POLITECNICO DI TORINO

Master of Science in Civil Engineering

Thesis Title

Implementation of Risk management, Monitoring and Controlling procedures in BIM process

Methodology applied in Italia' 61 Torino metro station project

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ACKNOLEDGMENT

To the soul of my father professor of North Carolina state university who sacrifice his life and career to fight and improve cure of-Magnaporthe oryzae- which is Fungal pathogen the most destructive disease of rice plant worldwide. My acknowledgment is my father acknowledgment when he was a master student in Karolinska Institute in Stockholm Sweden 1985.

''

…. Sacrificing your greatest treasure without thinking about the consequences and focusing instead on making another person happy may not make sense to the average person, but I believe sacrifice for The people we love is part of life , it's supposed to be , it's not something to regret it's something to which we should aspire , sometimes it's the only thing to be proud of , the only thing we've done right ……

''

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ABSTRACT

Building Information Modelling (BIM) technology has been improving in incredible ways in the past few years, and it is considered essential tool in engineering and construction management industry. The perfect execution and application phase of a building project has always been sensitive and critical due to time and financial challenges, but an efficient BIM implementation can overcome those pressures. This thesis provides a guideline of different risks currently affecting BIM process in different aspects and also presents method which could support and help risk managers and engineers to monitor and control time and costs related to different projects by implementing risk management, monitoring and controlling techniques in BIM processes. The goal is providing a complete implementation guideline to make the BIM process effective and more efficient especially in the big construction project, one of the most important technique requires the use of the EVM (earn value management), which is useful to control and monitor projects in terms of costs and delays at any stage. This methodology has been applied to project of Torino metro station Italia 61, part of metro line 1 in Turin. The implementation of EVM has been developed using several software, such as Autodesk Revit, Microsoft project professional, and SYNCHRO Pro to provide a color code at any given stage of the project indicating the state of the project in terms of schedule delays and cost overrun. Furthermore the same model has been used to create another implementation between the same model and RiskyProject software which is a complete made suite software of project risk analysis and tool for project risk management created in the same package of software that integrates and works perfectly with Microsoft Project, and other analyzing ,scheduling and planning tools, and covers the complete risk life cycle. Therefore, RiskyProject generates qualitative risk analysis procedure and risk management as well as quantitative Monte Carlo schedule simulation and cost risk analysis. Thanks to the implementation of BIM process, it was possible to build different scenarios and expected risks that could affect the project in terms of cost and delays then providing the visual result of the simulation to see in real life the effect of different risk scenarios on the project.

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CHAPTER ONE: INTRODUCTION

BACKGROUND

Building Information Modeling (BIM) technology had a major influence on the architectural engineering and construction (AEC)and Facility Management (FM) sector over the last few years. BIM has modified the method of preparation, design, implementation and execution of construction projects (Hardin, 2009) and has provided for more effective cooperation between all stakeholders , i.e. owners, developers, engineers, vendors, subcontractors, etc., throughout the life of the project (Azhar, Khalfan & Maqsood, 2012).

The advantages and popularity of BIM have prompted countries such as Singapore, the United States of America, or certain European countries to embrace it as a mandated public sector help (Eastman et al., 2011; Taborda & Cachadinha, 2012). In the European Union (EU), the Guideline on public procurement adopted on 15 January 2014 promoted the usage of BIM in building projects, so that all EU participants could suggest or even make numerical modeling obligatory for national public projects (European Parliament, 2014). In comparison, the use of BIM has grown dramatically over the last 5 years. This is apparent in the field of civil engineering, where 41% have been utilizing it in the last 3-5 years from12 years earlier, consumers have already established a substantial return on investment in three aspects: 3 dimensional (3D) simulation that offers easier connectivity and interpretation, enhanced architecture and lower costs. The Scandinavian countries became the initiators of the usage of BIM in Europe. Norway and Finland are regarded as the first BIM to follow and serve the two most developed BIM industries. For eg, Senatti, a Finnish state-owned corporation, has demanded that all ventures over EUR 1 million be BIM-based since 2007 (Mc Graw Hill Building, 2014). Germany has recently encouraged the usage of BIM in public markets with the "Planen Baunen 4.0" programmed. Created by national development organizations in February 2015, the goal of the BIM technique is to become a norm for public projects by 2020 (Hochtief ViCon, 2015). Next, in France, the Minister of Housing announced in

2014 a series of steps aimed at simplifying building requirements and ensuring the efficiency of building. One such step aims to make the use of BIM obligatory for public initiatives by 2017 (Le Moniteur, 2014). Thus, beginning in 2017, the design of new public buildings with a surface area of more than 2000 m2 would have to be handled by BIM (Images et réseaux, 2015). That is why the French Government has established a Numerical Transformation Strategy for the Construction Industry (Plan de Transformation Numérique dans le Bâtiment) to support and assist small and medium-sized businesses more explicitly (Dionisi, 2015). Finally, in the United Kingdom (UK), the government has established four stages of BIM maturity for the positive adoption of the BIM (NBS, 2014):

- Level 0 BIM: there is no collaboration. Projects are based only on 2 Computer-Aided Design (CAD) dimensional (2D) sketches. The exchange of data shall take place via paper and/or electronic printing.

- Level 1 BIM: the exchange of data is carried out electronically via the Common Data Environment (CDE). This work is based on 2D or 3D models. There is still no collaboration.

- level 2 BIM: there is a collaboration. Both parties are focusing on 3D CAD templates. It is not necessary that they operate on one single model, however the sharing of design data is done via a standard file format that enables all of them to incorporate their own details.

- Level 3 BIM: optimal complete partnership focused on a specific collaborative concept that is open and modifiable for both stakeholders.

The UK Government has mandated that, as of 4 April 2016, all public ventures be expected to function according to the second stage of BIM maturity (BIM Crunch, 2015).

In the Asian area, BIM projects have been more popular in the hotel industry, e.g. 5-10% of hotel construction projects in India use BIM. However, the high costs of the software and the lack of training are obstacles to the implementation process. In China, despite all its advantages and political will, the widespread use of BIM has proved difficult. It includes the need for improvements in the working patterns of staff. Moreover, apart from lack of experience, Chinese legislation allows the contractor not to engage in the design, which is counter to the concept of interoperability between stakeholders (Images et réseaux, 2015).

The execution process is one of the processes that may affect the use from BIM. This process is one of the most demanding and has often encountered in-situ difficulties such as exploration of design adjustments, defects, delays, etc. Effective implementation of the BIM will dramatically minimize the drawbacks and will be a valuable tool for building managers. The BIM principle can be implemented in a variety of areas: safety, contact between stakeholders, etc. It may also aid, for example, to predict in-situ challenges, such as the disputes of the numerous pipe networks, by testing some of the add-ins to the BIM program that detects these disputes.

Objectives and scope

This thesis offers a deeper insight into BIM and its use in construction management, at the beginning risk summary related to BIM process that can affect the BIM process ,then further examines the feasibility and opportunity of integrating BIM and EVM strategies in order to establish a structure that can offer great help to construction managers throughout the implementation process of the project.

The objective of this study is to create an EVM/BIM tool that allows direct visualization of cost and time performance of construction works in the BIM process, this process could be obtained by inserting some indicators calculated according to EVM principle. In this sense, 4EVM statuses are defined. They specify if the project is behind, or ahead of schedule and over, or under budget.

Also, the purpose of this thesis is to give a deeper insight into the usage of BIM in construction management, focus on managing risk. Risk according to ISO 31000 (2009) covers various facets (e.g. Economic, health, safety, and environmental objectives) that can be implemented at various levels (e.g. financial, Organization-wide, mission, commodity, and others). This research focuses on a particular aspect of Risk which is time and expense threats at project level that have a negative effect.

The process started by realizing the model using Autodesk Revit, then exported to SYNCHRO Pro to made the EVM calculations and analysis that help to monitor the project ,then the process of assigning codes has been made to make a visual color code related to the status of the project in terms of ahead of schedule or behind the schedule, and also in terms of cost like under budget or overbudget ,after that risk analysis has been made to study the effect of risk on the schedule and cost to create new Gantt chart with updated schedule and costs.

METHODOLOGY

The methodology has been applied in construction project of Italia '61, metro station in Torino city to achieve goal of build an EVM / BIM tool to create direct visualization of the cost and schedule output in any phase of the project. This methodology will be accomplished by interpreting certain parameters determined based on the EVM theory. In this context, four EVM statuses are identified. They state if the project is delayed, or ahead of schedule and above, or under the budget.

First a review of the most risks that affecting BIM process has been represented to discuss the importance of overcome those challenges and the impact of underestimating the risk on the BIM process.

Then a literature review is represented to obtain a full description of BIM and EVM theory, as well as current research that incorporate these principles of construction management.

After that, risk management integration in construction project has been discussed in the literature review, to provide a guideline of implementation risk management procedure in BIM process and at the same time on the case of study.

Then in chapter three and four a framework has been described to provide an integration plan to how the implementation has been made, figure 1 describe the framework:

Stage 1

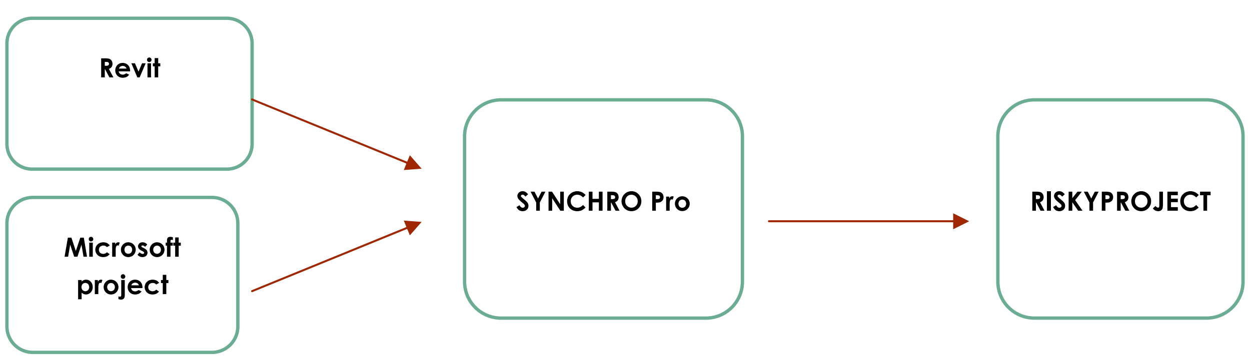


Figure 1- Framework stage 1

In the first stage Revit model has been integrated with SYNCHRO Pro and also the Gantt chart from Microsoft project. In SYNCHRO Pro the process of assigning the tasks to the 3D model, cost details, code formatting, code color assigning and modifying EVM parameters has been made to create color code to 3D model describing whether the schedule above or behind the schedule and over or under budget .After that the new created model exported to RISKYPROJECT software to apply risk management implementation process .

Stage 2

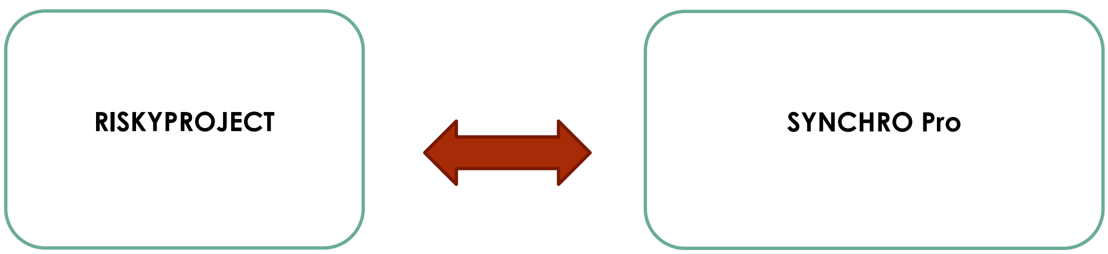


Figure 2- Framework stage 2

Second stage started from importing SYNCHRO Pro model to RISKYPROJECT professional software, in RISKYPROJECT the process of identifying risks , assigning risks to the tasks ,applying risk matrix to software and all other risk management process has been applied and described in detail in chapter four ,the result from risk analysis has been used to create worst case scenario in terms of delay and overrun and applied to the Gantt chart.

New generated chart created from RISKYPROJECT that have new duration and new budget based on worst scenario, that chart exported from RISKYPROJECT to SYNCHRO Pro again to compare the new one (with risks) with the original one (without risk) , in this stage its possible to visualize the effect of risks in the project by comparing Gantt chart ,costs, delays and also 3D model of the two scenarios in SYNCHRO Pro.

The implementation process between SYNCHRO Pro and RISKYPROJECT has been updated at every phase of the project to correct the schedule and costs related to the project till the end of the project.

Chapter five describes the result obtained in deferent stages of the project, also conclusion and final consideration has been described in chapter six, and also the challenges that effect the project. Figure 3 describe the research methodology:

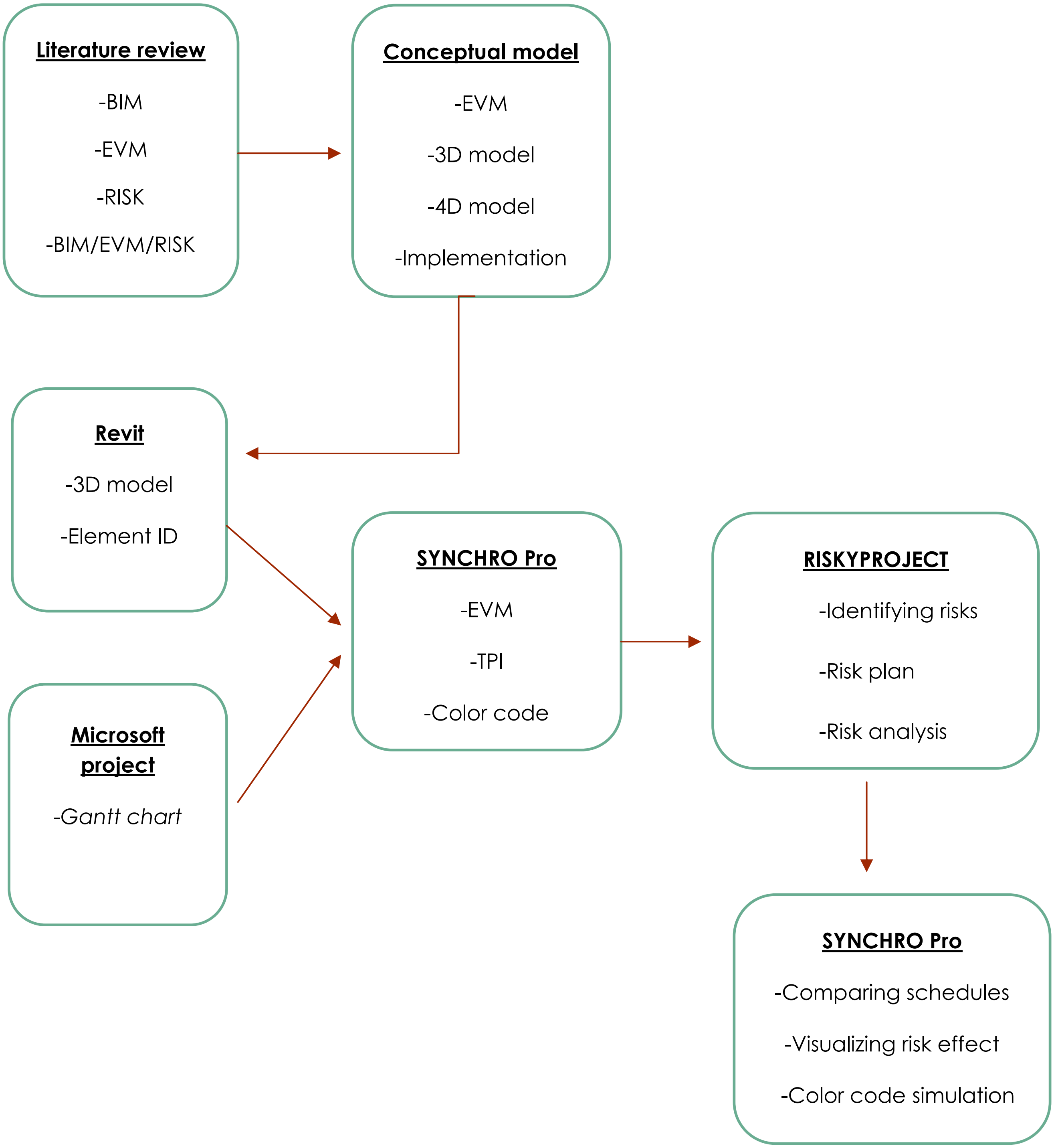


Figure 3- Research methodology

CHAPTER TWO: LITERATURE REVIEW

CASE STUDY

The case of study represent expansion project of Line 1 of underground is currently under construction of Turin, Figure 1 represents Torino metro station line 1. In particular, the extension towards the south along the route Nice, including the construction of two stations (Italy '61 and Bengasi) The “Italia 61-Regione Piemonte” station is located on via Nizza, in the widening between via Valenza and via Caramagna, with the atrium facing north. The east access is in the same clearing as via Nizza, almost parallel to the station body and directed towards the south.

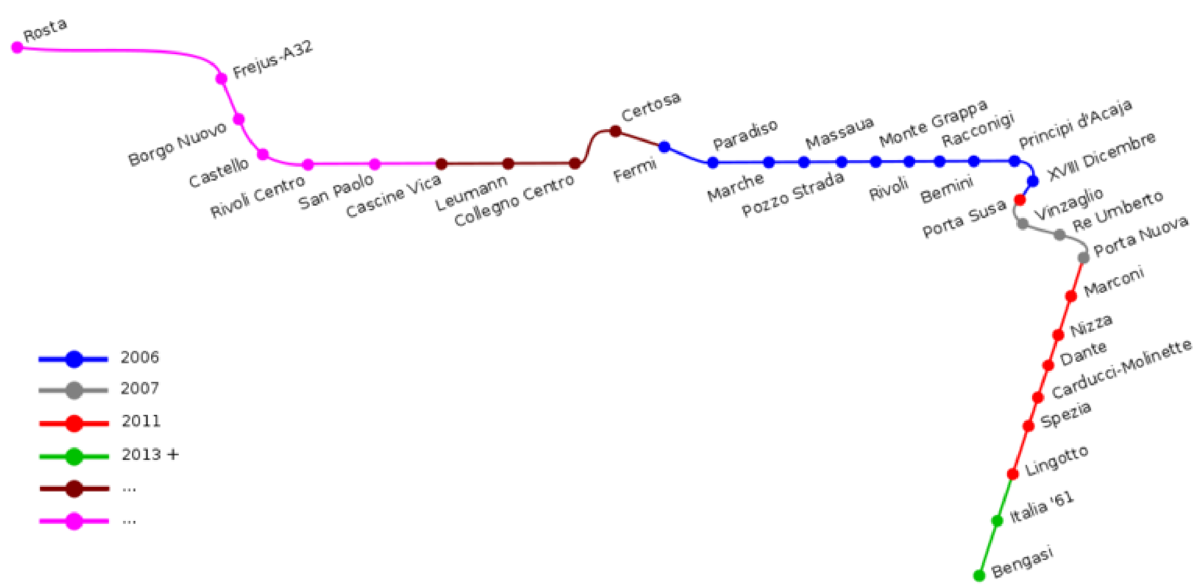


Figure 3-Italia 61 metro station

BIM IN CONSTRUCTION MANAGEMENT

Building Information Modeling is a representation technique for a construction project that collects all details about it during its development cycle. It therefore allows to minimize the expense and time of each step of the project while enhancing efficiency and competitiveness (Azhar et al., 2008). BIM may also be a computational framework that integrates all construction data into a specific platform that makes for more effective and reliable communication between all parties, i.e. owners, builders, architects, etc. Each of them will modify or improve the model in order to render it as detailed as practicable before the start of the implementation (Carmona & Irwin, 2007). In addition, Hardin (2009) points out that BIM should not just apply to an informed 3D model or simulation applications. It is also, according to him, a mechanism that can have a tremendous effect on project management processes or workflow.

