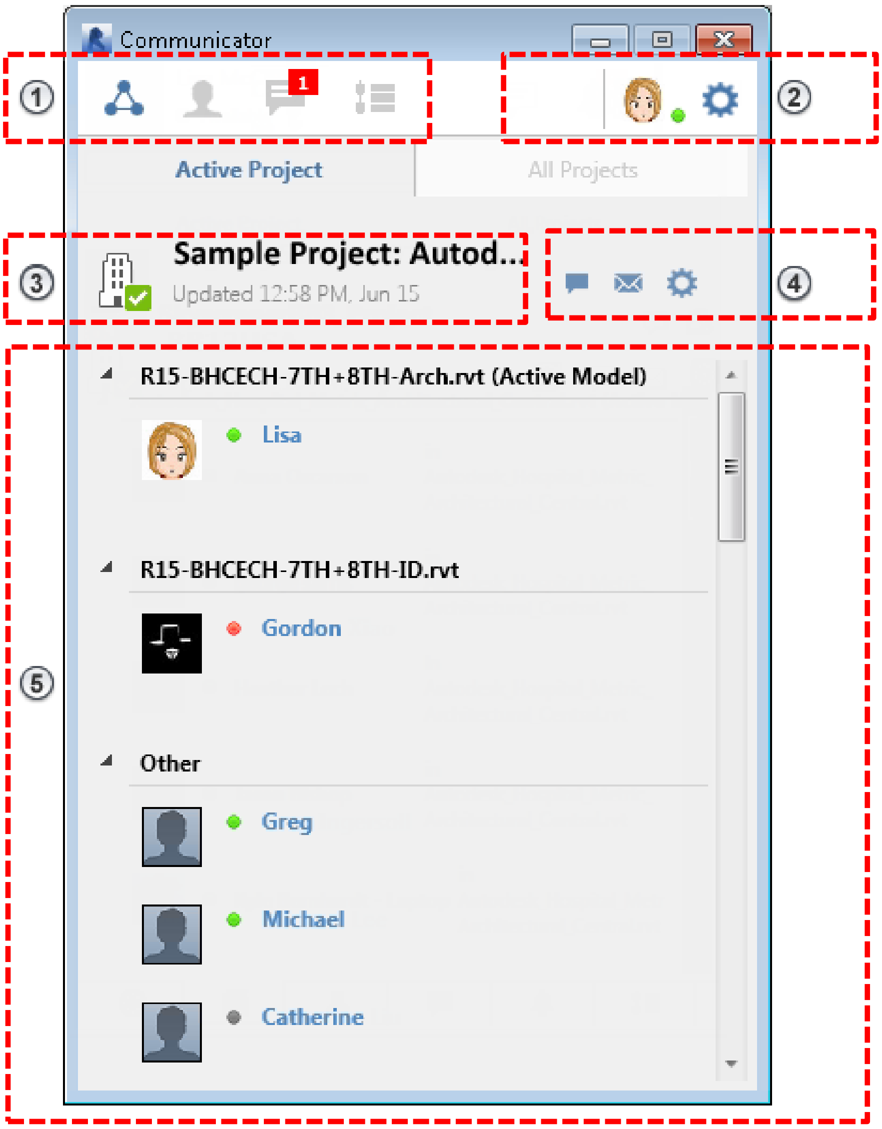


Figure 5.2-3 Revit interface showing options in Communicator tab, Source: (Autodesk n.d.)

Option 1: Information on projects in the cloud.

My Project: This tab shows all the projects in the personal A 360 account and includes two panels:

a) Active Projects: contains the projects one is currently focusing on in Revit. Here we can also find members lists for active projects.
b) All Projects: contains all the projects one is a member of listed and linked with the cloud. (Autodesk n.d.)

- My Contact: This tab has the option to display and manage contacts for the project selected in 'My Projects'. (Autodesk n.d.)