The thesis focusses on the management of construction projects, detailed study is then made of the BIM program in this field by analyzing a variety of research cases that demonstrate how BIM can be implemented. From the contractor's point of view, one of the major benefits of BIM usage is preventing in-situ clashes due to lack of communication between the multiple subcontractors and thereby saving time. BIM software will incorporate several resources to detect clashes. This factor is very useful for the MEP (Mechanical, electrical, and plumbing) teamwork, which includes the position of heating, ventilation, and air-conditioning (HVAC) ducts, pipes and electrical racing equipment (Wang et al., 2013). Common technique focused on 2D drawings consists of overlaying and analyzing drawings of-structure in order to define and eradicate spatial and functional intervention. This method is time-consuming and costly (Korman & Tatum, 2006)

Wang et al (2013) proposed a BIM strategy to optimize the configuration of the MEP from the conceptual design to the production process. In the first instance, as many MEP schemes may be given during the conceptual design, they choose the best in compliance with the building conditions and the budget after performing analyzes on the BIM model, such as the Indoor Air Quality Simulation. Second, model clashes are observed using BIM methods. Thirdly, the architecture is configured to ensure that the framework is installed in-situ and to maximize the productivity of the building works. Fourthly, the specification is tested, and the development variance is calculated during the implementation process by contrasting the actual status of the building with the established virtual details. The framework was introduced to the Shanghai Control Center, which has a complicated MEP scheme. The architectural and structural BIM models were designed with the Autodesk Revit and the MEP MagicCAD models. The result is convincing as the method of improving the MEP architecture makes savings of about €200,000 and shortens the 3-month plan, primarily due to the large number of major clashes found that might have contributed to rework. However, the latest calculation approach used was time consuming and labor-intensive (Wang et al., 2013).

In addition, BIM technology increases the productivity of quantity take-offs that are extremely important during the bidding process, for estimating costs. BIM tools will isolate the areas and the volume of spaces, the material quantity of the model components. (2011, Eastman et al.). Manning & Mesner (2008) agreed that this feature is one of the main advantages of BIM's experimentation with the application of BIM in two building projects: a medical testing laboratory and an expeditionary hospital in the United States. However, certain issues can emerge during the process, such as a particular degree of detail in the structural , architectural and building services BIM models or a failure to recognize prior collisions, which could leave the take-offs uncertain (Building Smart, 2012).

Also, with respect to building research and preparation, conventional approaches present drawbacks, such as laborious manual labor, lack of coordination between design and development, or a lack of knowledge of the timing of impacts on site management (Eastman et al., 2011). It is a time-consuming and error-prone manual job (Chevallier & Russel, 1998) primarily due to the absence of technical technologies that support it (Tauscher et al., 2009). However, the utilization of BIM data may help to achieve substantial time reductions (Kim et al., 2013). For eg, Kataoka (2008) has built a structured planning method using the Interpretable Templates (SPLIT) method that produces schedules or 4D visualizations based on 3D models. It generates structural structures for buildings with basic geometry by implementing proven construction techniques. Kim et al (2013) then developed a method to produce an automatic construction schedule by extracting data from a BIM model. In order to accomplish this aim, BIM data is first retrieved. These details relate to the components, position and quantity of each feature of the model and are processed according to their place in the house. Secondly, using the output rates stored in the database, the activities and their period are produced based on the previous knowledge. Third, these tasks are sequenced, and a tentative schedule is then developed in the scheduling program. Finally, the plan received is optimized by professional building professionals. The schedule dependent on the BIM was Successfully used to produce a timetable for two tiny houses. The construction model was developed utilizing ArchiCAD and the scheduling program was MS

Project. However, it only took into consideration specific building elements such as slabs, walls, doors, windows and so on, not all elements were included.

Safety is an essential concern in building sites, but the increasing usage of BIM is shifting the safety and health strategy of the AEC / FM industry (Zhang et al., 2013). Bansal (2011) describes safety preparation as the detection of all possible dangers and the choice of suitable protection steps. Typically, this is achieved independently of implementation preparation, which is troublesome. Indeed, several foreign reports have pointed out the absence of integration between design and protection (Vacharapoom & Sdhabhon, 2009). In this sense, the State Technical Research Center of Finland has established a manual protocol for protection preparation, management and contact with Tekla Systems utilizing BIM technology. As part of the 4D-construction preparation, they were able to imagine the BIM-based 4D protective railing for fall / edge defense (Sulankiv, 2010). In addition, Zhang et al (2013) has established an automatic safety monitoring framework focused on Tekla Systems, concentrating on possible fall hazards such as gaps such as exposed windows or slab holes. The device will classify the holes in the building model and allocate a preventive method to be implemented based on the form of the void. Both attributions are based on the regulations of the Workplace Safety and Health Administration (OSHA). It also includes supplementary details applicable to the decision-maker, such as the expense database for the protection equipment needed based on the quantity of take-offs or the timetable for their installation and removal.

The increased costs and delays induced by miscommunication between project stakeholders are true. The National Institute of Standards and Technology (NIST) of the United States has published a report evaluating the additional costs of insufficient interoperability (NIST & Fiatech, 2006). Gallhaer et al. (2004) describe the above as the capacity to handle and coordinate electronic product and project data within partnering firms and within the planning, development, repair, and business process structures of individual businesses in the construction industry. The findings of the analysis found that around $\$15.8 \times 10^9$ (€14×10^9) a year was wasted due to lack of interoperability in American capital facilities.

RISKS IN DEALING WITH BIM PROCESS

Building Information Modeling (BIM) implementation entails a variety of threats that discourage users from achieving possible advantages. The aims of this analysis are to define the risks connected with the application of BIM.

Building Information Modeling (BIM) has changed design, building and construction Industry in several countries (Azhar, 2011), therefore they obtained growing attention from both researchers and to the practitioners. Application areas of the BIM spread in large scale like location analysis, concept options analysis, and 3D presentation. Including also concept of teamwork, cost estimate, energy modeling, clash identification, building method plan, schedule analysis, quantity take-off, building efficiency forecasting and the off-site processing. This research also reported a variety of advantages that can be obtained from BIM process. The table below represent an overview of deferent risks affecting BIM process:

Type of risk	source	Risk	citation
Internal risk	Owners	Change of the design	
Internal risk	Designers	Designing mistakes and drawing mistake	Peckien & Ustinoviius, 2017; Kelly & Ilozor, 2016; Al Hattab & Hamzeh, 2015
Internal risk	Contractors	Construction accidents Poor quality Low productivity	Peckien & Ustinoviius, 2017; Bråthen & Moum, 2016; Kim, Cho & Zhang, 2016; Barazzetti et al., 2015; Whong & Zhou, 2015; Chen & Luo, 2014; Bryde et al., 2013; Zhang et al., 2013
Internal risk	Suppliers	Delays of materials supplies	Irizarry et al., 2013
External risk	Physical economic	Unexpected weather Materials process increases	

Table 1: An overview on how BIM is addressed for managing risks in construction projects

Many types of organizations are dealing with internal and external factors that makes it unclear whether they can accomplish their aims or not. The impact of this instability on the company Objectives are called 'Risk. ISO 31000 (2009) defines risk as 'the impact or uncertainty on objectives' (p.1). Van Well-stam et al. (2013) Say that a risk is an event that may or may not occur which can result in: increased prices, increasing of the length of the Projects that do not satisfy the quality, information or company requirements. Serpella et al., 2014) Describes risk as an umbrella word for two varieties; an opportunity that is a danger of beneficial effects; And a threat that is a risk of negative effects. Tomek & Matějka (2014) plotted these varieties in a plot Diagram (Figure 2) along two dimensions of the risk. The first dimension is the chance, which implies the uncertainty, the probability that an incident would occur. The second factor is the effects, i.e. Severity of impact in the event of a risk scenario. The sum of the probability of danger and the consequences Results in generating a level of risk. The risk matrix is where the level of all known threats is plotted. A diagram in which the two dimensions are defined by the axes of the two diagrams. All essential risk relationships Graphically seen in the vertical middle panel.

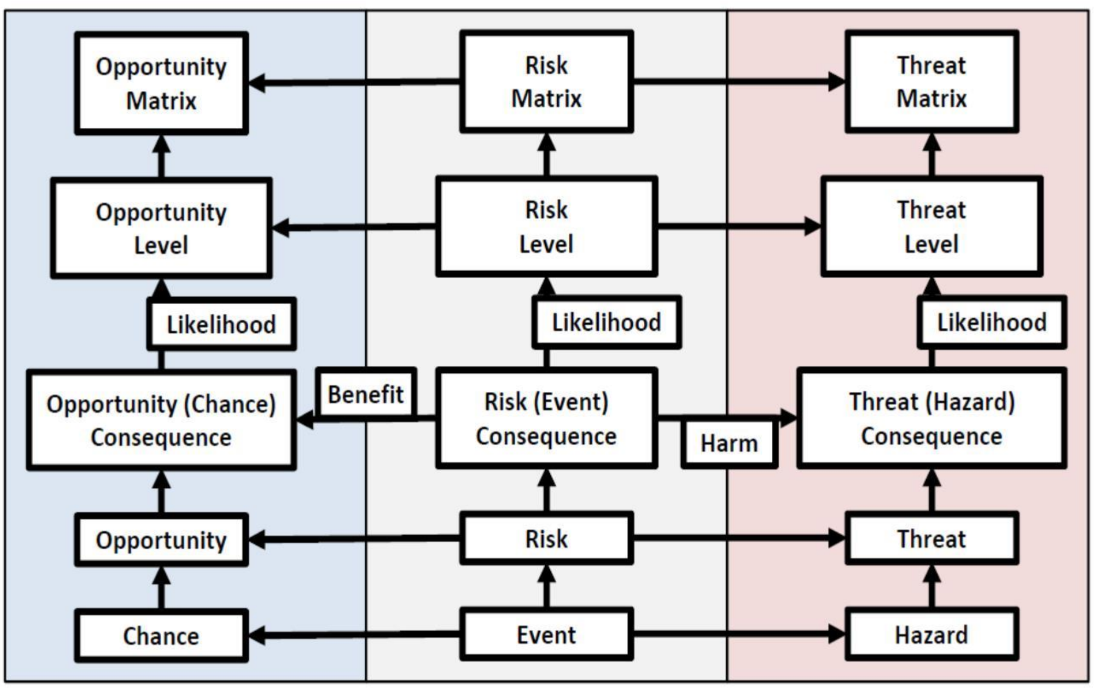


Figure 4 - Relation in risk terminology (Tomek & Matějka 2014)

Risk is defined by the Project Management Institute (2008) as 'an unknown event or situation Which, whether it happens, has a beneficial or negative impact on the objectives of the project

(p. 446). Kliem and Ludin (1997) Have a common concept for project risk, that is the occurrence of an incident have consequence or Effects on projects This demonstrates that the risk often has a relation to the final target of the project, the same as the impact and uncertainty too. According to Keizer et al . (2002), project operation is viewed as dangerous when:

• The probability of a bad outcome is high.

• The capacity to remove the impact of the risk under the time and cost constraints is small.

• The future implications are severe.

Halman (2008) describes project risks as special and dynamic, which means that the project is a complex project, infrequently arising dynamic risks. This implies that the threats to the project must be determined subjectively and It may be disrupted throughout the process.

CATEGORIZATION OF RISKS

Risk analysis focused on the base of the ISO standard relates to the interpretation of the risks involved, Effect and probability of those consequences. The risk identification, based on the circumstances that can be qualitative or quantitative, Qualitative risk management is defined as a method of prioritizing threats for further analysis, while Quantitative risk assessment is the method of empirical review of the consequences found on Risks and the effect on the project. A quantitative risk analysis is usually followed by a qualitative analysis. In certain situations, there is little requirement for comprehensive analyses in order to determine appropriate risk control Factors for the selection of the method(s) to be utilized. This is the different risk levels are based on the following properties (Halman, 2008):

• Capacity to assess (objective or subjective).

• Capacity to influence.

• Frequency of incidents.

Table 2 offers a description of all the related activities, of regular threats are statistically observable as there is sample historical evidence available. Infrequent threats are subjective and measured in the basis of perceptions (Halman, 2008).

	Frequent	**Infrequent**
Static (gamble vision)	Objectively measurable For example: unworkable days in a construction planning	Subjectively measurable For example: buying a share in a stock market
Dynamic (management vision)	Objectively measurable For example: quality procedures in a process industry	Subjectively measurable For example: project management

Table 2 - Risk categorization (Halman, 2008)

Serpella et al. (2014) and Banaiten & Banaitis (2012) describe risk management as: 'the process of recognizing and evaluating risk and implementing measures to minimize it to a reasonable level.' This must be achieved with the intention of recognizing, assessing and managing threats within a project that can contribute to the completion of the project. Marcelino-Sádaba et al. (2014) describes risk management as follows: 'risk management is a structured mechanism aimed at recognizing and handling risk in order to respond on it (eliminating, mitigating or monitoring it) through implementing processes and procedures for detecting, assessing, reviewing and resolving risks inherent in each project' (p. 329).

Risk management can be implemented in order to provide a good understanding of risks, to enhance the project management process and to allow optimal usage of resources (Banaitiene & Banaitis, 2012). Centered on Sousa, et al . (2012) Risk assessment is used to minimize ambiguity in building projects to satisfy the expectations of stakeholders. According to Marcelino-Sádaba et al. (2014), risk management can lead to the understanding of project priorities, improve project monitoring, increase the performance rate, improve communication with project partners and promote decision-making and prioritization of activities.

Based on the similarity in the meanings, it can be inferred that risk management is a systemic and cyclical method for defining, evaluating, and eventually handling threats. The purpose of this can be described in terms of time, resources, and efficiency, but also in terms of enhancing cooperation with stakeholders in the project.

APPLYING RISK ON CONSTRUCTION PROJECT

The risk assessment method involves standard risk principles, terms, and procedures (Jamieson & Jones, 2013). The phase starts with the recognition of the background, beginning with the planning of project objectives, the identification of success indicators, the evaluation of stakeholder relationships and the identification of the danger zone. The first phase in risk management is to define risks, their risk factors, and types of risk. The second element addressed by the risk assessment is 'risk analysis,' in which defined threats are measured by likelihood of occurrence and potential impact. The third factor is the prioritization of danger and the identification of the threats towards which action is required. Following these three elements, risk assessment often discusses the cause of threats, including approval, mitigation, reduction or exclusion, or transfer and sharing of threats. Figure 3 displays a schematic of the aspects mentioned. In addition to these measures, coordination and consulting play an essential role in the process. Stakeholder input is needed to accomplish the aims of the project, ensure participation, and share risk details. Monitoring and control examines improvements in risks and the creation of emerging threats related to developments in the global climate, risk assessment and mission objectives (Scannell et al., 2013). The highest degree of uncertainty about the future occurs in the initial step of the project (Uher & Toakley, 1999). It is Necessary in the implementation of risk management to be done from the initial stage of the project precisely because, at that level, greater control may be exercised on choices in the coordination and selection of construction methods (Banaitiene & Banaitis, 2012). It is necessary for the application of risk management to be clear who is accountable for carrying out risk management and at what stage priority should be given to it. According to Gehner (2008), risk assessment can be carried out at all time and involves strong coordination between the project manager and the relevant project team members.

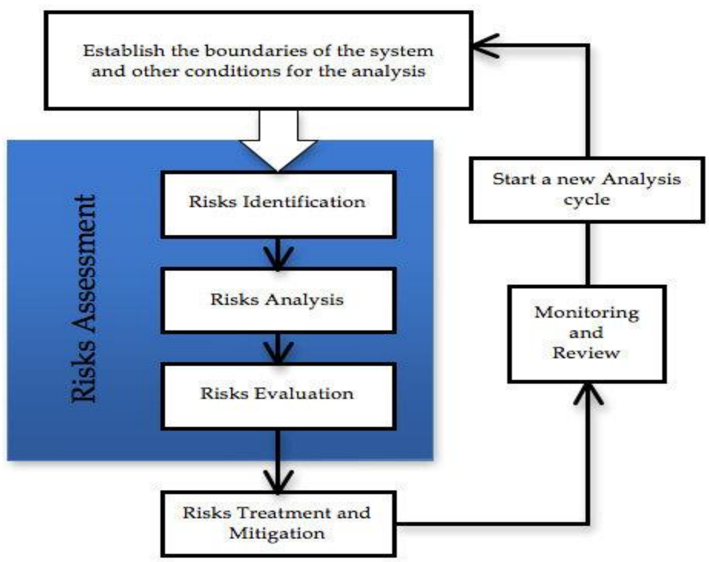


Figure 5- Risk management process (iso 31000,2009)

Risk identification

Risk identification is the process of defining, understanding, and explaining risks. This includes understanding the origins of threats, incidents, their triggers, and their possible effects. In this phase, historical evidence, statistical research, educated and expert views and the interests of stakeholders (ISO) may be assessed.

(31000, 2009) Yes, Purdy (2010) states that risk identification requires a structured method to consider what could happen, how, where and why. Van Well-Stam et al. (2013) adds that the project can be approached at in a comprehensive way and from various perspectives to ensure that the risk detection is as complete as practicable. The aim of the identification process is to identify sources of risk, areas of influence, incidents (including changes in circumstances) and their triggers and possible effects (ISO 31000, 2009). Risk identification is an iterative method so new threats can emerge or become identified with the development of the project (Project Management Institute, 2008). However, when defining risks, a remark should be made. El-Sayegh (2008) states that defining all threats is time-consuming and may function counter-productively. The key is to recognize and monitor the most important threats in the building project.

RISK ANALYSIS

The purpose of the risk analysis is to assess the effect of the risk factors on the framework. Risk analysis entails consideration of the causes and origins of risk, their positive and negative outcomes, and the possibility that these effects can arise (ISO 31000, 2009). Several methods are required to define and/or assess various threats. As stated earlier, threats may be evaluated quantitatively and qualitatively, but organizations prefer to use qualitative evaluation methods to classify threats because expert advice is the best tool available (Ahmed et al., 2007). Several literature methods commonly used for project planning can also be used for risk analysis, see Table below.

Tool	Description	Sources
Estimation of project reliability	In a project, most of the elements are integrated together in a serial or parallel way. The project reliability is established as the cumulative effects on its critical components.	• ISO 8402 • Ahmed et al., 2007
Event tree analysis	In an event tree analysis, a sequence of events that could occur is identified that represents the possible scenarios in a tree diagram where each branch represents an alternative possibility. The probability of occurrence of a particular outcome is determined as a product of all probabilities of occurrence in the associated branch.	• Chapman & Ward 2004 • Ahmed et al., 2007
Fault tree analysis	A fault tree analysis works in the same way as the event tree analysis but then in a reversed way, working backward from a particular event (the top-level event) that might occur. From that point, the analysis is worked down by passing through logical gates to identify all possible sequences of events that lead to this top-level event. In the end, this analysis gives an overview of the risks in the overall project and the specific components in the lower levels.	• Ahmed et al., 2007 • Chapman & Ward 2004
Decision tree analysis	Decision tree analysis is used to evaluate outcomes from uncertain events. By using decision nodes, future managerial decisions can be made after some uncertainty has been resolved and more information has been obtained, before proceeding to the next stage. It includes probability of returns associated with decisions and estimation of expected returns.	• Ahmed et al., 2007 • de Reyck et al., 2008
Portfolio management	Portfolio management compares risks of multiple projects in terms of investment and returns. Projects are positioned on a graph with on the horizontal axis the magnitude of risk, and the on the vertical axis the magnitude of the return. Projects with a high risk and low return are placed at a different position than low risks with high return allowing managers to take better decisions based on the company's strategy.	• Ahmed et al., 2007 • De Maio et al., 1994

Multiple criteria decision-making method	Multiple criteria decision-making method considers the negative and positive factors of a decision. These project attributes are weighted according to predefined criteria. The product of the relative weight and the score for an attribute gives a weighted score for that attribute. The project is then evaluated through a difference from a standard project attribute. If the total weighted score is positive, the project should be selected, if the score is negative the project should be rejected. This technique can be applied to risk analysis if risk events are compared to standard events and weighted against them.	• Ahmed et al., 2007
Failure mode effect analysis (FMEA)	FMEA provides a structure for determining causes, effects and relationships in a project. FMEA is used to define, identify and eliminate known and/ or potential failures, problems, errors and so on from a system/\, design, process and/ or service so that solutions for rectifying these problems can be visualized.	• Ahmed et al., 2007 • Chin et al., 2009

Table 3- different method to risk analysis

Earned Value Management (EVM) is a management approach employed in a number of fields, such as the Information Technology (IT) project or building programs, with the goal of tracking the expense, schedule and technological efficiency of the project (Fleming & Koppelman, 2005). One of its key applications is project expense and time estimation using performance indexes (Kenley & Harfield, 2015). It is an early indicator of output issues when correctly implemented (Abba, 2001).