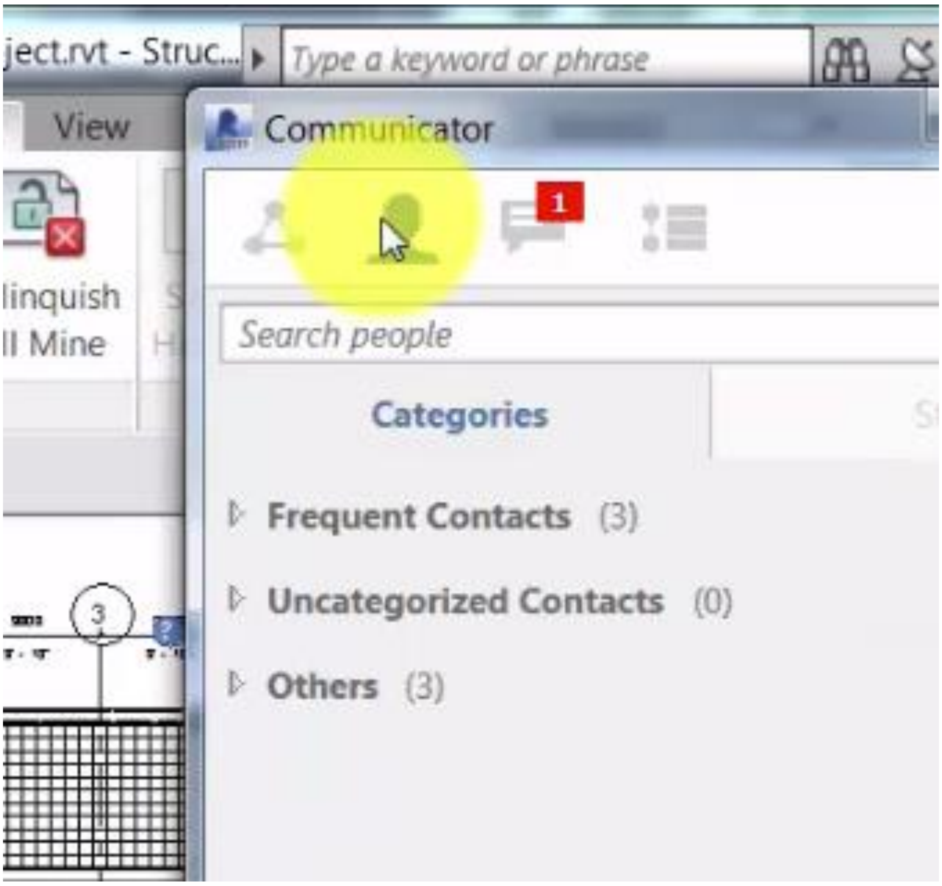


Figure 5.2-4 Revit interface showing Communicator options, Source: (Autodesk n.d.)

- Chat: In this tab, members can chat and review their conversations with contacts listed in their 'Contacts' tab. Revit interface showing chat options in communicator

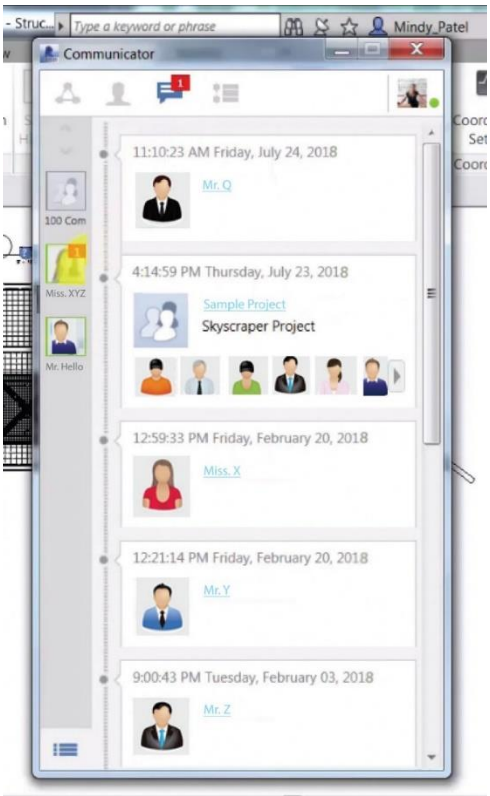


Figure 5.2-5 Revit interface showing chat options in communicator, Source: (Autodesk n.d.)

Timeline: In this tab, we can review the sync activities of the shared model.

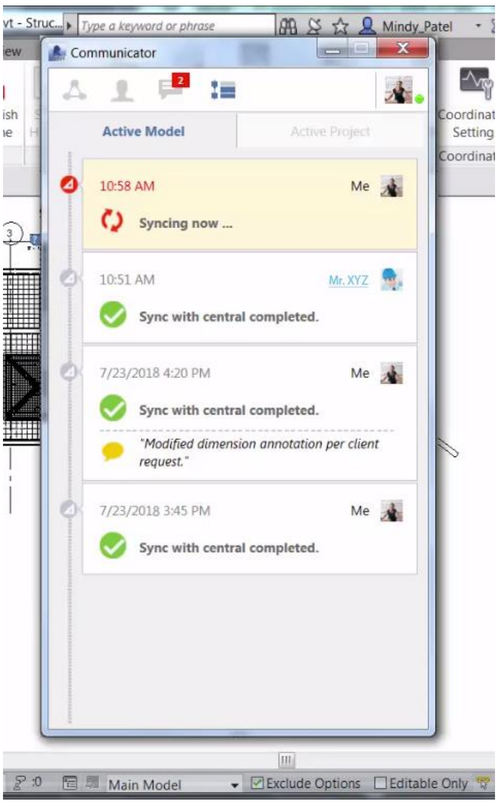


Figure 5.2-6 Revit interface showing timeline options in communicator, Source: (Autodesk n.d.)

Option 2: This option includes two features.

My Profile: Here members can access their profile and change their status to online/offline.

Settings: This tab provides setting options for the communicator window and startup preference.

Option 3: Here the name of the Project is displayed along with details about the date and time that the project was last updated.

Option 4: There are three options to the right of the Project name.

a) Instant Chat: For sending instant messages to all project members relating to a project. There is also an option to send a private message to a particular contact list in the project.
b) E-mail: This option allows one to send an e-mail to all members of the project.
c) Settings: Here we can change the settings on A 360 team.

Option 5: This is the main area of the communicator window and changes according to the selected views illustrated in the above 1 to 4 options. The above illustration shows that the project view is selected and showing the model activity and members for the current project. Members marked in green are currently online and orange shows that they are ‘away’.

The communication options offered in BIM-based programs like Revit makes for faster and clearer communication. This leads to a fast-paced project not only at the design and planning stage but during the whole life cycle of the project.