It is based on the representation in the cost-time graph of three S-curves. Each curve reflects the accumulated data for a given parameter. Project Management Institute (PMI) (2005) describes the following three feedback parameters:

- Planed Value (PV) or Budgeted Expense of Work Scheduled (BCWS) or Performance Measurement Baseline (PMB). Dependent on the working plan, the expected expense of the project work is to be carried out at some point in the timeline. PV is the Budget at Completion (BAC) equivalent to the overall budget standard for the operation (Anbari, 2003).

- The Actual Expense (AC) or Total Cost of Work Performed (ACSW) which reflects the sum of money required to accomplish the actual work performed. It needs a framework for monitoring costs over time and by project component.

- The Earned Value (EV) or the Budgeted Cost of Work Performed (BCWP) which reflects the sum of work performed to or within a specified time.

The PMI (2005) suggests various approaches to test the EV. The strategies rely on the length of the operation and the tangibility of the product. For example, with set formulas X / Y, X percent the work is assumed to be full for the calculation duration in which the work starts without paying attention to how much is already completed. The remaining Y percent is awarded after the job is completed. It is more suited for short-term activities with a visible commodity. Another strategy called a weight milestone, which is ideally tailored to a long-term mission of a concrete object, splits the job to be completed into parts. Any of these segments would conclude with a measurable landmark. The EV shall be awarded with the achievement of each phase. However, the best and quickest strategy is to calculate the percentage of work completed: the percentage of work done is decided by the accountable manager for each assessment point.

the three inputs enable time and cost indexes to be measured, and their analysis offers details on the timing and cost output of the current project at a given period, as well as forecasts. Table 4 introduces and demonstrates the significance of the key EVM metrics.

Project Management Question	**EVM Performance Measures**	**Interpretation**
Time analysis and forecasting: How are we doing timewise?		
Are we ahead or behind schedule?	Schedule Variance (SV) SV = EV – PV	SV < 0: behind schedule; SV = 0: on schedule. SV > 0: ahead schedule.
	Percentage (SV%) SV% = SV/PV	The project is SV % behind/ahead schedule.
How efficiently are we using the time?	Schedule Performance Index (SPI) SPI = EV/PV	SPI < 1: schedule performance is poor; SPI = 1: schedule performance is efficient. SPI > 1: schedule performance is excellent. On average for each month worked on the project, considering 20 working days, only 20*CPI days' worth of the planned work is being performed.
When are we likely to finish work?	Time Estimate at Completion (EACt) EACt = (BAC/SPI)/(BAC/total duration) = total duration/SPI	The work is likely to finish at EACt assuming a constant SPI.
Cost Analysis and Forecasting: How are we doing cost-wise?		
Are we under or over	Cost Variance (CV) CV = EV - AC	CV < 0: over budget. CV = 0: on budget; CV > 0: under budget.

budget?	Percentage (CV%) CV% = CV/EV	The project is CV % over/under budget.
How efficiently must we use our remaining resources?	To Complete Performance Index (TCPI) TCPI = (BAC – EV)/(BAC – AC)	To achieve the BAC, the CPI for the remaining work must improve to TCPI. It helps to determine how efficient must be the remaining work to meet a specific endpoint.
How much is the project likely to cost?	Estimate At Completion (EAC) EAC = BAC/CPI	Assuming that the CPI remains constant for the duration of the project, the project is likely to cost at completion $EAC.
Will we be under or over budget?	Variance At Completion (VAC) VAC = BAC - EAC	VAC < 0: over budget at completion; VAC = 0: on budget at completion; VAC > 0: under budget at completion.
	Percentage (VAC%) VAC% = VAC/BAC	There will be an additional cost of VAC% of the initial cost.
What will be the remaining work cost?	Estimate To Complete (ETC) ETC = (BAC – EV)/CPI	Assuming a CPI constant, the remaining work will cost $ETC.

Table-4 key EVM metrics

CHAPTER THREE: IMPLEMENTATION OF EVM IN BIM

EVM WORKING STEPS

Antvik & Sjöholm (2012) suggested an important solution to the implementation of the EVM definition to the project. They also identified 10 EVM Phases to be recognized in the Integrated Project Management Phase. These measures may be separated into two sections. The first section deals with the preparation process of the project which includes 6 phases, from the description of the goals to the timing of the project and its projected costs. The second component, which includes four phases, deals with the implementation process of the project, and focuses on the computing of basic EVM details.

Stage 1: Identifying the priorities of the project:

This first phase consists in identifying and outlining the goals of the project based on the desires, criteria, and goals of the various stakeholders (Antvik & Sjöholm, 2012). Kerzner (2009) points out that each project must have at least one specific purpose understood to all stakeholders interested with the project. Otherwise, the project will not work if it is not explained.

Stage 2: Specifying the scope:

According to the PMI (2013), the key benefit is the commitment of a clear scope. It provides input and feedback to all stakeholders on the success of the project. The scope description method consists of the study and perception of the three main factors expense, time, and quality. In order to provide a proper and correct framework, the manager must take into consideration the desires and expectations of the stakeholders. The EVM is focused on a detailed task Breakdown Framework (WBS). It offers the appropriate framework to monitor the progress of the project to allocate the completion of sections of the project (Kenley & Harfield, 2015). WBS is an effective strategy that lets the management team evaluate the task by decomposing all the work to be done into tiny items called work packages. These bundles are also simpler to handle and monitor. (PMI, 2008; Antvik and Sjöholm, 2012). WBS collects structured project details that involves job summary, tools available, quality requirements, and so on. Job that is not available in the WBS is known to be beyond the reach (ed. PMI , 2013).

Stage 3: Description of the Breakdown mechanism of the company:

The Company or organization Breakdown Structure (OBS) is then defined and typically displayed as an organizational map. The PMI (2008) describes it as a description of a project organization that relates task packages to functional groups, teams, or divisions. It determines the job aspect has been allocated to which person.

Phase 4: Description of the Matrix of Responsibility:

The Assignment responsibility Matrix (RAM) is a coordination mechanism that binds the duties and obligations of the project to the nature of the project by linking OBS i.e. project team members to WBS i.e. tasks or job packages. It also means that everyone has been given the entire scope and that there is no limitation (ed. PMI, 2013; Antvik & Sjöholm, 2012).

	PERSON				
ACTIVITY	**Ana**	**Ben**	**Carlos**	**Dina**	**Ed**
Definition	A	R	I	I	I
Design	I	A	R	C	C
Development	I	A	R	C	C
Testing	A	I	I	R	I

R = Responsible; A = Accountable; C = Consult; I = Inform

Table 5 – Example of a RAM (Adapted from ed. PMI,2008)

Phase 5: Scheduling:

A schedule results from all the prior phases. The PMI (2008) describes the creation of the schedule as a mechanism that analyzes the sequence of events, their length, the resources needed and the time constraints. The plan can be described in several formats: collection of events, Gantt charts, network arrow events, network node activities, etc. (Sousa & Almeida, 2015).

Stage 6: Identification of the planned value:

After the creation of the WBS, it is simple to find the costs of each project operation (Chitas, 2014).

Stage 7: Assessment of actual costs:

Assignment of the actual cost to all tasks in all phases.

Stage 8: Determination of the results obtained:

According to Antvik and Sjöholm (2012), the success obtained relates to the analysis currently carried out or carried out.

Stage 9: Calculation of the Earned Value, i.e. the Achieved Output Worth.

Calculation EV and all other parameter attached to it.

Stage 10: Analysis:

The process consists of the description of all the parameters listed above, including the research of the S-graphs obtained or of the EVM indicators.

Example:

Anbari (2003) provides an example of the implementation of the EVM method to a project budgeted at $100,000 at completion. The overall time scheduled is not provided, but it is estimated to be 10 months. Table 4 describes the WBS and the EV at the period T. The EV was collected using a percentage of the completed process. The related EVM graphs as displayed in Figure 3. In this scenario, at the time of T

- PV = $50,000.
- AC = $60,000.
- EV = $40 000.

it can be shown that, on the one hand, the value earned is below the period baseline. So, the period T project is behind budget. On the other side, the real expense is over the amount received, which means that the project is outside the target. The estimation of metrics allows it easier to measure delays and additional costs. The analyses and their explanations are listed in Table 6.

Project ($)	**Budget**	**%Completed**	**Earned Value**
Phase 1			
Work Package 1.1	20 000	100	20 000
Work Package 1.2	40 000	50	20 000
……			
Phase 2			
Work Package 2.1	…		
Work Package 2.2	…		
……	…		
……	…		
Total	100 000		40 000

Table 6– WBS and determination of the Earned Value at a given time T (Adapted from Anbari, 2003)

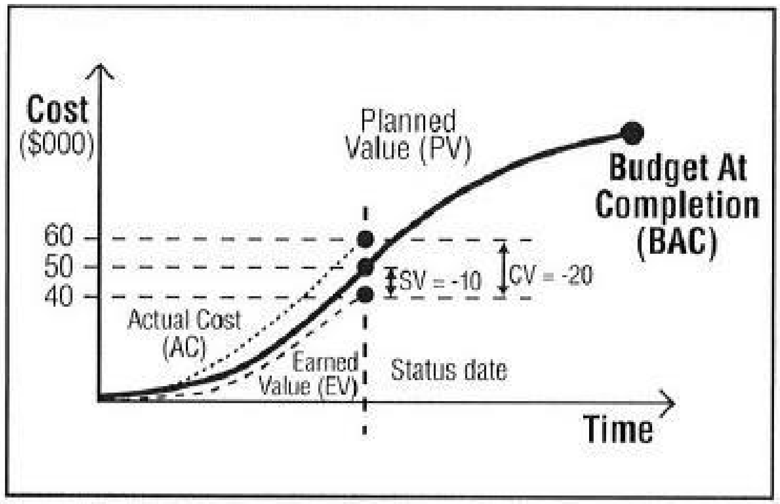


Figure 6 – S-curves of PV, AC, EV at a given date T (Anbari, 2003, p14)

Values of EVM Performance Measures	Interpretation
Time analysis and forecasting	
<u>Schedule Variance</u>: SV = EV – PV = 40,000 – 50,000 = -$10,000	SV < 0: The project is behind schedule.
<u>Percentage</u>: SV% = SV/PV = 10,000/50,000 = -20%	The project is 20% behind schedule.
<u>Schedule Performance Index</u>: SPI = EV/PV = 40,000/50,000 = 0.80	SPI < 1: The schedule performance is poor. On average for each month worked on the project, considering 20 working days, only 16 days worth of the planned work is being performed
<u>Time Estimate at Completion</u>: EACt = months/SPI =10/0.8 = 12.5 months	The work is likely to finish at 12.5 months assuming a constant SPI
Cost Analysis and Forecasting	

Cost Variance: CV = EV – AC = 40,000 – 60,000 = -$20,000	CV < 0: The project is over budget.
Percentage: CV% = CV/EV = 20,000/40,000 = -50%	The project is 50% over budget.
Cost Performance Index: CPI = EV/AC = 40,000/60,000 = 0.63	CPI < 1: The cost performance is poor. The project has an efficiency which provides $0.63 worth of work for each dollar spent in the project to date.
To Complete Performance Index: TCPI = (BAC – EV)/(BAC – AC) = (100,000 – 40,000)/(100,000 – 60,000) = 1.5	To respect the BAC, the remaining work must improve from 0.63 to 1.5.
Estimate At Completion: EAC = BAC/CPI = 100,000/0.63 = $150,000	Assuming that the CPI remains constant for the duration of the project, the project is likely to cost $150,000.
Variance At Completion: VAC = BAC – EAC = 100,000 – 150,000 = -$50,000	VAC < 0: The project will be over budget at completion.
Percentage: VAC% = VAC/BAC = 50,000/100,000 = 50%	There will be an additional cost of 50% of the initial cost.
Estimate To Complete: ETC = (BAC – EV)/CPI = (100,000 – 40,000)/0.63 = $90,000	Assuming a CPI constant, the remaining work will cost $90,000.

Table 7 – EVM indicators of the example

EVM/BIM Process

A research project of 50 foreign design construction professionals showed that EVM and BIM are perceived to be two of the most prevalent project control methods (Kenley & Harfield, 2015). Several experiments have demonstrated the ability to merge the two principles of construction management. For example, in Poland, Foremny, Kluczuk & Nicał (2014) have developed a Mobile Earned Value Management System (MEVMS) to increase the speed and quality of the on-site monitoring schedule and costs with the MS Excel interface and to assist the customer inspector who is one of the stakeholders in the construction projects in Poland. It may be found in emerging technologies such as smartphones or laptops. The user has to enter the core system to process all input data,i.e. EVM details (AC, PV and EV) and specification papers, including schedules, costing estimates and sketches. Outputs obtained are EVM indices, graphs and tables and are transferred directly to the client. The case analysis of the Warsaw office building design project shows positive EVM performance with the project ahead of budget and that the MEVMS was a helpful method for the client's inspector. However, a laborious manual entry of data into the device center was discovered, which was achieved in this case using Google Drive and MS OneDrive.

With a different method in Japan, Kim et al (2010) has programmed a 5-dimensional (5D) EVM-based mechanism that enables real-time plan and real-time costs to be calculated concurrently by scheduling and controlling costs. It was used in the sense of the building of a bridge in Seoul (2nd Guemgang Bridge: 2008-2011). The BIM framework was used to model the project in 3D, so that it could help identify clashes, schedule, schedule, and so on. The 4th and 5th dimensions are focused on the Received Value Management Method (EVMS) for expense and time success measurement. It consists of a sub-activity WBS and a cost-breakdown structure (CBS) at the cost object unit. Uploaded every month, this is the input info. When the 5D device is operating, this interface displays the 3D model, the model elements display, the Gantt chart and the EV map in separate windows. Simulations of the timetable may also be operated with a set of colors that illustrates the timetable state. There are different colors for elements related to delayed or completed activities or activities which, for example, have not begun.

Marzouk & Icham (2014) begun to integrate the Bridge Information Modeling (BrIM) with EVM, which they described as an intelligent representation of bridges gathering all the information required for bridges over their entire life cycle. They introduced a BIM-based cost estimating framework that incorporates the EV principle to manage costs and time during the implementation process of the project. The cost estimate is based on two modules. The first is an estimated cost estimating module, which is based on the quantity derived from the BrIM model to the MS Excel register. It multiplies these quantities by their equivalent unit costs, which could be either the default values in this module or the user's input. The second is a detailed cost estimation module that integrates BRIM with bridge construction knowledge related to labor and equipment productivity, material costs, and labor and equipment rates. It does, however, only cover direct costs (equipment, materials, and labor) and not Indirect (taxes, taxation, etc.). With regard to the EV aspect, it is important to note that there is one module which aims to determine the performance at any date by using the EV concept at two levels of utilization: the task level or the element level. It is based on control accounts in which data on costs and time can be obtained and maintained (Figure 5 and Figure 6).

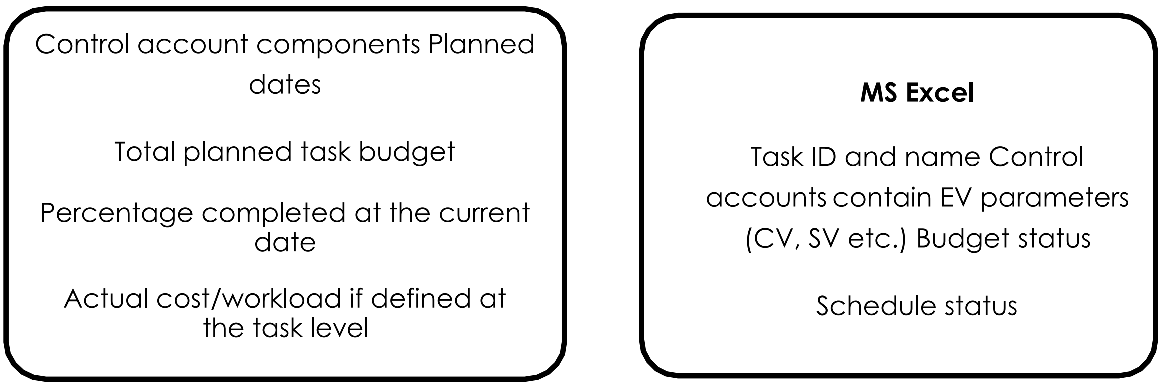


Figure 7– Process at the task (Adapted from Marzouk & Icham, 2014)

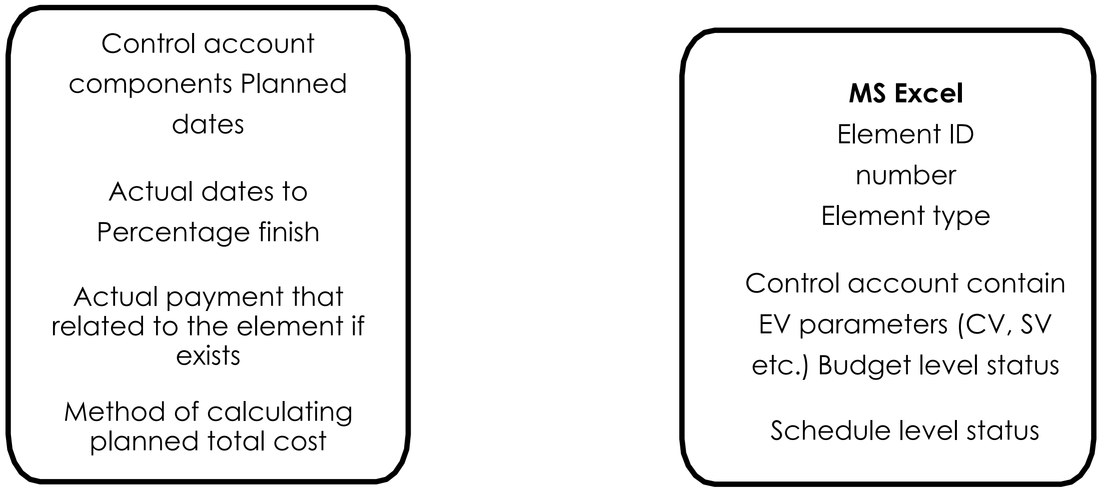


Figure 6 – Process at the element (Adapted from Marzouk & Icham, 2014)

As the monitoring process is a manual operation and submitted to a personal judgment that increases the likelihood of incomplete and imprecise reporting, researchers are trying to find an automated way to track it, Several innovations have potential to be used and could be associated with BIM and EVM: Radio Frequency Identification (RFID), Global Positioning System(GPS), Ultra-Wide Band (UWB), Photogrammetry and 3D laser scanning (Bosché et al., 2014). Laser scanning was the best technique accessible to collect 3D details on a quick and precise project in the AEC / FM region (ibid.; Huber et al., 2010; Jacobs, 2008). One of its key uses is the reconstruction of as-built 3D BIM models from acquired 3D point clouds: 'Scan-to-BIM.' When the laser scans of the building sites are linked to the 3D BIM models and the 3D model artifacts can be identified automatically, they are named "Scan-vs-BIM." Turkan et al (2013) used the following concept to track the design of houses. The concept is to search the building regularly using a terrestrial laser that gives 3D point clouds and hence provides data on the built-in status. These clouds are compared with a 4D BIM model built in the same coordinates system, based on the as- planned status of the construction project over time which lead to identification of the as-built artifacts helps Assessment of success of the project. the plan may be revised periodically as well as the EV indices, The EV research is carried using the cost Accounts (CA) method, where CA are the WBS components used for accounting (ed. PMI, 2008). Both contributions of each form of project work for a specified period are contained in a CA: real costs, initial cost forecasts, content size, and labor. Thus, after 3D recognition, the quantity of each object can be calculated using BIM in terms of weight or volume. Since each object belongs to a CA, EV parameters and project performance indices can be computed using the CA input data. Two case tests, rendered on a steel framework and a reinforced concrete framework, showed that object recognition attained, on average, 93 percent accuracy on steel and 100 percent on concrete. However, even though it does not have a large effect on EV outputs, clouds are not suited to small-scale elements and minor delays are difficult to spot.