Revit offers not just one option for communication, even is also an option to facilitate communication for shared projects, this tool is called ‘Editing Request’,

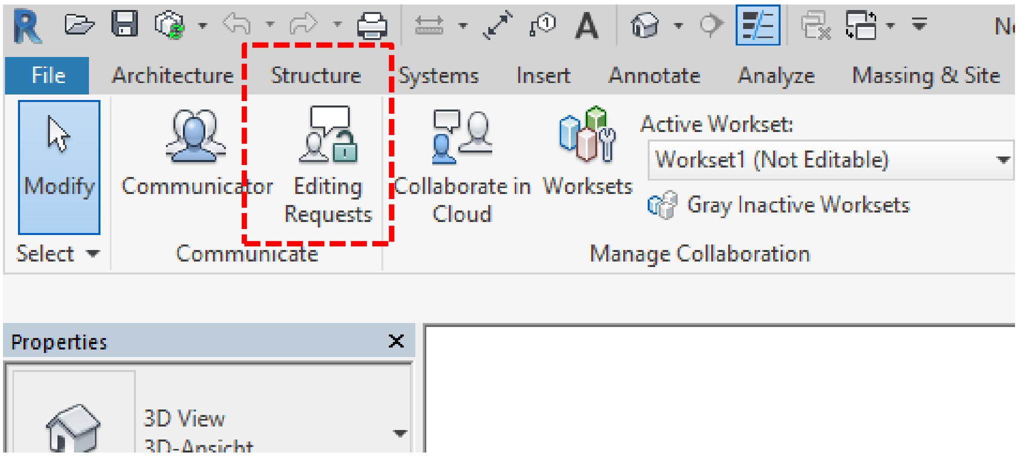


Figure 5.2-7 Revit interface showing Editing request in Communicate option

Editing Request helps each team member involved in the project to request other members to edit the model. Team members receive automatic notification messages when requests to borrow elements are requested, granted, and denied. When a team member requests an element, or grants or denies a request, a message displays the project name, the requested element, and the team member who requested the element or acted on the request.

Notification messages are displayed for approximately 30 seconds. After this time, you can use the Editing Request dialog to check for pending requests and to act on requests from team members. (Respond to Editing Request Notifications 2016)

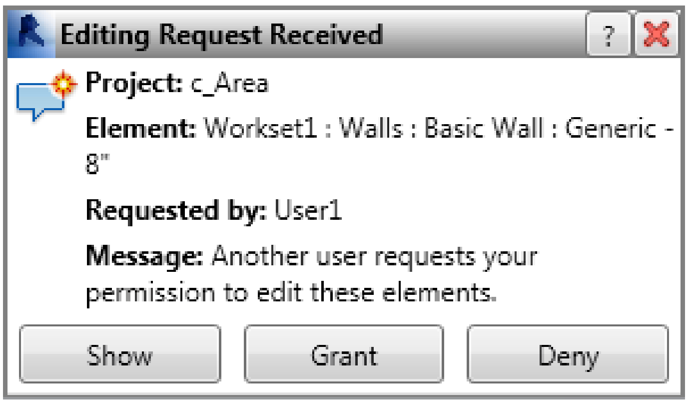


Figure 5.2-8 Editing request pop-up window in Revit, Source: (Autodesk n.d.)

B. Lack of coordination among different disciplines

As with lack of communication, lack of coordination is also one of the main risks in managerial risk events. Coordination and collaboration between all the disciplines involved in a project are vital for the growth of a project.

BIM-based programs are designed in a very smart way to reduce this risk event from occurring. Here the author explains how BIM-based coordination and collaboration options work, giving examples by use of the BIM-based program Revit.

As with the 'Communicator' service in Revit, the 'Collaboration in Cloud' service is an essential cloud-based service allowing multiple team members and stakeholders to work on the project simultaneously from any part of the world. Members can access the service on the desktop or mobile devices to collaborate on any project and can be from the same or different disciplines. This service provides a cloud-based centralized platform for users to work on cutting out the need for an expensive common server.

All the collaborating teams in a Revit project must have an A360 team account. This service supports more than 100 file types. There are also search, filter and find services for project data which provide a smoother working environment. Back-ups can be also saved on A360.

The following image illustrates an A360 collaboration on Revit, showing that there are multiple teams are working together at the same time on their local model, which is