Although the elements of the MEP represent a critical problem owing to its significant proportion of construction costs, Bosché et al (2014) has repeated the experience of monitoring them. They tested the efficacy of the Scan-vs-BIM method applied to MEP works. As before, the goal here is to compare as-built state capture in the form of 3D point clouds with the predicted state of the BIM model. It is not as definitive, though, as with the systems, Indeed MEP elements may present more variations than structural elements due to their flexibility and variability during installation The case study carried out at the Department of Chemical Engineering of the University of Waterloo, where they were installed using the traditional method, showed that the system does not appear to have well recognized the installed MEP elements. Confidence levels are approximately 50 percent, while structural elements are higher than 80 percent, in reality this monitoring technique could be more suited to prefabricated elements.

The research work developed considers existing literature and proposes an innovative approach to support construction managers during the implementation phase of the construction project. The possibility of a correlation between BIM and EVM information utilizing the BIM paradigm as visual support has been exploited to automatically transpose the effects of the EVM study with the assistance of a color code scheme.

The structural phase of the case study has been made by Autodesk Revit, describing the full 3D view of the structural model of the metro station, all element family in Revit linked to element ID that will be used later in linking the element with the tasks in the implementation process.

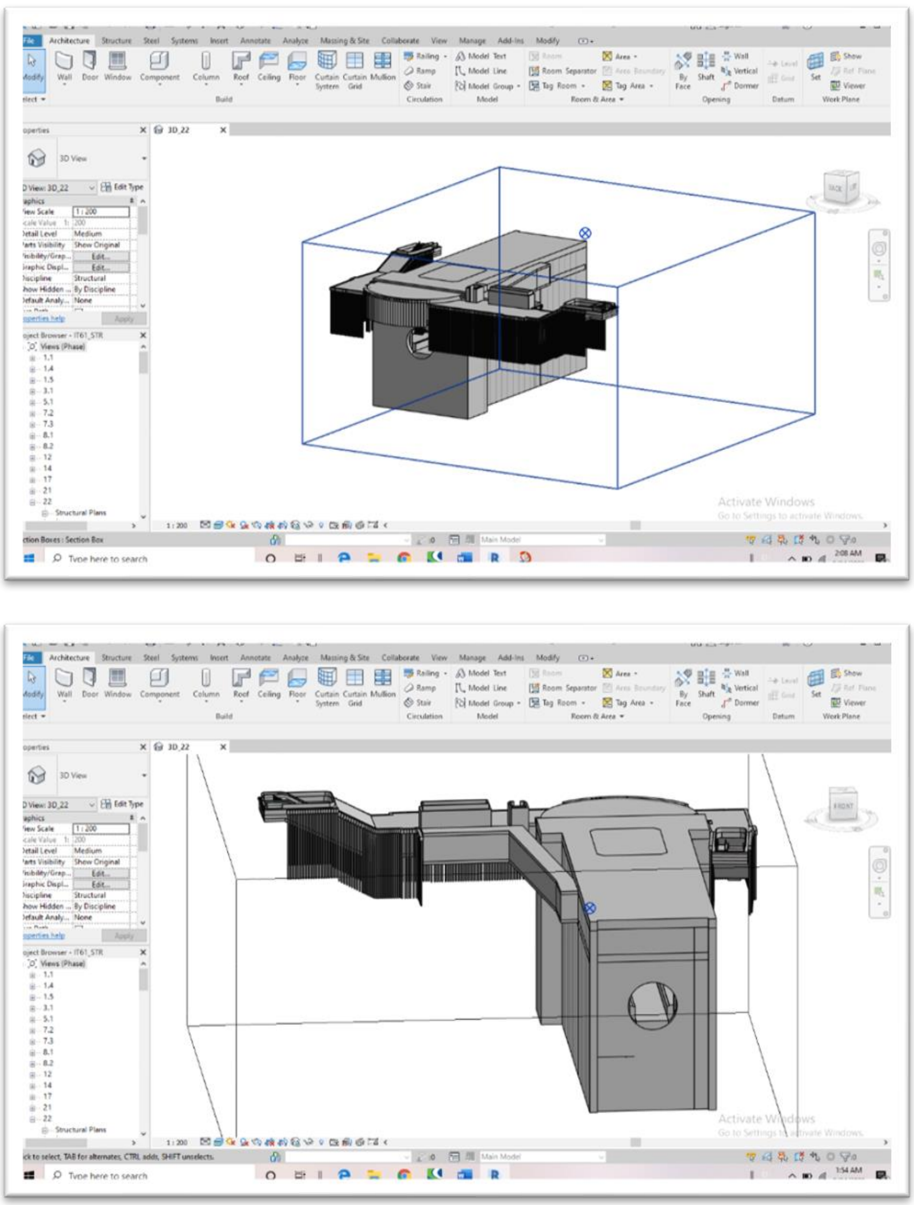


Figure 8- 3D model of Italia 61 metro station in Revit

After creating the Revit model (Revit model has been created in previous research from Politecnico Di Torino), the Gantt chart created using Microsoft project professional 2016 (created by Alessio Giovine) describing all the tasks related to the structural model with duration planned. Gantt chart describe the path of the project and the critical path that can affect the progress and delay of the project.

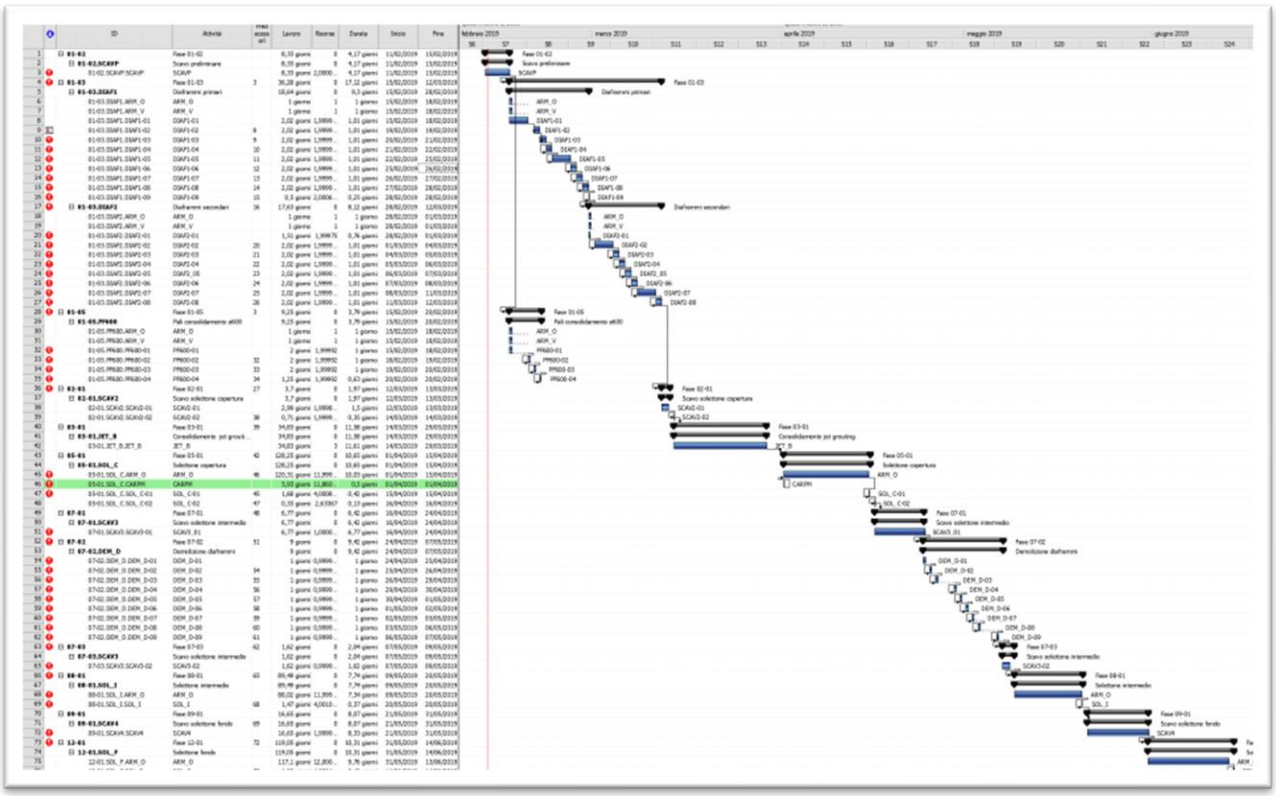


Figure 9- model Gantt chart (Alessio Giovine thesis-2019)

The reason behind using Autodesk Revit and Microsoft project professional is that they allow the exporting process of the file in variety of formats that can guarantee no loss of the data beside the advantage of it can work with almost all BIM process softwires .The next step we used SYNCHRO Pro to link all these files together in one stand ,the implementation process started with importing the Revit file as IFC format to SYNCHRO Pro , then importing the Gantt chart from Microsoft project as .XML format but before that file from Microsoft project should be converted to XML format because Microsoft project export with format .MPP and that should be convert to XML to guarantee no loss of Data. After importing the Gantt chart from Microsoft project and the 3D model from Revit we need to assign all the tasks with the task ID in the model to make SYNCHRO Pro to define which task related to each part of the model.

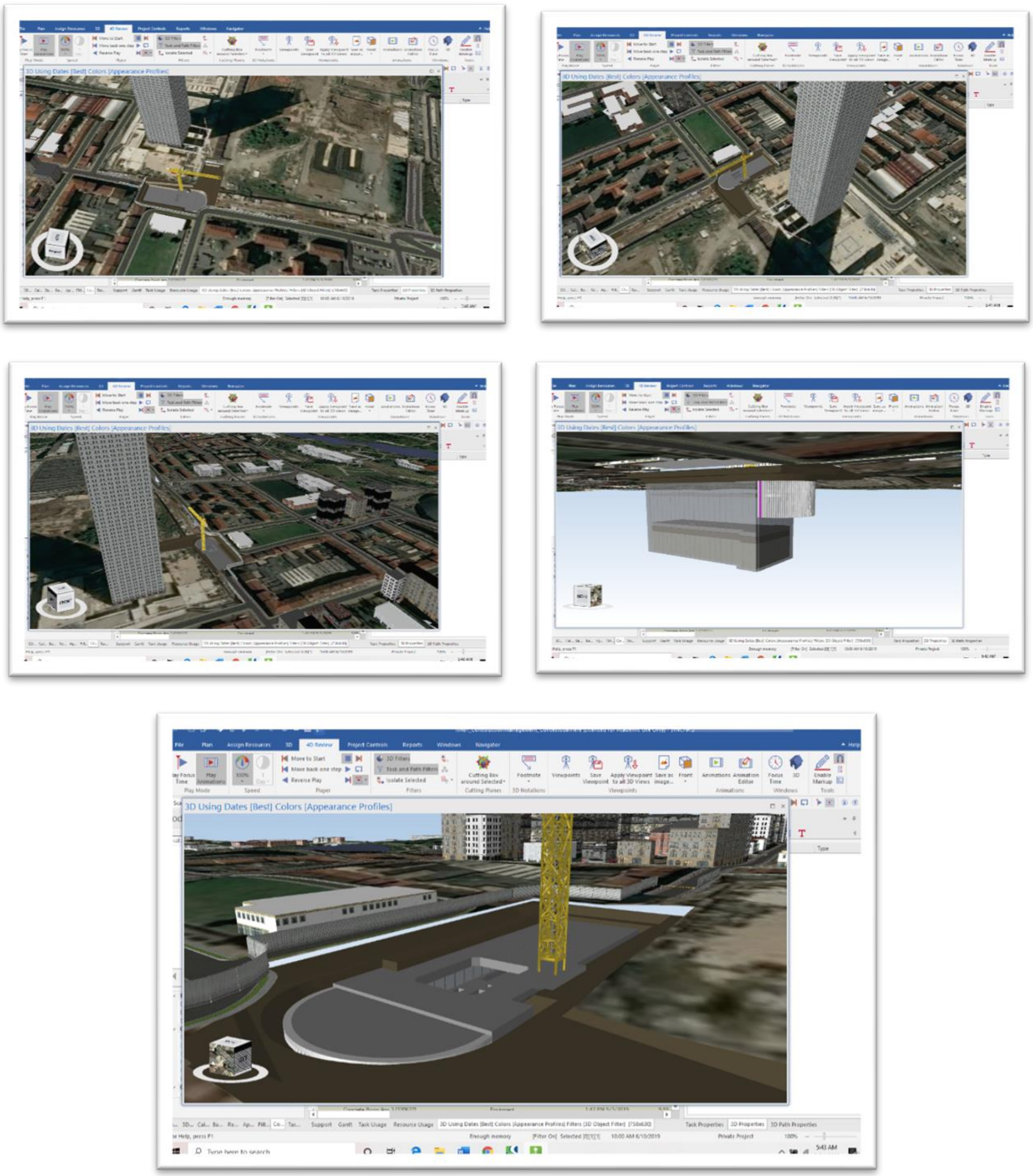


Figure 10 – Italia 61 model at SYNCHRO Pro

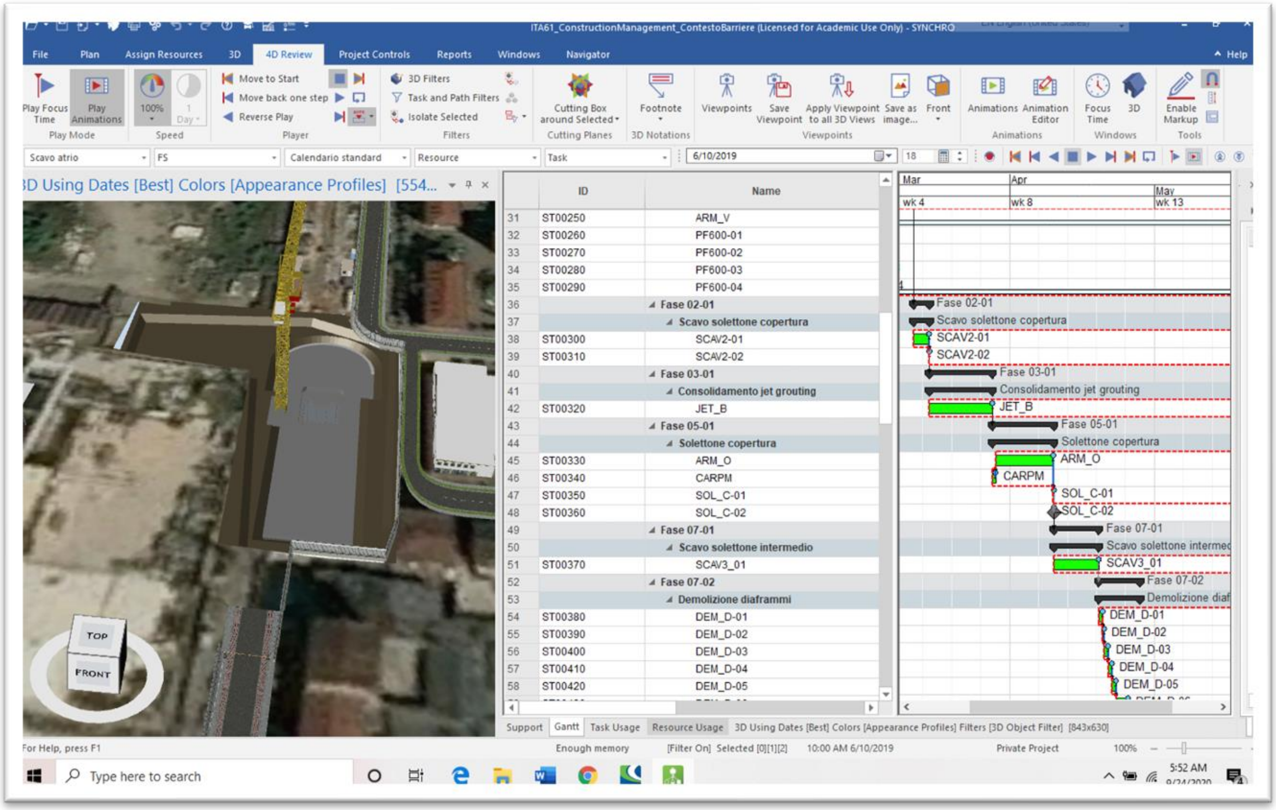


Figure 11- The ability to display the Gantt chart and the tasks descriptions with the 3D model

Now the model has been assigned to the tasks the next step is to apply the parameter of earn value management by customize the column of the task display in SYNCHRO Pro and adding another 6 column indicate all the parameter that help to identify the parameter of EVM , once we creating those column the process of adding the cost and planed valued should be made following few steps. going back to the SYNCHRO Pro model, we customize the column in the view to add all column related to earn value which is illustrated below:

	Variance At Completio...	Schedule Variance [...	Schedule Performan...	Planned Value Cost...	Estimate At Completio...	Earned Value Cost...	Cost Variance [...	Budget at Completio...
6	$10,223.00 More	$0.00 More	1	$80,223.00	$70,000.00	$80,223.00	$10,223.00 More	$80,223.(
7	$21,777.00 More	$0.00 More	1	$77,000.00	$55,223.00	$77,000.00	$21,777.00 More	$77,000.(
8	$880,889.00 L...	$0.00 More	1	$110,234.00	$991,123.00	$110,234.00	$880,889.00 L...	$110,234.(
9	$99,786.00 More	$0.00 More	1	$99,786.00	$0.00	$99,786.00	$99,786.00 More	$99,786.(
10	$494,876.00 M...	$0.00 More	1	$504,876.00	$10,000.00	$504,876.00	$494,876.00 M...	$504,876.(
11	$12,543.00 Less	$0.00 More	1	$30,987.00	$43,530.00	$30,987.00	$12,543.00 Less	$30,987.(
12	$1,734.00 More	$0.00 More	1	$10,934.00	$9,200.00	$10,934.00	$1,734.00 More	$10,934.(
13	$569.00 More	$0.00 More	1	$20,345.00	$19,776.00	$20,345.00	$569.00 More	$20,345.(
14	$3,859.00 More	$0.00 More	1	$20,203.00	$16,344.00	$20,203.00	$3,859.00 More	$20,203.(
15	$2,334.00 More	$0.00 More	1	$10,234.00	$7,900.00	$10,234.00	$2,334.00 More	$10,234.(
16	$0.00 More	$581.00 Less	0	$581.00	$581.00	$0.00	$0.00 More	$581.(
18	$18,557.00 More	$0.00 More	1	$69,000.00	$50,443.00	$69,000.00	$18,557.00 More	$69,000.(
19	$12,258.00 More	$0.00 More	1	$90,123.00	$77,865.00	$90,123.00	$12,258.00 More	$90,123.(
20	$8,034.00 More	$0.00 More	1	$88,907.00	$80,873.00	$88,907.00	$8,034.00 More	$88,907.(
21	$3,142.00 More	$0.00 More	1	$102,987.00	$99,845.00	$102,987.00	$3,142.00 More	$102,987.(
22	$4,753.00 More	$0.00 More	1	$70,987.00	$66,234.00	$70,987.00	$4,753.00 More	$70,987.(
23	$1,764.00 More	$0.00 More	1	$20,987.00	$19,223.00	$20,987.00	$1,764.00 More	$20,987.(
24	$0.00 More	$0.00 More	1	$55,097.00	$55,097.00	$55,097.00	$0.00 More	$55,097.(
25	$1,210.00 More	$0.00 More	1	$101,432.00	$100,222.00	$101,432.00	$1,210.00 More	$101,432.(
26	$1,991.00 More	$0.00 More	1	$77,089.00	$75,098.00	$77,089.00	$1,991.00 More	$77,089.(
27	$9,949.00 More	$0.00 More	1	$232,294.00	$222,345.00	$232,294.00	$9,949.00 More	$232,294.(
30	$316.00 More	$0.00 More	1	$20,870.00	$20,554.00	$20,870.00	$316.00 More	$20,870.(
31	$5,660.00 More	$0.00 More	1	$15,660.00	$10,000.00	$15,660.00	$5,660.00 More	$15,660.(
32	$0.00 More	$0.00 More	1	$23,432.00	$23,432.00	$23,432.00	$0.00 More	$23,432.(
33	$0.00 More	$54,887.00 Less	0	$54,887.00	$54,887.00	$0.00	$0.00 More	$54,887.(
34	$0.00 More	$52,100.00 Less	0	$52,100.00	$52,100.00	$0.00	$0.00 More	$52,100.(
35	$0.00 More	$65,345.00 Less	0	$65,345.00	$65,345.00	$0.00	$0.00 More	$65,345.(
38	$0.00 More	$4,678.00 Less	0	$4,678.00	$4,678.00	$0.00	$0.00 More	$4,678.(

Figure 12 – columns of EVM indicators

Adding the planned value Costs and actual cost and earned value at any stages:

there are three types of cost can be loaded to the project in SYNCHRO Pro:

Resource cost: which is added in resource level under resource property cost, and you can choose between 5 different options fixed, hourly, hourly complete, daily, and finally per unit. when we are applying the cost, we have to identify which type of costs related to each task.