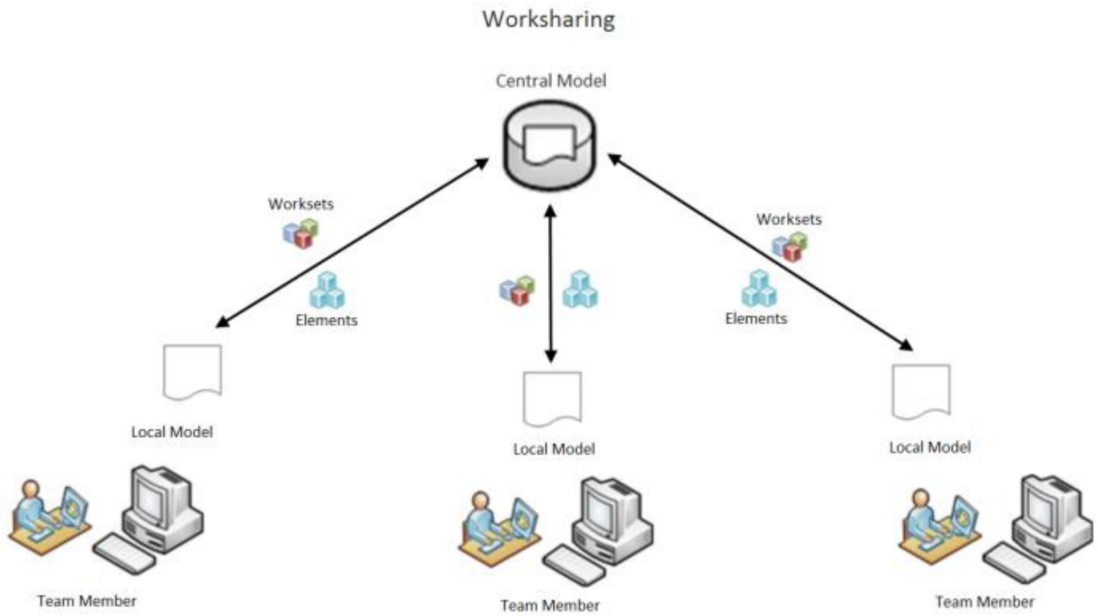
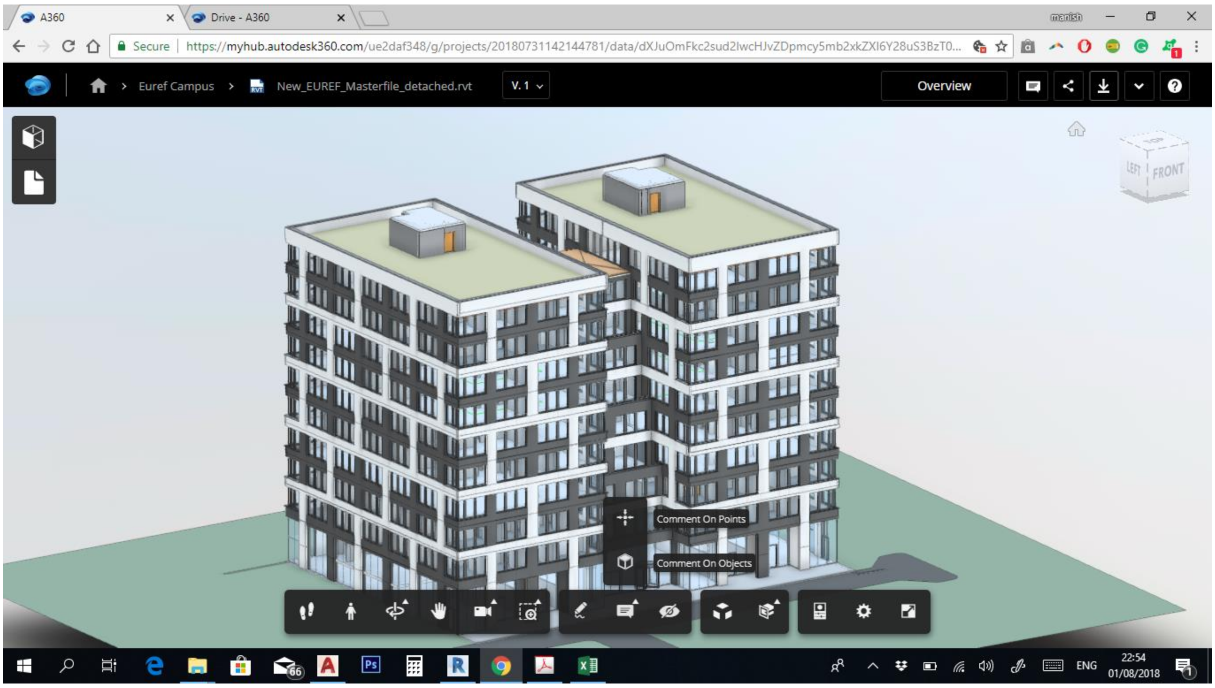
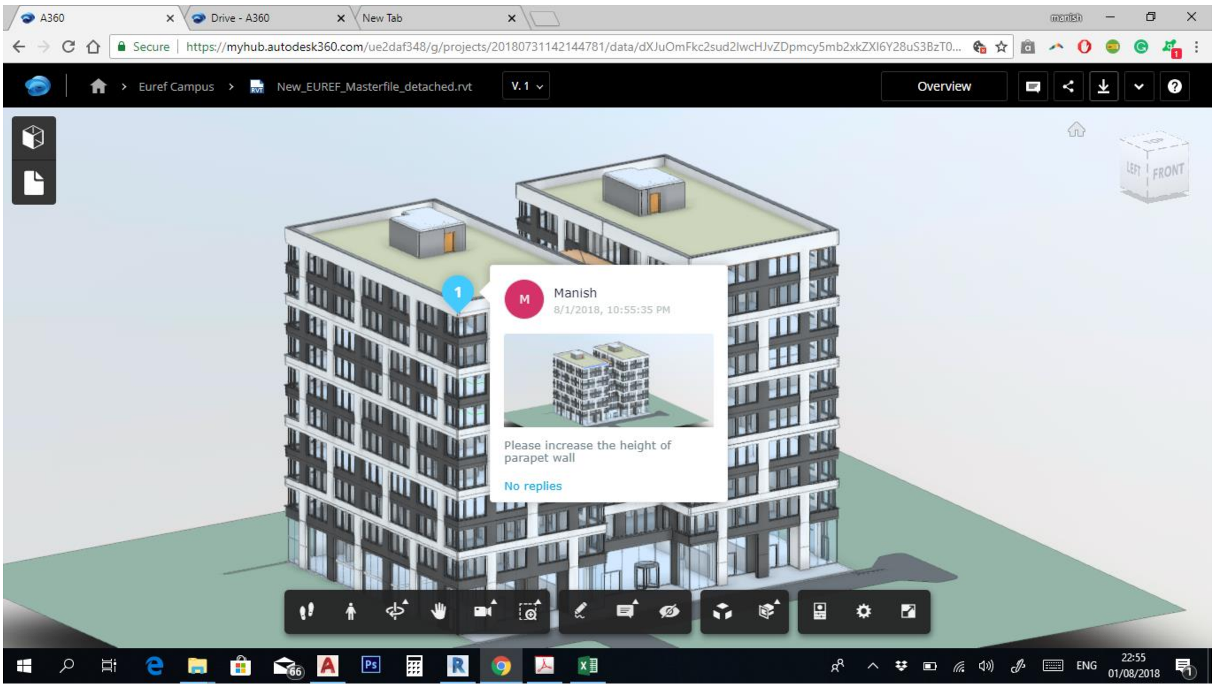


Figure 5.2-9 Central Model Diagram, Source: (Autodesk n.d.)

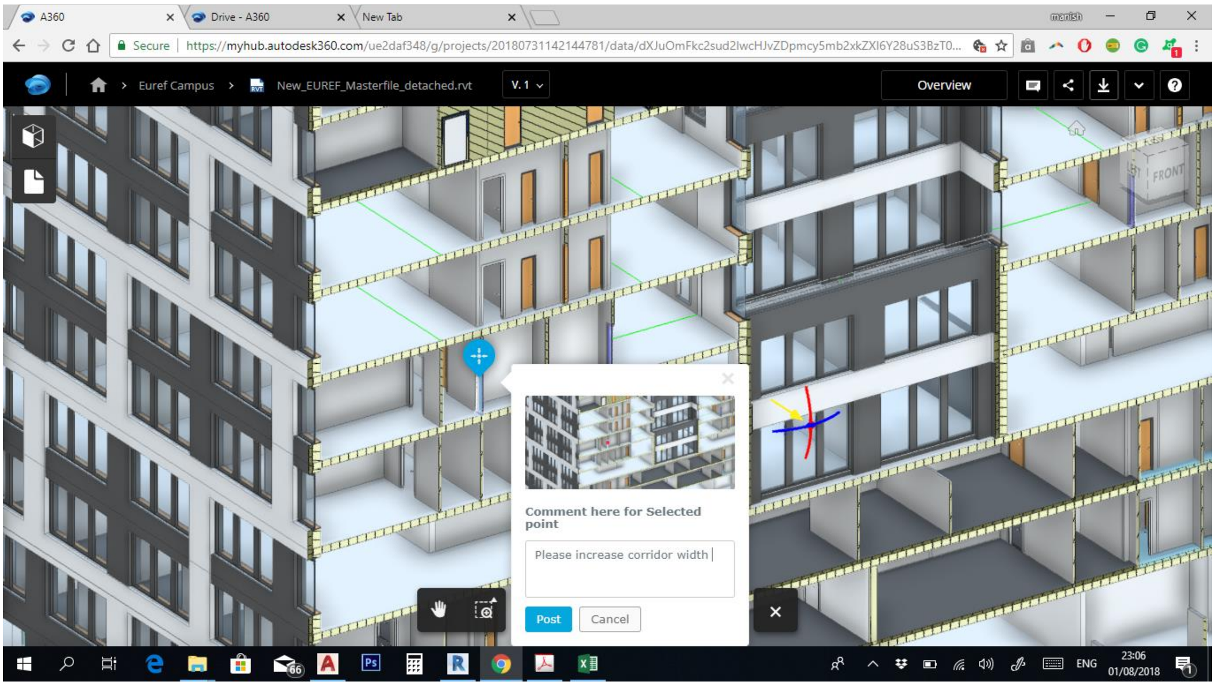
directly collaborated with the central model. The central model can be accessed on the web from the desktop, mobile or tablet. A member can read about the model, leave comments on the model, review comments and send feedback.

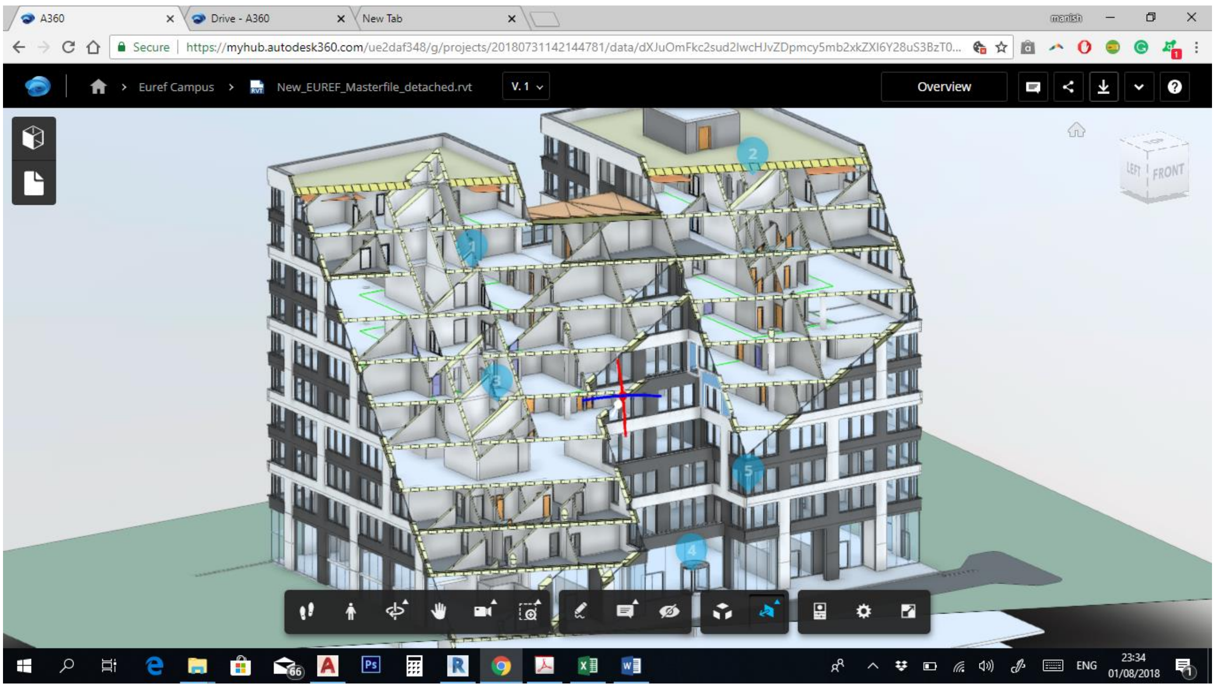


In the above model, we can see that there are many ways to leave a comment, including adding notes to the comment. There are options for commenting on objects, points and marking among others. In this way, there are a sufficient number of ways to communicate with other stakeholders.