Risk cost: Risk must assign to the task before they given a cost, in task property risk we can select increment whether from the window and then adding a cost.

The next step is to track budgeted to the actual cost Actual cost can be recorded only when task a status has been changed to start or finished when the task status changed between planed or started or finished the actual cost are automated updated but only comprised on proportion of the of the budgeted total cost ,To add actual direct cost we go to task property monitoring and add and tap a right click on the tap windows to add actual expense select new expense and add a new cost and the actual new cost update in the Gantt chart.

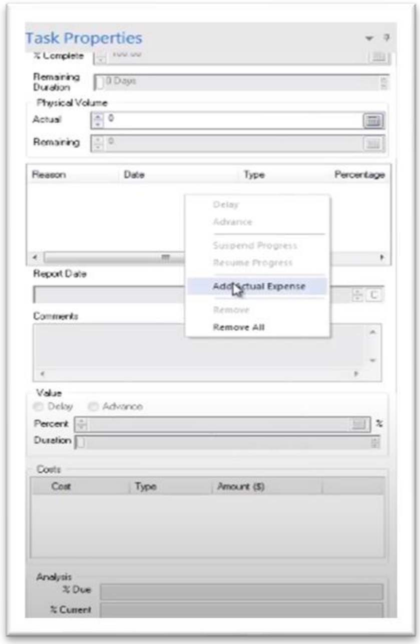


Figure 13- assigning costs in SYNCHRO Pro

Then after we added all the costs of the task from the contractor and added the percentage completed from the properties we can calculate and track the earn value at any stage of the project. we can perform the EVM curve by identifying our state and position of the project by dragging the status bar at any time and stage on the Gantt chart by moving the bar and identifying the starting task and finished tasks the software able to create the earn value graph to track the earn value and compare it to the planed value at any stage in the project.

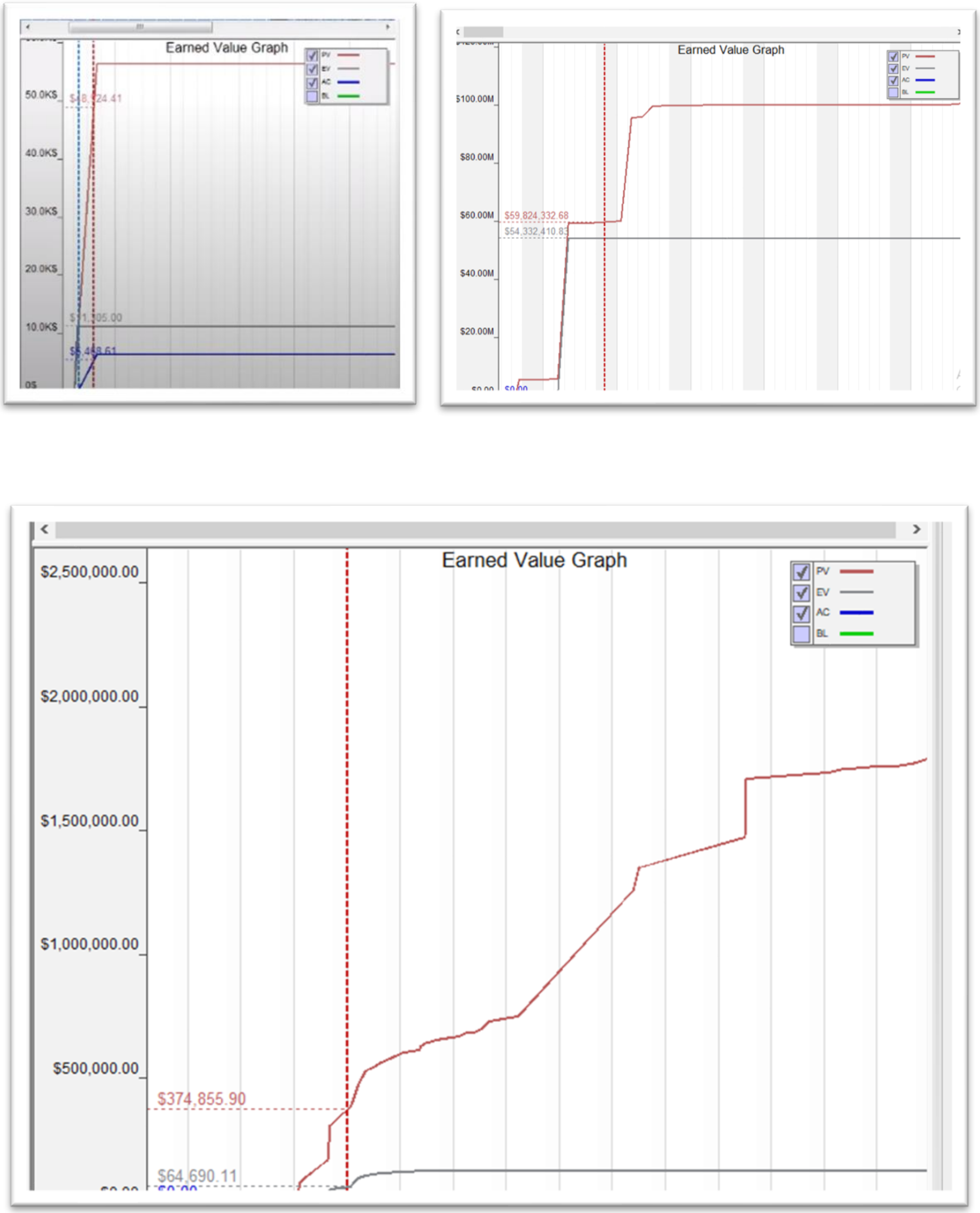
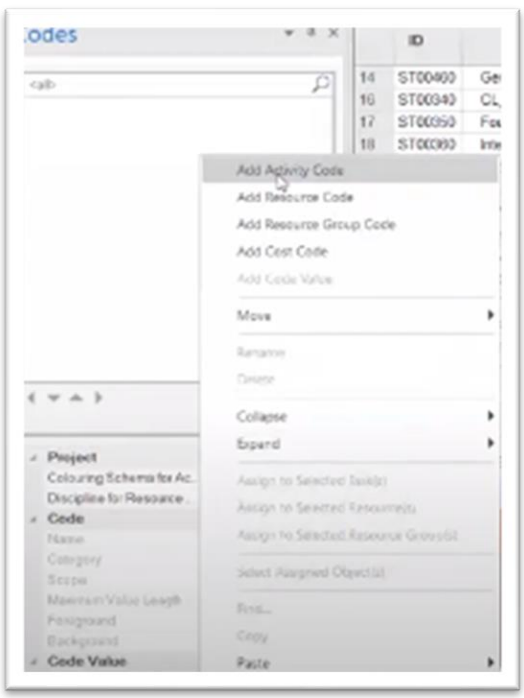


Figure 14 – EVM graph at deferent stages of the project

ADDING COLOR CODES TO THE MODEL

To assign color code to the 3D view of the model, first should create code in the section code in task properties , at the beginning has been created two codes to the activity code, the first one is ahead of the schedule with the color green , and the second one in behind the schedule with the color pink .

The steps to make the codes is to go to code menu and click add code in the code window we press right click then we add activity code.



Fighre 15 – Adding activity code in SYNCHRO Pro

And we adds two codes the first one is for the earn value management And its contains two option which is called code values behind the schedule witch is in red And above the schedule witch is in green. The second code is the risk code which is we discuss it later in the risk part.

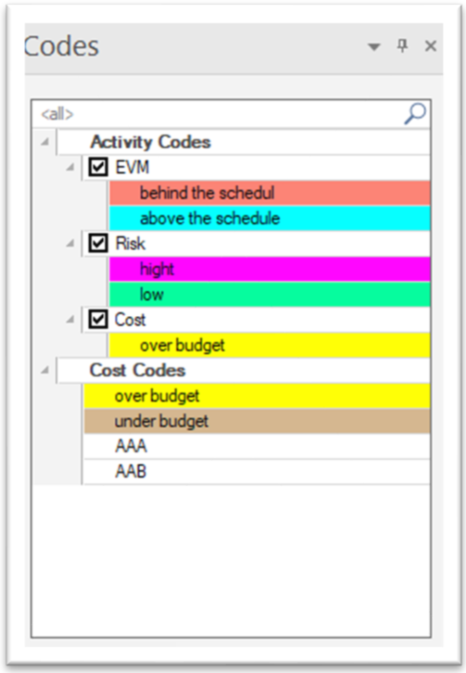
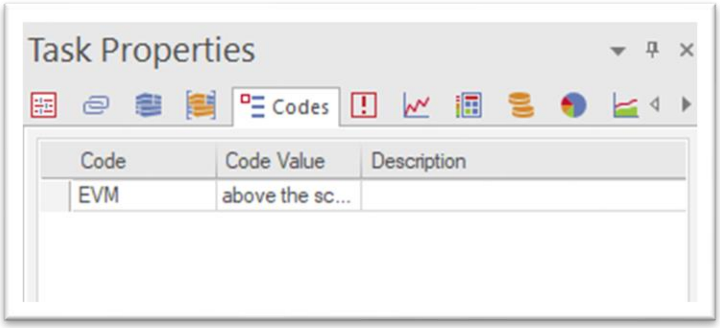


Figure 16 – assigning codes in SYNCHRO Pro

Now the activities do not have the codes assigned to the tasks We activate the codes then going to the grouping windows and pressing group by code then the codes appear in the Synchro pro window.

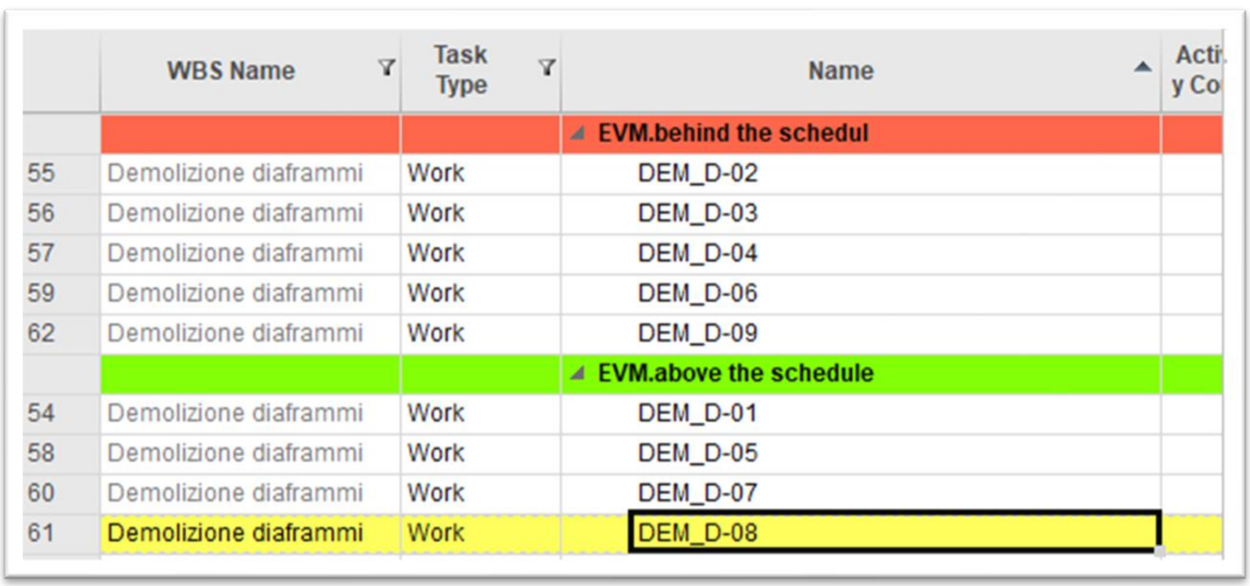
To assign code to the activities we go to task properties to codes windows and we drag the tasks with the same codes to the Gantt chart then after that we will notice that at the at the task properties any task assigned to a EVM codes.



Code	Code Value	Description
EVM	above the sc...	

Figure 16 - EVM code

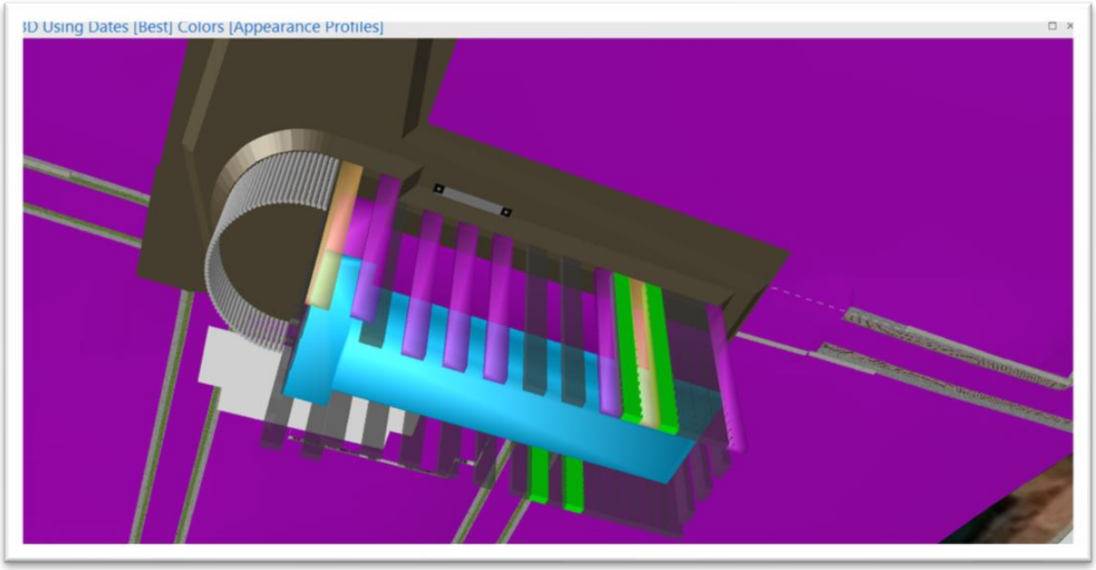
After that we are grouping the tasks based on the codes assigned in the beginning, we found that the activity codes divided to two group in EVM code The first is behind the schedule and the second is above the schedule.



	WBS Name	Task Type	Name	Acti y Co
			EVM.behind the schedul	
55	Demolizione diaframmi	Work	DEM_D-02	
56	Demolizione diaframmi	Work	DEM_D-03	
57	Demolizione diaframmi	Work	DEM_D-04	
59	Demolizione diaframmi	Work	DEM_D-06	
62	Demolizione diaframmi	Work	DEM_D-09	
			EVM.above the schedule	
54	Demolizione diaframmi	Work	DEM_D-01	
58	Demolizione diaframmi	Work	DEM_D-05	
60	Demolizione diaframmi	Work	DEM_D-07	
61	Demolizione diaframmi	Work	DEM_D-08	

Figure 17 - grouping the codes

Then after that we assign the codes to the 3D model, SYNCHRO Pro allows to link and assign the codes with the 3D windows then the result will be like this:



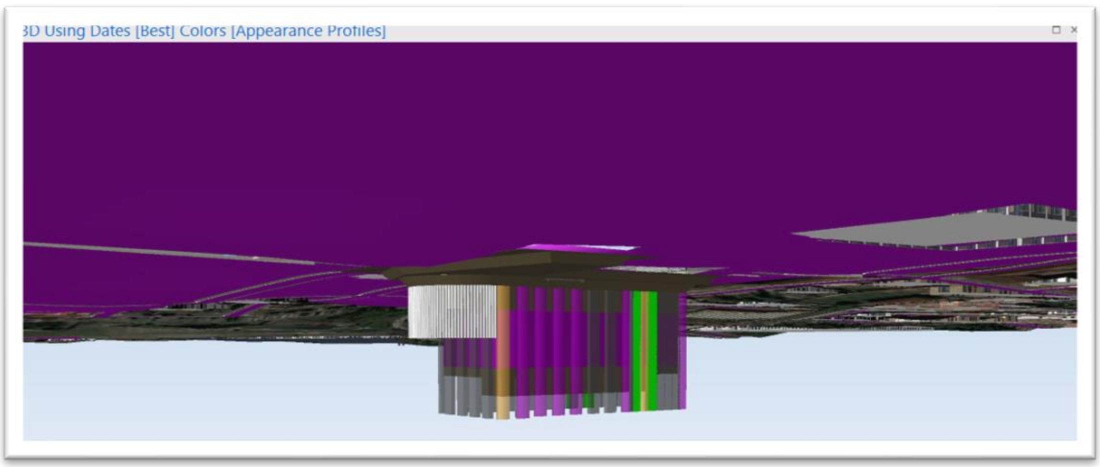


Figure 18 – Color code representation of the model

TPI METHOD

Another way to apply color code to the 3D model is by applying time performance index which is tracking the earn value in term of only schedule of the project that mean applying a color code whether the project is above or in or behind the schedule.

The schedule performance index (SPI) or (TPI) is a tool to measure of how far the project is to be finished compared to the timeline.

As a percentage ratio it is defined by dividing the budget cost of work performed, or earned value, by the planned value.

For example:

A project has a budgeted cost of 120,000 €.

According to the schedule, 15% of the project should have been completed after one month (planned value). That is 120,000 € x 15 / 100 = 18,000 €.

But after a month, only 12% of the project has been completed (earned value). That is 120,000 € x 12 / 100 = 14,400 €.

SPI = EV / PV = 14,400 / 18,000 = 0.8

This means that for all and every estimated work hour, the project is only completing 0.8 hours (just over 45 minutes).

If the percentage ratio has a value more than 1 this indicates the project is going well against the schedule. If the SPI is 1, then the project is progressing exactly as planned. If the SPI is less than 1 then the project is going behind schedule.

To apply this methodology in SYNCHRO Pro we start by introducing the TPI to the software by customizing the column in the task view and add TPI column, Time variance, BL start, BL finish and BL duration.

After that we apply a conditional formatting on the TPI column and then we can introduce the criteria of special formatting to apply the condition of TPI based on coloring cells and value in the same time as showing below:

TPI >1 (Ahead of schedule) assign to Green color.

TPI<1(Behind of schedule) assign to pink color.

TPI=1(On schedule) assign to yellow color.