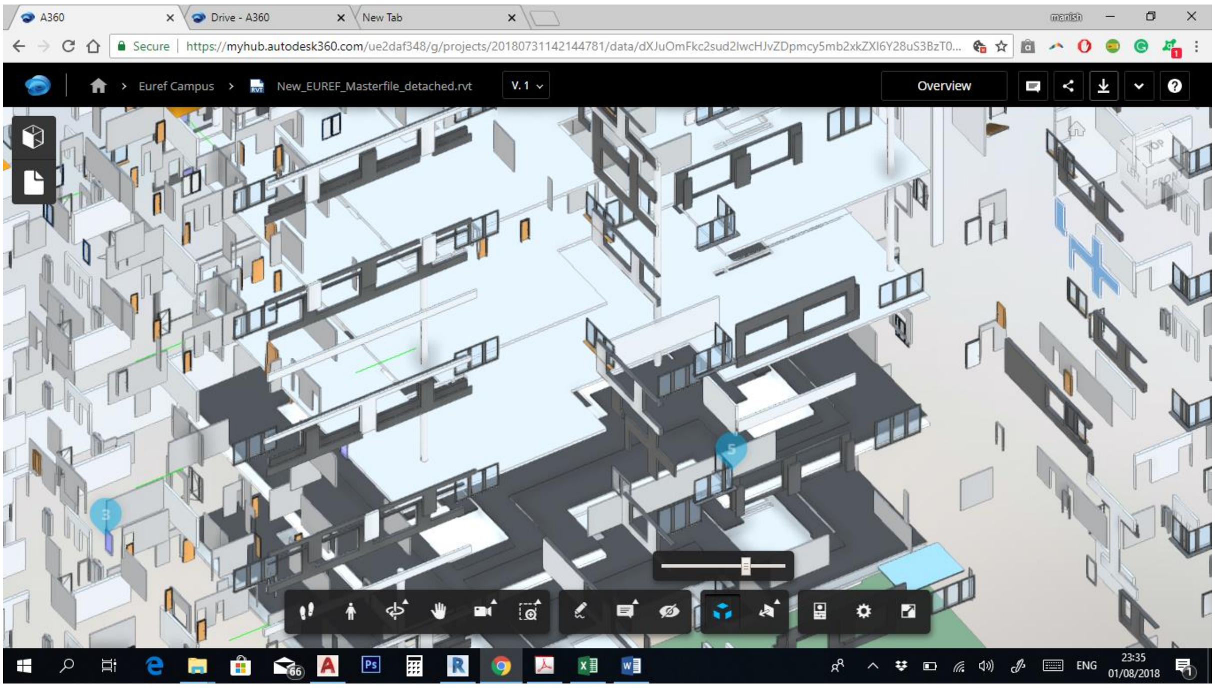


These images demonstrate how comments appear in the Revit model, how they can be reviewed by all stockholders and hidden if not required.

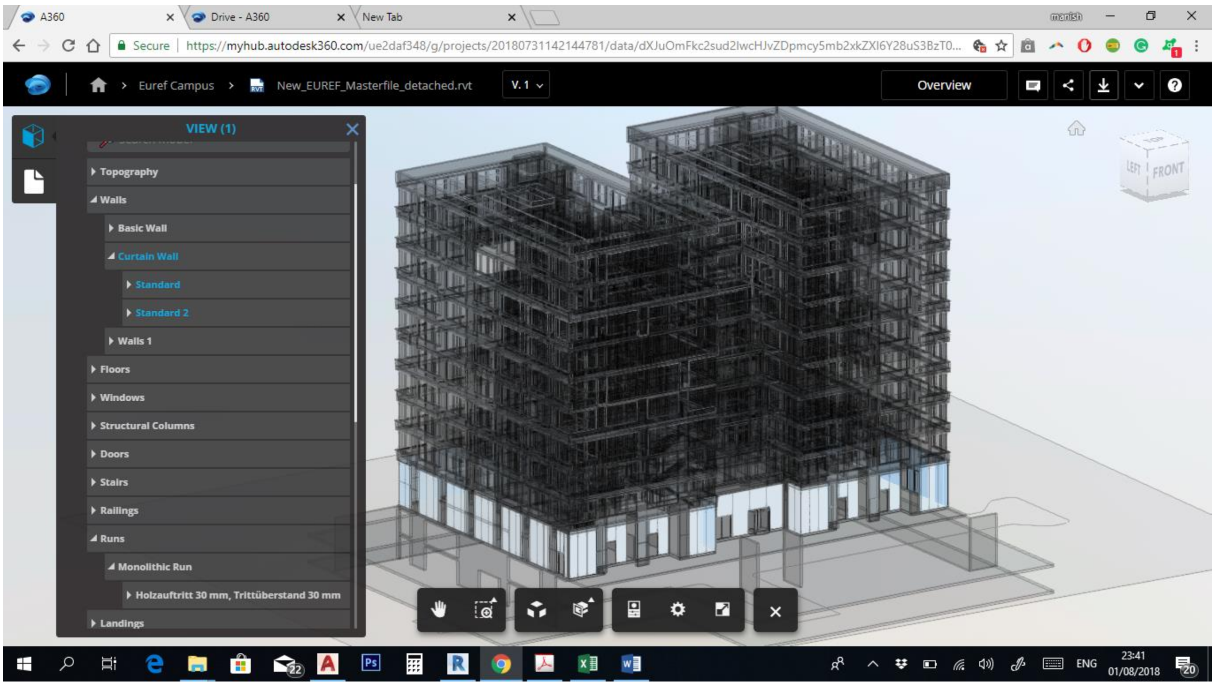




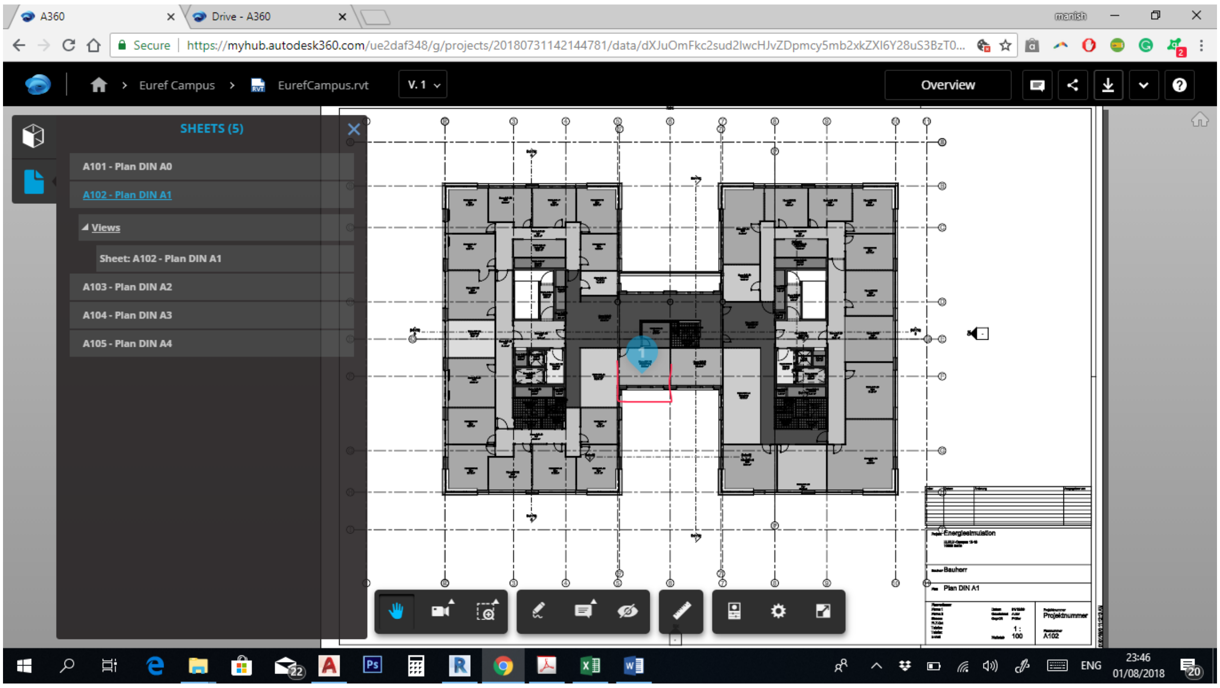
There is the option to see and review sectional views from any angle plane, not just the outer surfaces



Using the ‘explode model’ option helps to make the model visible from the inside and also creates a clear view of all the elements of the model. The ‘comment’ option is also available in this view.



Filters to review the model with element types such as walls, doors, floors, and ceilings, helps to highlight and review particular elements. In the above picture, the curtain walls are highlighted.



Sheet sets can be also reviewed and can be marked comments

In the absence of cloud-based collaboration, local servers can be used collaborate however not without limitation, for only the person or team with access to the server can use the service. Thus, overseas collaboration or multiple-location teams are prevented from working together in this way. Consequently, this option is only feasible for offices which have all the consultants working on a given project sitting in-house.

Figure 5.2-10 Server based collaboration option on Revit, Source: (Autodesk n.d.)

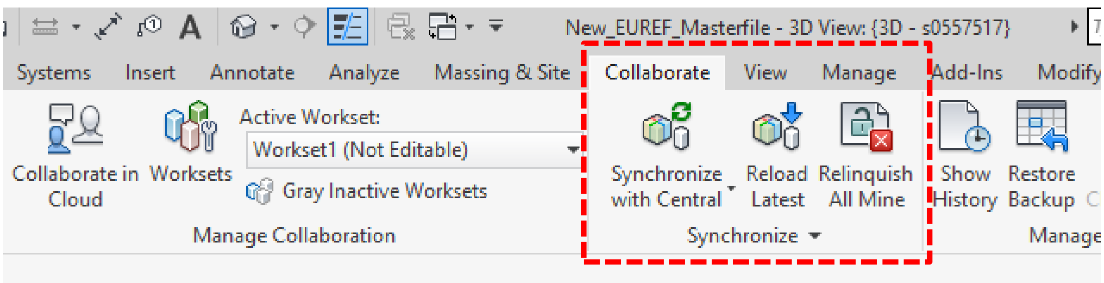


Figure 5.2-11 Synchronize option in Revit

Using this tab, team members can synchronize their local model with the central model both if they are working on cloud-based or A360-based collaboration.

5.2.3 **External risk events**

A. Changes in consultants or stakeholders

Changing consultants during the design and development phase can pose a considerable risk for a project. For example, data is at risk of being mishandled when it is passed between leaving and joining consultants and the architect or project management team.