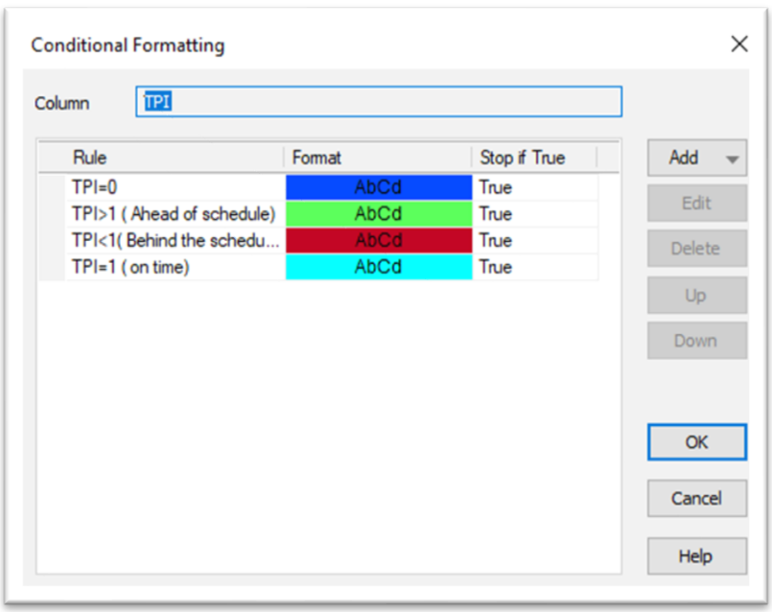


Figure 19 – Conditional formation on SYNCHRO Pro

RISK ANALYSIS.

OVERVIEW

The structural phase of metro station Italia 61 has been assigned to the contractor Lombardi Engineering Ltd. Some assumption has been made to make the implementation of the BIM process more flexible since in real life may be more complex as some tasks may be done by sub-contractor which make some information like cost data may be confidential for some parties . however, we assumed that all the phase has been constructed by only the same contractor.

Purpose of the Risk Management Plan:

The purpose of risk plan is to identify the risks limits in the prospective of the owner and all other shareholder in the project and it should be made by collecting information and the limits of risks from the prospective of the owner and to what delay and overrun is consider risky.

RISK IDENTIFICATION

Risk identification may include the Project Staff, the relevant stakeholders which would require the consideration of environmental conditions, the corporate culture and the Project Management Plan (PMP), including the duration, timeline, expense or efficiency of the project.

Methods for Risk Identification:

The following methods (discussed in the Standard Operating Procedure for Risk Management, Appendix B) may be used to assist in the identification of risks associated with Italia 61 metro station project:

- Brainstorming
- Affinity Diagrams
- Checklists
- Risk Breakdown Structure (RBS)

- Expert Interviews
- Strengths, Weaknesses, Opportunities, Threats (SWOT) Analysis
- Lessons Learned
- Delphi Technique

List of risk identified

	Risk Name
1	Availability of only one crane
2	Delay in delivering materials to the site
3	Delivery of broken materials
4	delivery of wrong materials
5	Errors in detail design
6	Labour specialites
7	payment delay due to COVID -19
8	Redusing the worker because of sotial destanc

Figure 20 – Risks identified on Italia 61 metro station

RISK ANALYSIS

All known risks will be assessed in order to determine the spectrum of potential project outcomes. Risks would be prioritized by their level of importance.

Qualitative analysis of risk:

The probability and impact of occurrence of each identified risk will be evaluated by the PM, with feedback from the Project Team using the following approach:

• Probability-is the possibility that there will be a chance.

• Impact-is the influence that the risk would have on the project as it arises.

Risks are measured against a common impact / probability scale using a well specified framework as described in Table 7 to minimize the uncertainty between the various meanings of High, Moderate and Low Effect and to provide a better view of Large Priority Risks. Risks with large impacts and probabilities are those which need to be tackled first.

Risk Exposure Rating	Description	Color Code
HIGH (H)	Unacceptable. Major disruption likely: different approach required; priority management attention required.	**Red**
MODERATE (M)	Some disruption: different approach may be required; additional management attention may be needed.	**Yellow**
LOW (L)	Minimum impact: minimum oversight needed to ensure risk remains low.	**Green**

Table 7. Risk Exposure Rating

PROBABILITY OF RISK

Probability of Occurrence Rating for each root cause using the specified criteria shown in Table 8, below. The PM must validate these definitions or modify them as necessary for their project.

Rating	Value Assigned	Probability of Occurrence
Near Certainty	0.90	~90%
Highly Likely	0.70	~70%
Likely	0.50	~50%
Low Likelihood	0.30	~30%
Not Likely	0.10	~10%

Table 8 - Probability of Occurrence Rating

IMPACT OF RISK

The impact of a risk is categorized into expense, schedule, and performance (i.e. software and technological requirements / quality) effects. Ratings and categories of impacts for each risk are calculated using the parameters listed in Table 9:

Rating	Value Assigned	Program Impact	Technical Impact	Cost Impact	Schedule Impact
Marginal	**0.05**	Remedy will cause program disruption	Performance goals met, no impact on program success	Program budget not dependent on issue; no impact on program success; development or production cost goals not exceeded or dependent on this issue	Schedule not dependent on this issue; no impact on program success; development schedule goals not exceeded or not dependent on the issue
Significant	**0.10**	Shorts a significant mission need	Performance below goal, but within acceptable limits. No changes required, acceptable alternatives exist, minor impact on program success	Program budget impacted by < 1%; minor impact on program success; development or production cost goals exceeded by 1 - 5%; program management resources do not need to be used to implement workarounds	Non-critical path activities late; workarounds would avoid impact on key and non-key program milestones; minor impact on program success, development schedule goals exceeded by 1-5%
Serious	**0.20**	Shorts a critical mission need	Performance below goal, moderate changes required, alternative would provide acceptable system performance, limited impact on program success	Program budget impacted by 1 - 5%; limited impact on program success; development or production cost goals exceeded by 5 - 15%; program management reserves do not need to be used to implement workarounds	Critical path activities one month late; workarounds would not meet program milestones; program success in doubt; development schedule goals exceeded by 5-10%
Very Serious	**0.40**	Potentially fails key performance parameter	Performance unacceptable; significant changes required; possible alternatives may exist; program success in doubt	Program budget impacted by 5-10%; program success in doubt; development or production cost goals exceeded by 15-20%; program management reserves must be used to implement workarounds	Critical path activities one month late; workarounds would not meet program milestones; program success in doubt; development schedule goals exceed by 10 -15%
Catastrophic	**0.80**	Jeopardizes an exit criterion of current acquisition phase	Performance unacceptable; no viable alternatives exist; program success jeopardized	Program budget impacted by 10%; program success jeopardized; development or production cost goals exceeded by 20 - 25%	Key program milestones would be late by more than 2 months; program success jeopardized; development schedule goals exceeded by 20%

Table 9: Rating and Types of Impact Criteria

Project Risk root cause identification and analysis integrates the technical performance assessment, schedule assessment, and cost estimates using established risk evaluation techniques. Each of these risk categories (cost, schedule, and performance) has activities of primary responsibility, but is provided inputs and support from the other two risk categories. This helps to keep the process integrated and ensures the consistency of the final product.

Table10, Risk Matrix, identifies the distribution of High (H) (red cells), Moderate (M) (yellow cells) and Low (L) (green cells) Risk Rating to be used when analyzing a risk. Projects shall use this Risk Matrix or tailor it to better fit the size and scope of specific projects or management practices of the organization. If the PM chooses to tailor the Risk Matrix, ISDDG shall be consulted.

PROBABILITY						
	Near Certainty (0.9)	0.045	0.09	0.18	0.36	0.72
	Highly Likely (0.7)	0.035	0.07	0.14	0.28	0.56
	Likely (0.5)	0.025	0.05	0.1	0.2	0.4
	Low Likelihood (0.3)	0.015	0.03	0.06	0.12	0.24
	Not Likely (0.1)	0.005	0.01	0.02	0.04	0.08
		Marginal (0.05)	Significant (0.1)	Serious (0.2)	Very Serious (0.4)	Catastrophic (0.8)
		IMPACT				

Table 10: Risk Matrix

Risks that fall within the RED and YELLOW zones will have risk response plan which may include both a risk response strategy and a risk contingency plan.

QUANTITATIVE ANALYSIS OF RISK

Analysis of risk events which have been prioritized utilizing the qualitative risk analysis approach and their effects on project operations will be calculated, numerical rating will be applied to each risk based on quantitative analyses and reported in this portion of the risk management strategy.

Quantitative Risk Analysis approach offers a numerical calculation of the overall risk effect on the goals of the project, based on existing expectations and details, while evaluating risks at the same time. The outcomes of this type of analysis will be used to measure the probability of progress in achieving the best target of the project and to determine the contingency reserves, typically for the time and expense acceptable to both the uncertainties and the risk tolerance of the project stakeholders.one of the method used in quantitative risk assessment is The Monte-Carlo method.

The Monte-Carlo method

The Monte-Carlo approach is a mathematical algorithm that uses random sampling to measure the performance. Monte-Carlo approaches are widely used for the simulation of physical, statistical, and economic processes. From the other hand, the Monte Carlo simulation is a class of computer algorithms that rely on random iterations to determine their performance. The Monte Carlo simulation is also used to represent a statistical or physical structure. Due to their dependency on redundant equations and inaccurate or random numbers, Monte Carlo methods are typically designed to operate on a machine. The tendency to use Monte Carlo methods is further strengthened whether it is impractical or unjustified to determine the right solution using deterministic algorithms. Monte Carlo simulation techniques are particularly valuable for the analysis of structures where there are several variables correlated with the degree of freedom of pairs. In addition, Monte Carlo approaches are often effective for simulating phenomena with large input uncertainties, such as project risk estimation. Such simulations are still commonly used in mathematics. The Monte Carlo simulation is a comprehensive, computer-intensive simulation method to assess the importance and probabilities of potential results of a project goal, such as a project timeline (e.g. completion date) or a cost estimate (e.g. estimated expense). It measures the schedule or expense calculation several times using inputs taken at random from the ranges defined with the probability distribution function for the length of the schedule of operations or the expense line objects. Solutions using these various input values are used to create a histogram of potential project results and their relative likelihood, and the total possibility with which to measure the desired contingency reserves of time or expense. Additional findings show the relative value of each data in deciding the total expense and schedule of the project. Examples of the performance of the program and the cost-risk effects are seen in the figures. RiskyProject used this approach to analyze quantitative risk analysis.

The process of implementation of risk management procedure in BIM process should be continuously implemented and updated at deferent stages and phases of the project, the responsible of this process is the risk department of the project. risk assessment process should be baseline of the project and should be made at the first stage of the project to help the procedure of predict the approximate schedule and cost that needed to finish the project.

RISKYPROJECT professional has been used in the process of risk management, due to easy use and the ability to import files from deferent resources like Primavera, Project Management and Excel made it one of the best supports of the BIM process.

Implementation process started from exporting the model from Synchro pro in format of .XML then after that this format should be converted to .MPP format through long process of conversion and may be needed a professional conversion software. the reason of this process is in order to guarantee no loss of the data. the SYNCHRO Pro model should be opened by Microsoft project in format .MPP and the problem in Synchro pro only export xml format.

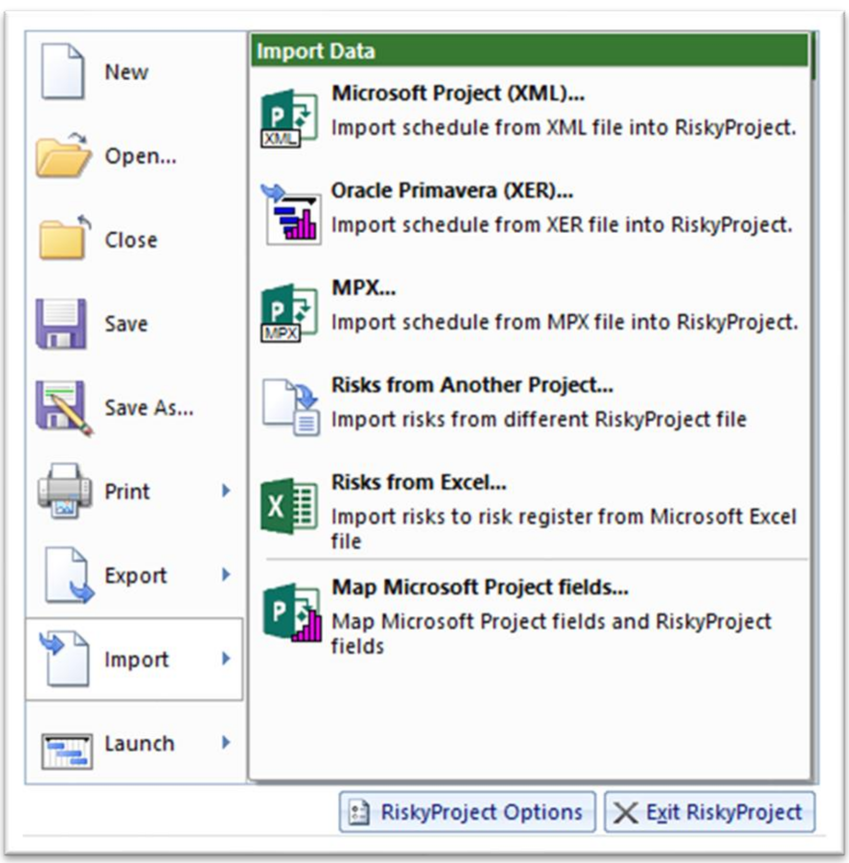


Figure 21- Type of data imported by Riskyproject

After importing the model in Microsoft project we make sure that no loss of data in converting process by comparing the schedule and the costs of activities in Microsoft project between Synchro pro and Microsoft project , after importing the file to Microsoft project we export it to Riskyproject in .XML format again and it's not the same XML format in the beginning because its general technical issue that the programmer of the software didn't fix it yet that all the files should be passing through Microsoft project which is as a bridge to the BIM process.

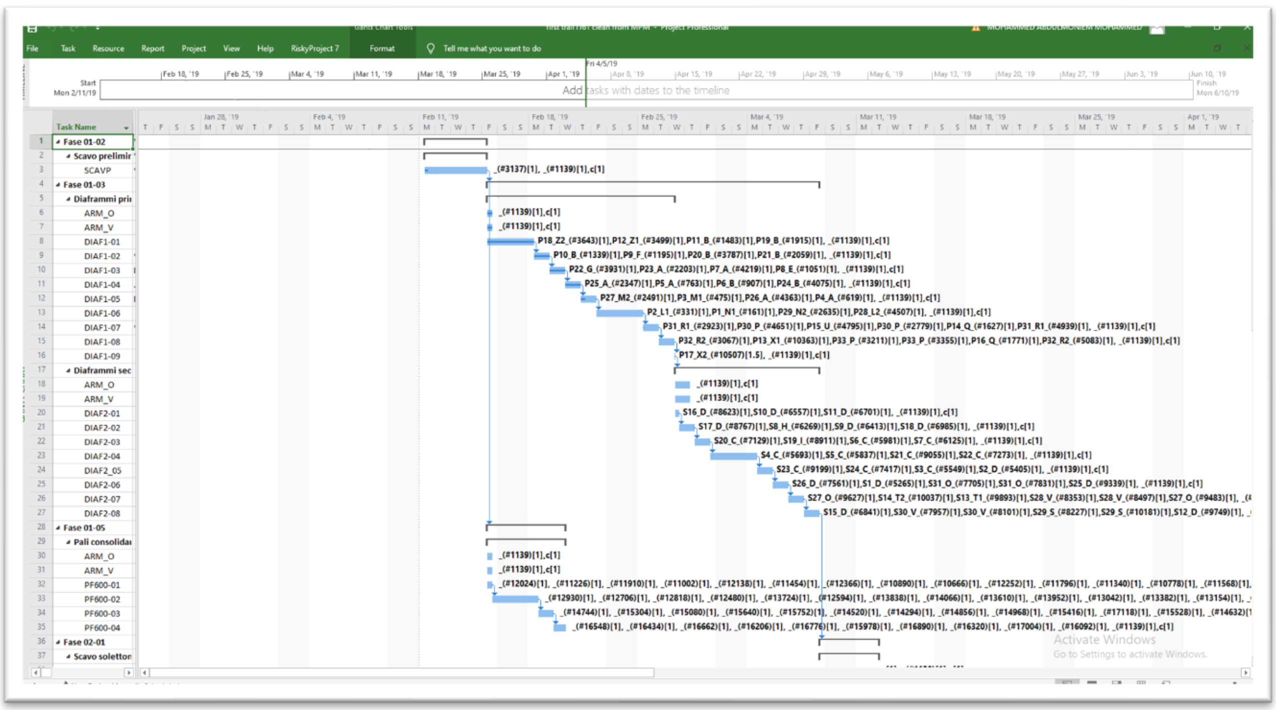


Figure 22-Model after exported and imported to Microsoft project

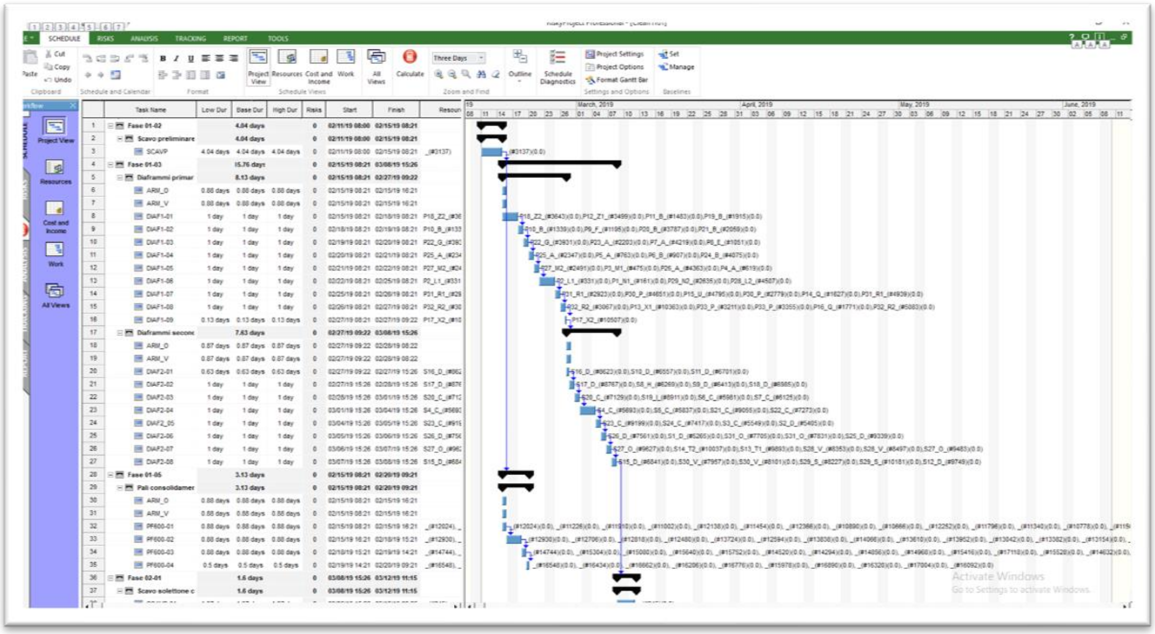


Figure 23- Model after imported to Riskyproject professional

After importing the model to Riskyproject we follow the risk management steps to set up the software to work as the risk plan of the project by applying the risk matrix of probability and impact that discussed before:

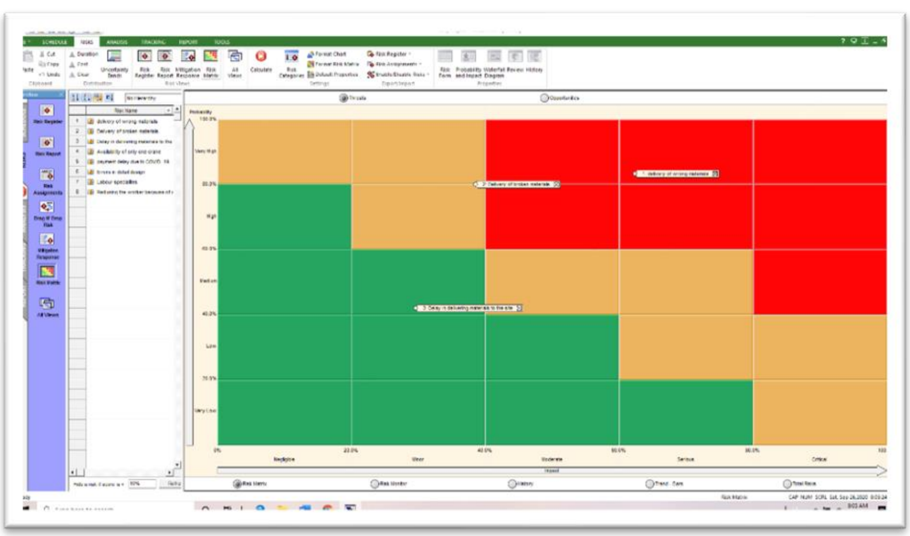


Figure 24-Risk matrix of the project in Riskyproject

Risk is registered in the software by inserting all the detail needed about the risks Setting Columns for Risk Registry ,The user may change the Risk Register by adding, changing or hiding columns based on the type of details you choose to display. The view of the Risk Register helps the user to identify the upper column header for the category of columns. The upper header will include two lines of text and a tooltip. It could have various backdrop colors, outline colors and text colors. There are two predefined upper headers: pre-mitigation and post-mitigation.

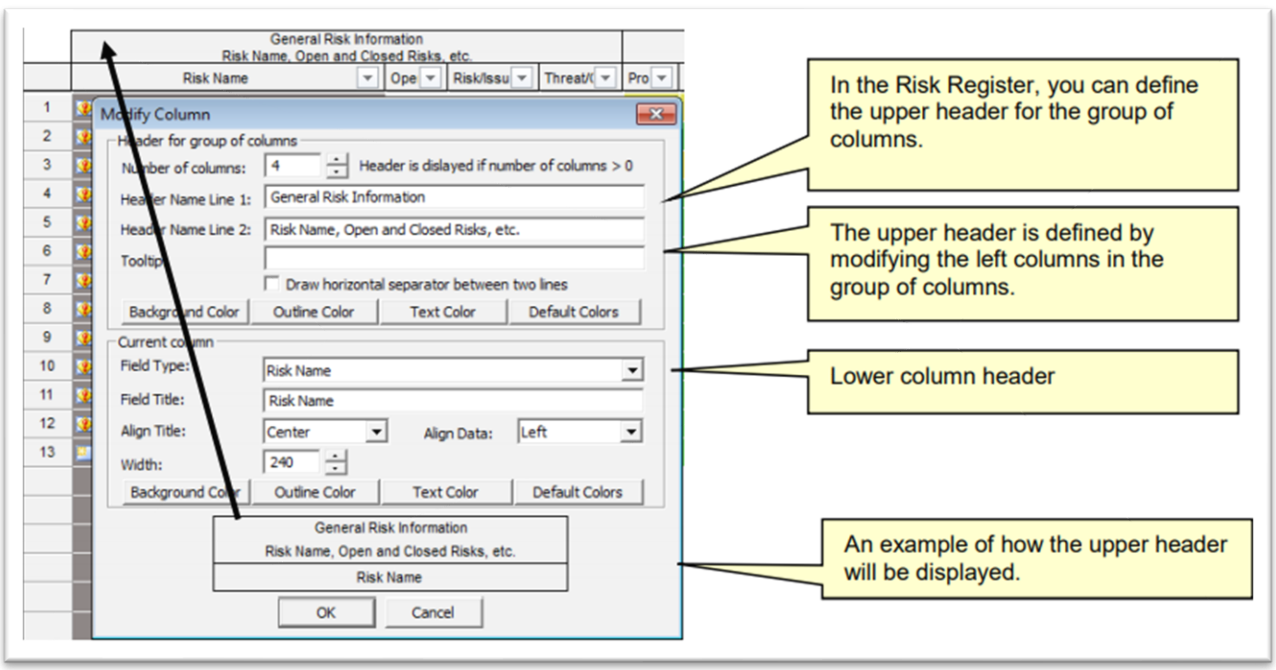


Figure 25- Risk register in Riskyproject

Adding risks to the register of risks:

1. Tap on the Threats tab. Tap on the Risk Views category in the Risk Register.

2. Click an empty row on the Vulnerability Register.

3. Enter a special danger term. The danger has now been applied to the registry.

Danger withdrawal from the Event Registry:

1. Tap on the Risks tab. Click the Vulnerability Register on the Plan Views Category.

2. Choose the chance that you want to remove. You may pick a single risk or several risks.

3. Right-click the Risk ID and select Delete Risk from the Shortcut menu.

Updating the risk properties of individual risks:

To change the risk properties by utilizing the Risk Register:

1. Activate the Log of Hazards.

2. Tap on the properties of the risk and make the desired adjustments.

RISK CATEGORY

Risk categories are a compilation of risk consequences. RiskyProject measures the risk likelihood, effect and ranking for each group. The default risk groups are as follows:

- Duration
- Price
- Climate
- Legal
- Efficiency
- Technology

RiskyProject measures the score and rating of all threats in each risk group. You will see risk ratings and rankings for each risk group or for all categories.

Figure 26-Risk register status

RISK PROBABILITY AND IMPACT

Risk Likelihood is the measured possibility that an occurrence will occur. You can see the risk likelihood in the Risk Matrix, Risk Tracker, and other views and dialog boxes. Risk Chance is the risk likelihood input parameter. Risk chance (input parameter) and risk likelihood (calculated attribute) can be different specifically, where risk has several mutually exclusive alternatives as possibility and chance as an input parameter for each alternative. In such situations, the risk probability is determined based on the risk possibility for each mutually incompatible alternative.

RISK OUTCOMES

Risk Results indicate the magnitude of a risk occurrence within a particular type of risk. You need to enter risk outcomes as you identify risk chance and form of outcome. For example, the default risk results for the risk category Schedule are as follows:

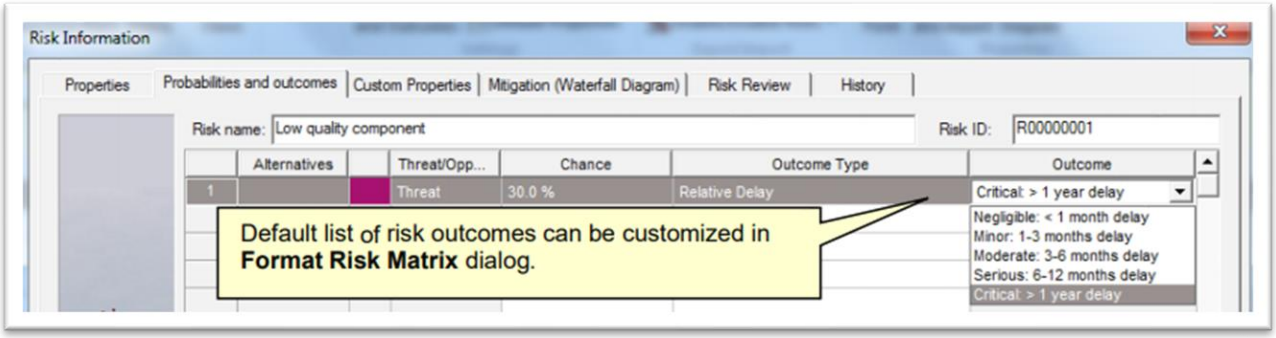


Figure 27- Risk information

Outcome categories can be a mark (e.g. Critical > 1-year delay) or a number (e.g. 5 percent) or a mixture of both. You will set how you want to join and display the risk effects in the Format Risk Matrix dialog box. Each mark is correlated with a percentage that is the midpoint of the mark.

Interval of each label:

	INTERVAL	MIDPOINT
Negligible: < 1-month delay	from 0% to 20%	10%
Minor: 1-3-month delay	from 20% to 40%	30%
Moderate: 3-6 months delay	from 40% to 60%	50%
Serious: 6-12 months delay	from 60% to 80%	70%
Critical: > 1-year delay	from 80% to 100%	90%

When you describe the output categories as a percentage, you may enter them as any amount from 0 percent to 100 percent. In this case, the mark would be correlated based on the interval to which the percentage refers. For egg, 76% correlates to "Serious: 6-12 months delay".

The diagram below illustrates the interaction between the risk levels, the forms of risk consequences and the risk Performance.

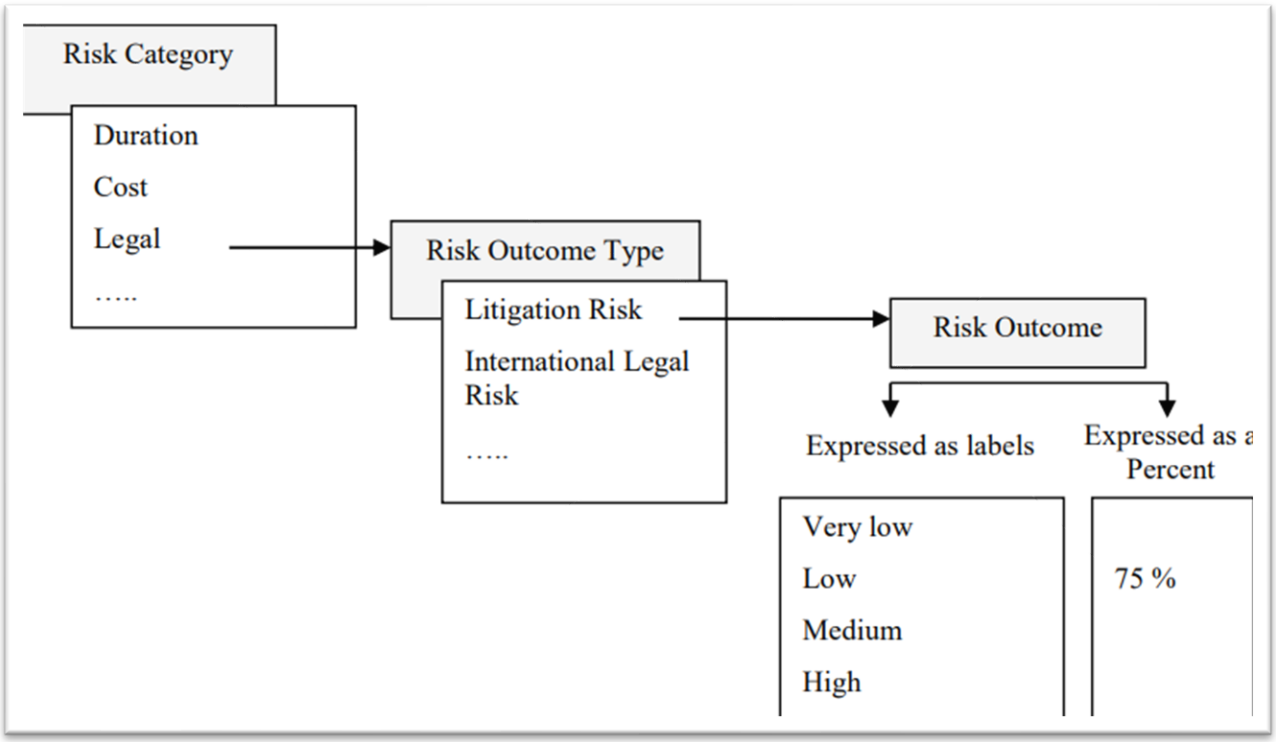


Figure 28- Interaction between the risk levels

<u>Assigning risks using the Drag and Drop Risk view</u>

This is the way method for adding risks to complex tasks of projects as it allows to fast assign risks to tasks or resources.

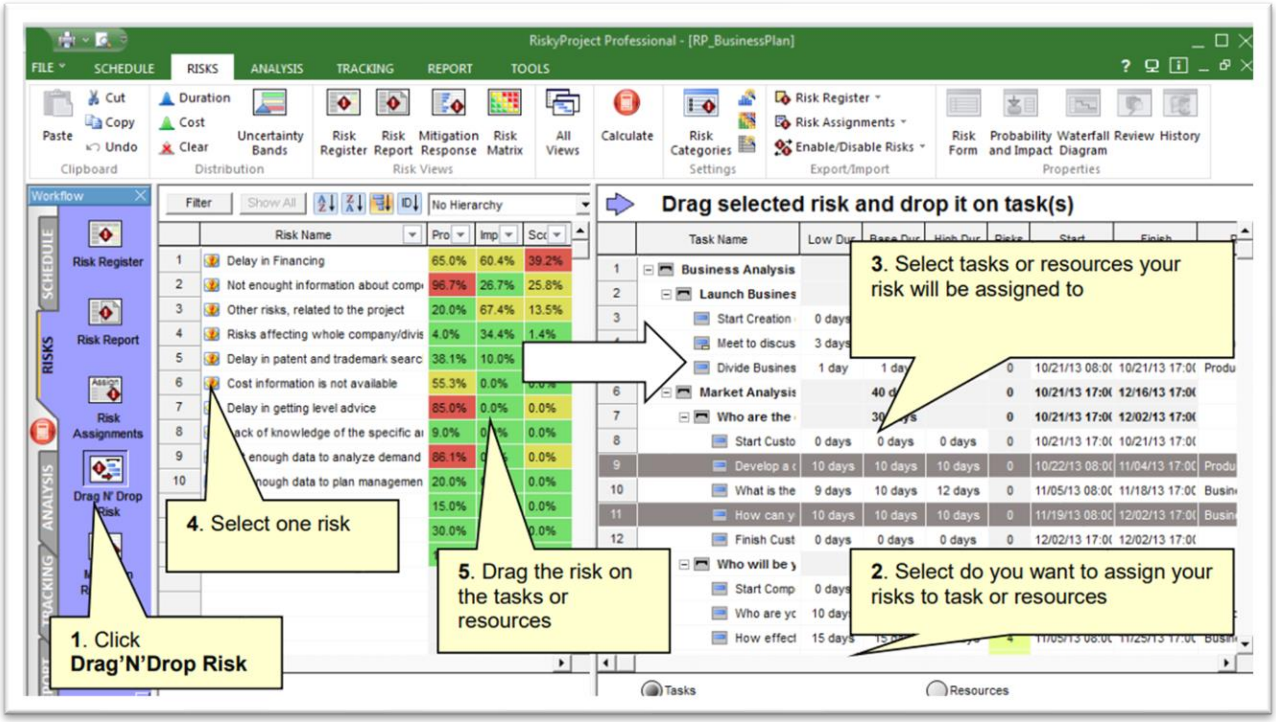


Figure 29-Assigning risks using the Drag and Drop Risk view

1- On the Risks bottom, click on the Drag and Drop Risk view.

2- You must indicate whether assigning the risk to Tasks or Resources using the options under the list of tasks. Select of Task or Resources and the right panel will list change based on your selection. By default, the view is set to Tasks.

3- Select tasks or resources your risk will be assigned to.

4- Select one risk.

5- Drag risk onto the tasks or resources.

6- The Assign risk to task or resource dialog box opens. It shows a list of the task or resources that the risk will be assigned to and allows you to define risk chance, outcome type, outcome, and moment of risk

Running probabilistic calculations.

BY Pressing the Calculate tab the user can cancel the probabilistic estimate at any time however, if the number of simulations carried out is less than 20, no probabilistic effects will be determined. We made simulation at 10000 intervals.

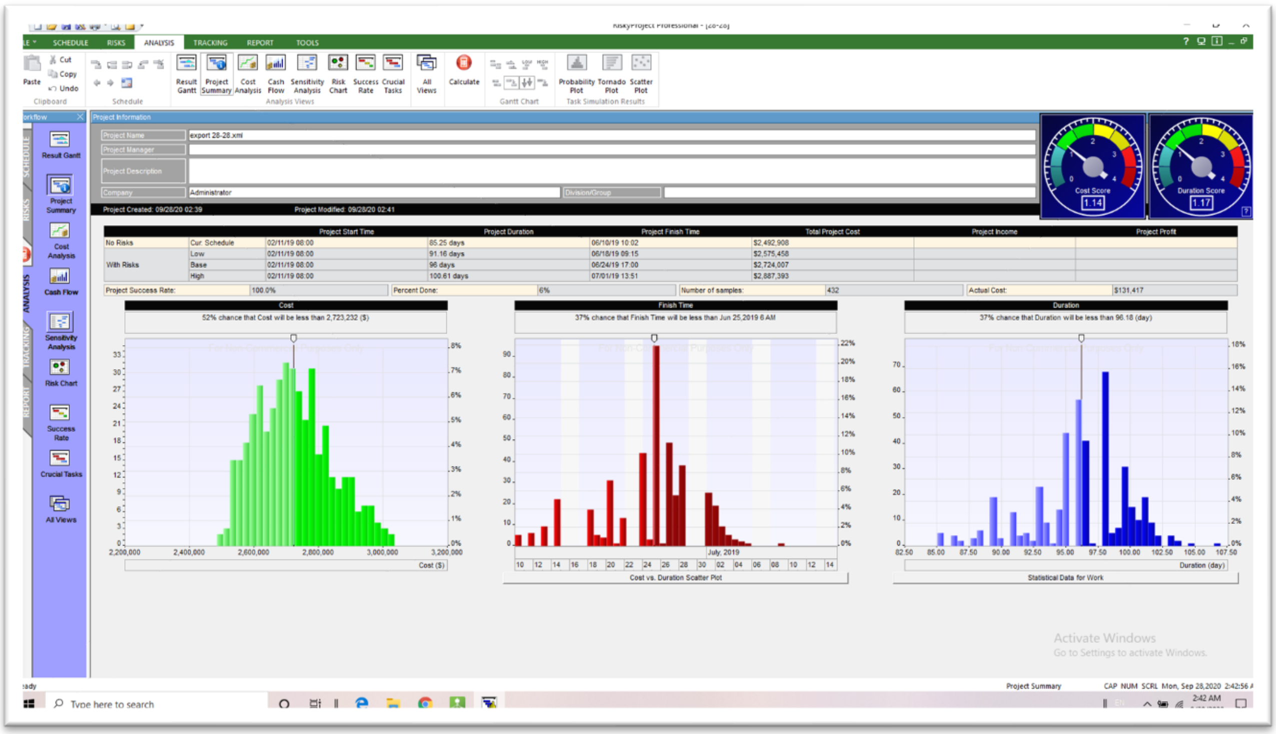


Figure 30-Example of result

After saving the new Gantt chart generated from the worst case scenario again we exported it and imported to Synchro pro in format of .XML passing again by the same procedure through the Microsoft project Then to Synchro pro which is generated in synchro pro new updated Gantt chart with new delay and new overrun in cost.

CHAPTER FIVE: RESULTS

As mention before the main goal of this thesis is to providing a complete implementation guideline to make the BIM process effective and more efficient especially in the big construction project, in our case of study we can say in general the goal has been achieved in advance level except there is some limitation and challenged not been fixed yet and it will considered in the next chapter .