When using the traditional 2D CAD method, the latest data may not be delivered to the project management team or architect when a consultant leaves a project. On the other hand, the BIM-based program offers a central model on which all consultants and team members work together using the collaboration and work set options. Thereby the BIM-based program ensures that all the data in the central model is up to date with the latest improvements made by all team members and consultants working on the project. The overall benefit is that no data will be lost; this then prevents delays associated with data loss.

B. Overseas Consultant's or Contractor’s Headquarter

Involving consultants or contractors who are based overseas on a project also poses an external risk due to the logistics required to share data when using the traditional method.

However, as has already been discussed, communication and collaboration options when using cloud-based BIM programs can reduce this risk event.

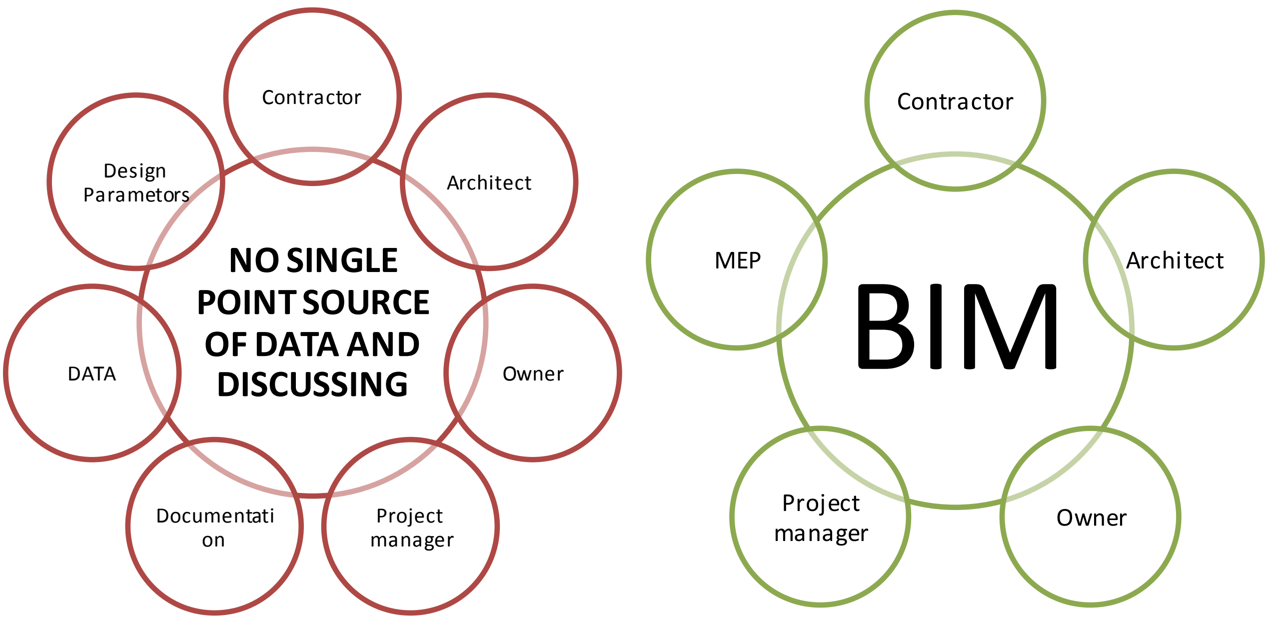
6. Conclusion

The thesis is concluded as followed;

Since the traditional methods of risk management are not sufficient for the increasing demand of the market and lack the framework to be used in different construction projects. It is observed that adopting Building information modeling for construction projects not only enhances the project productivity in all phases of the project but also can be used efficiently to foresee risks, risk assessments, and risk mitigation.

BIM is proving to be an essential tool or rather say a methodology for bringing drastic changes in the AEC industry. BIM is used for assessing and analyzing document errors, reducing construction cost, reducing project duration and reducing litigation in a very early stage of planning and design. Therefore, even though not being conceptually a risk management tool it can be very essential to reduce the risk events occurring in the design and planning of the project.

As investigated in the above chapters the BIM is central object to the building process and therefore can control the project in a systematic framework rather than the conventional method of architect or project manager being at the center seat and forced to do collaboration and documentation jobs to their regular jobs increasing the risk of loss of data etc.



During the design and planning of the project the design undergoes various changes Although each design change is intended on the parameter to improve the building, it becomes difficult to transport the idea among all stakeholders and judge the change from their perspective. All the changes must also subsequently approve by codes and litigation authorities. BIM technology makes the process fair and transparent and technically riskless.

Conventionally the energy simulations for a building project were carried out at a stage, when all the details of construction are fixed in the project. If the design is changed at this stage, it leads to tremendous loss of time and resources to carry out these changes. Rather BIM facilitates one to have a real time energy simulation result. Not only this BIM can also provide recommendations at an early stage of design for an energy efficient building. This recommendation and design changes can be easily compared with each other to find the right solution.

Managerial risks in the planning and design of the building project can be impactfully reduced if all the data is stored in a single server from where the equal access is given to all the stakeholders. This reduces the risk of data loss and time taken for data logistics. BIM reduced errors and omissions in documents, which enhances the productivity. The possibility of real-time communication makes it even easier for stakeholders to discuss the subject for the benefit of the project without any misunderstandings and confusions which is directly helping cost and risk reductions.

Also, very important is the for the project to document the design changes because, if for some external reasons the stakeholder or consultants are changed they shall be presented the entire project development so far with only integrating then into the BIM model. This is efficiently managed by BIM.

The case study resulted in the overall conclusion that BIM method is a more integrated working process and more efficient in the design phase. However, in order to fully utilize the compatibility, further development of the engineers is recommended. The development could give design skill with BIM for engineers.

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Date

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