EVM IMPLEMENTATION RESULT

CODING METHOD

The process of implementation EVM starts from inserting all the costs need to calculate the earn value cellulation is by assigning code in codes section in SYNCHRO Pro in the same time grouping the tasks behind the schedule and above the schedule by grouping process in synchro pro in side and on the other side making another code indicating over budget and under budget tasks by the same process , the process is long and time consuming and almost all the steps has been made manually which is make this method not technically useful ,the result of this method as following:

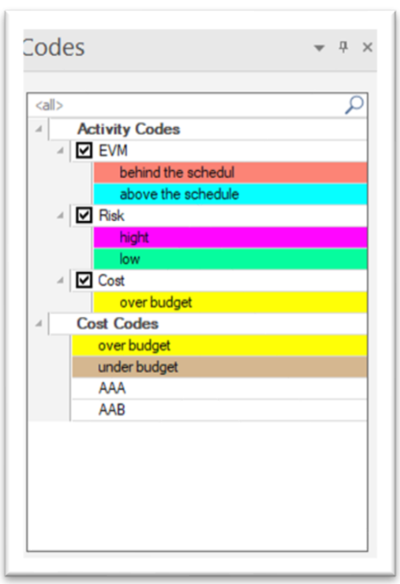


Figure 31- Code assign to SYNCHRO Pro

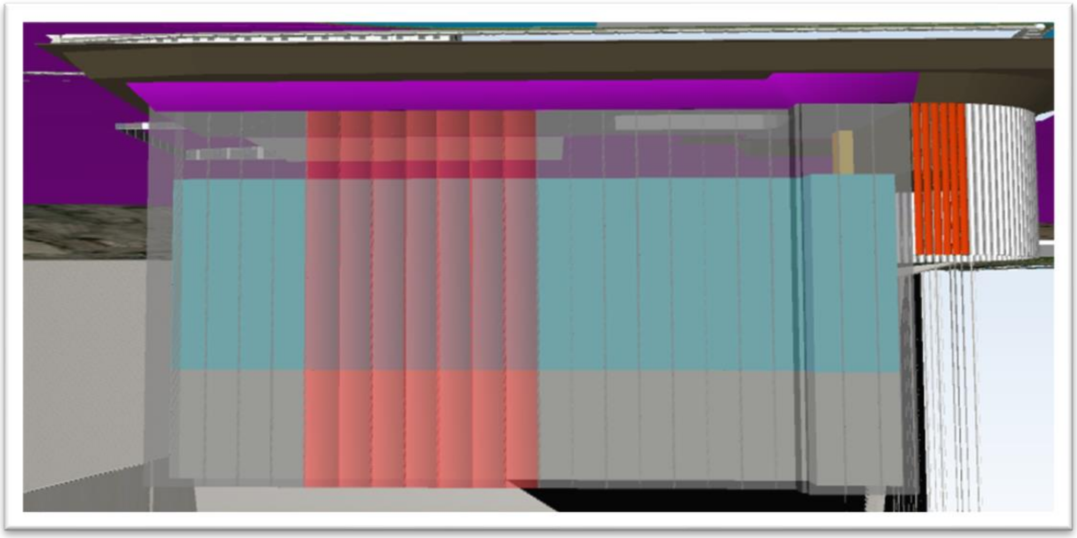


Figure 32- Orange color indicate behind the schedule

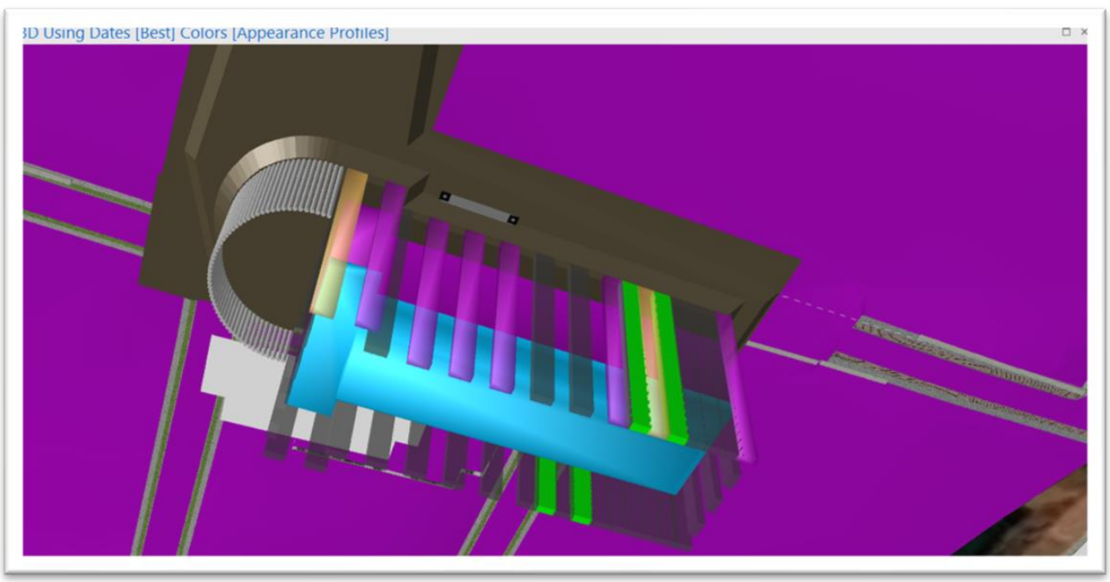


Figure 33- Blue color indicate above the schedule

With this method we can only apply one code at the time next trial we applied the cost code which indicate under budget and over budget tasks by applying the same process of the previous one.

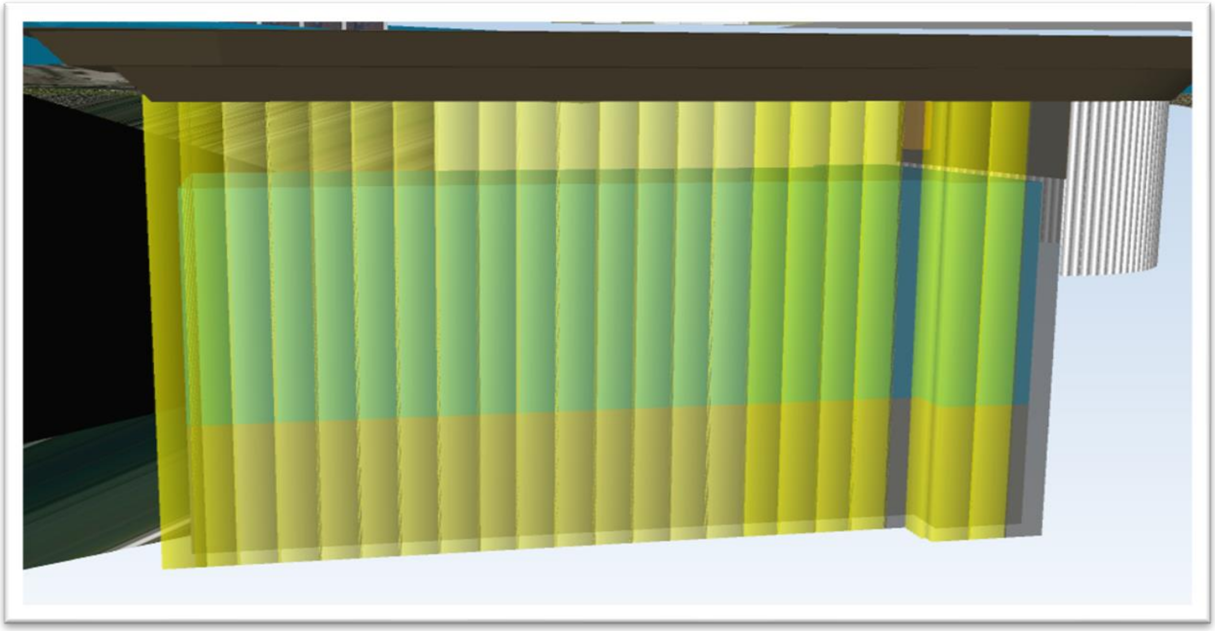


Figure 34- Yellow color indicate over budget

TPI INDEX METHOD

There is another method , more effective and easy to apply in Synchro pro which is depending in TPI index (time performance index) to measure the performance of task in the prospective of time, which is for schedule only and it doesn't depending of the cost , which is doesn't need resource loading or cost loading schedule .

Schedule baseline has been created to calculate TPI value, then customizing the column to add TPI column and the baseline start and base line finish duration column:

Include in TPI	TPI	BL Duration	BL Start	BL Finish
False				
False				
True				
False				
False				
True				
True				
True				
True				
True				
True				
True				
True				
True				
True				
True				
False				

Figure 35- Customize column for TPI

After applying the specific baseline that created for TPI click activate of TPI its now populated and displayed:

Include in TPI	TPI	BL Duration	BL Start	BL Finish
False	1.00	4d, 20m	8:00 AM 2/11/2019	8:20 AM 2/15/2019
False	1.00	4d, 20m	8:00 AM 2/11/2019	8:20 AM 2/15/2019
True	1.00	4d, 20m	8:00 AM 2/11/2019	8:20 AM 2/15/2019
False	0.51	15d, 6h, 4m	8:19 AM 2/15/2019	3:23 PM 3/8/2019
False	1.00	8d, 1h, 1m	8:19 AM 2/15/2019	9:20 AM 2/27/2019
True	1.00	7h	8:19 AM 2/15/2019	4:19 PM 2/15/2019
True	1.00	7h	8:19 AM 2/15/2019	4:19 PM 2/15/2019
True	1.00	1d	8:19 AM 2/15/2019	8:19 AM 2/18/2019
True	1.00	1d	8:19 AM 2/18/2019	8:19 AM 2/19/2019
True	1.00	1d	8:19 AM 2/19/2019	8:19 AM 2/20/2019
True	1.00	1d	8:19 AM 2/20/2019	8:19 AM 2/21/2019
True	1.00	1d	8:19 AM 2/21/2019	8:19 AM 2/22/2019
True	1.00	1d	8:19 AM 2/22/2019	8:19 AM 2/25/2019

Figure 36- Activate column for TPI

after that we inter the TPI column and insert special formatting to make the software calculate the value of TPI automatically as following:

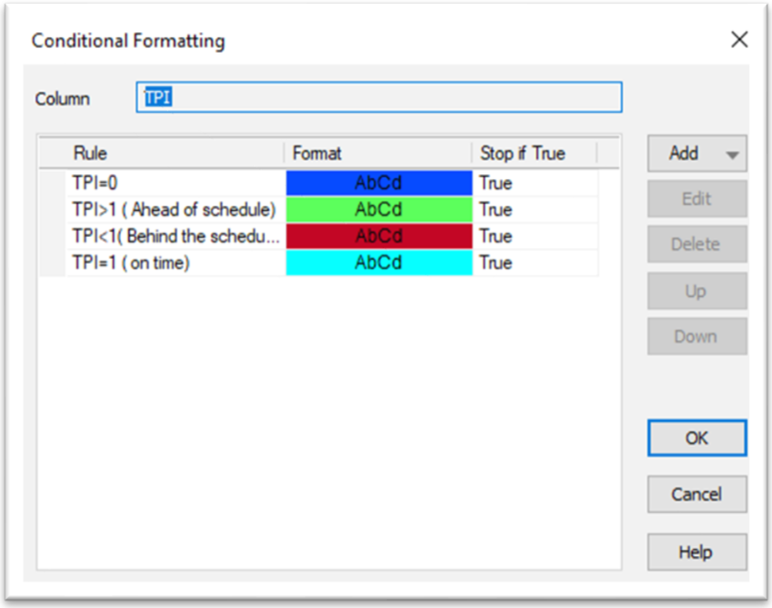
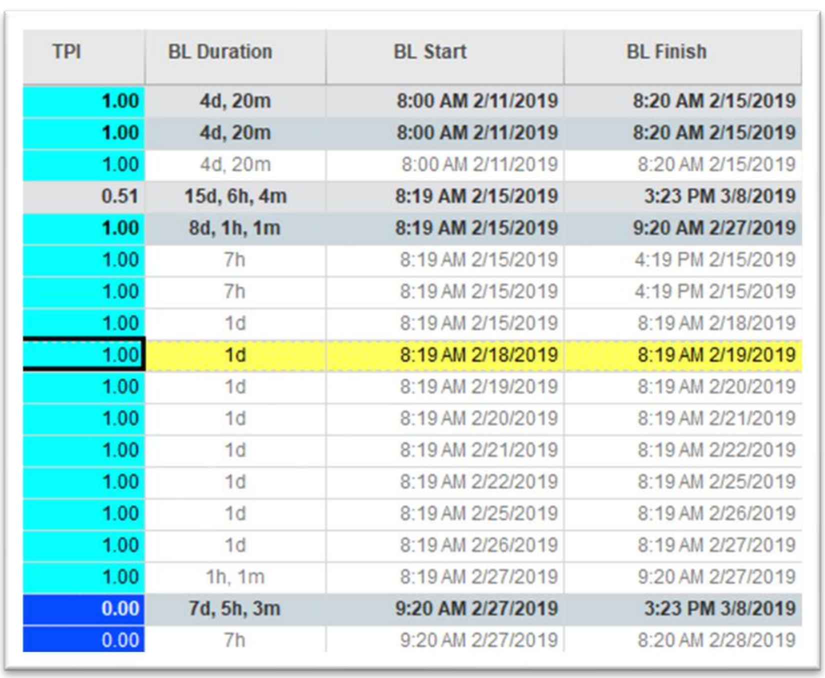


Figure 37- Conditional formatting for TPI

After applying the conditional formatting automatically columns filled automatically:



TPI	BL Duration	BL Start	BL Finish
1.00	4d, 20m	8:00 AM 2/11/2019	8:20 AM 2/15/2019
1.00	4d, 20m	8:00 AM 2/11/2019	8:20 AM 2/15/2019
1.00	4d, 20m	8:00 AM 2/11/2019	8:20 AM 2/15/2019
0.51	15d, 6h, 4m	8:19 AM 2/15/2019	3:23 PM 3/8/2019
1.00	8d, 1h, 1m	8:19 AM 2/15/2019	9:20 AM 2/27/2019
1.00	7h	8:19 AM 2/15/2019	4:19 PM 2/15/2019
1.00	7h	8:19 AM 2/15/2019	4:19 PM 2/15/2019
1.00	1d	8:19 AM 2/15/2019	8:19 AM 2/18/2019
1.00	1d	8:19 AM 2/18/2019	8:19 AM 2/19/2019
1.00	1d	8:19 AM 2/19/2019	8:19 AM 2/20/2019
1.00	1d	8:19 AM 2/20/2019	8:19 AM 2/21/2019
1.00	1d	8:19 AM 2/21/2019	8:19 AM 2/22/2019
1.00	1d	8:19 AM 2/22/2019	8:19 AM 2/25/2019
1.00	1d	8:19 AM 2/25/2019	8:19 AM 2/26/2019
1.00	1d	8:19 AM 2/26/2019	8:19 AM 2/27/2019
1.00	1h, 1m	8:19 AM 2/27/2019	9:20 AM 2/27/2019
0.00	7d, 5h, 3m	9:20 AM 2/27/2019	3:23 PM 3/8/2019
0.00	7h	9:20 AM 2/27/2019	8:20 AM 2/28/2019

Figure 38- Conditional formatting for TPI with code color

As in the graph when TPI bigger that 1 that mean is task is ahead of the schedule and give it a green color and when less than 1 it gives a red color and when equal 1 that mean the schedule on time and give the tasks blue color

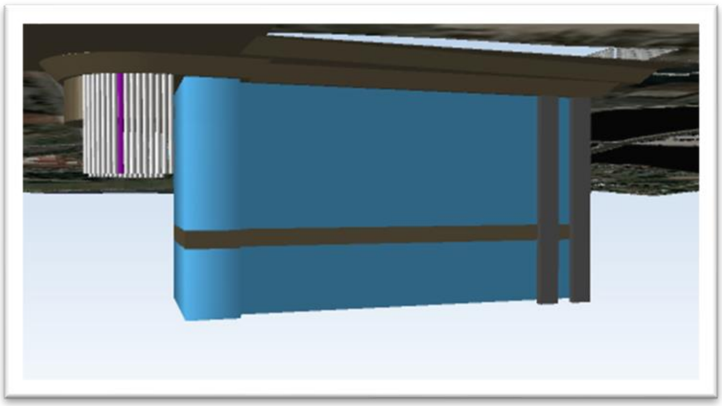


Figure 39- Color code for TPI

Figure 40- Color code for TPI

The main advantage of this method is that in shows the manager that certain area from the project need to be accelerated to avoid expecting delay, At the same time showing the overall performing of the project.

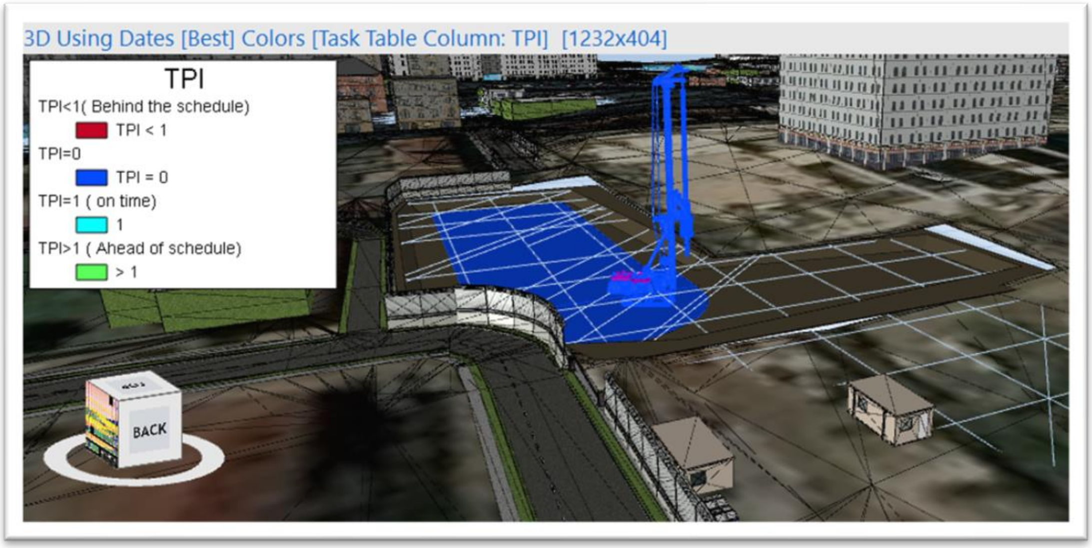


Figure 41- Color code for TPI

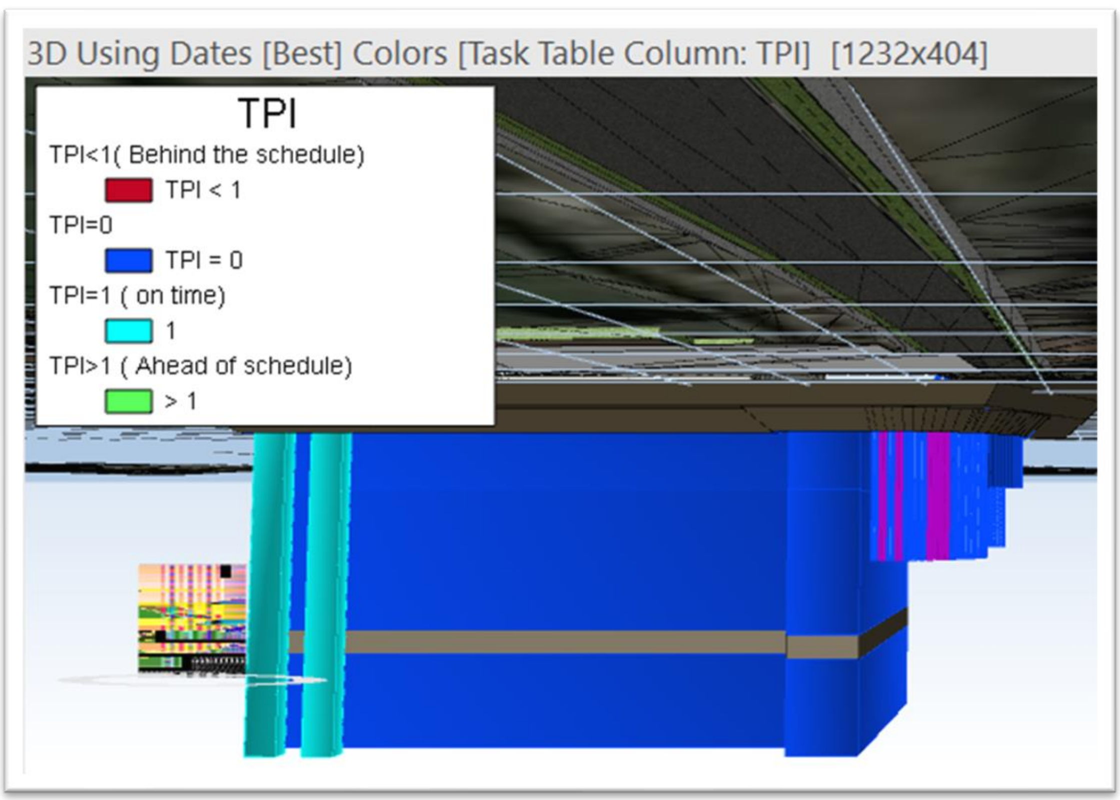


Figure 42- Color code for TPI

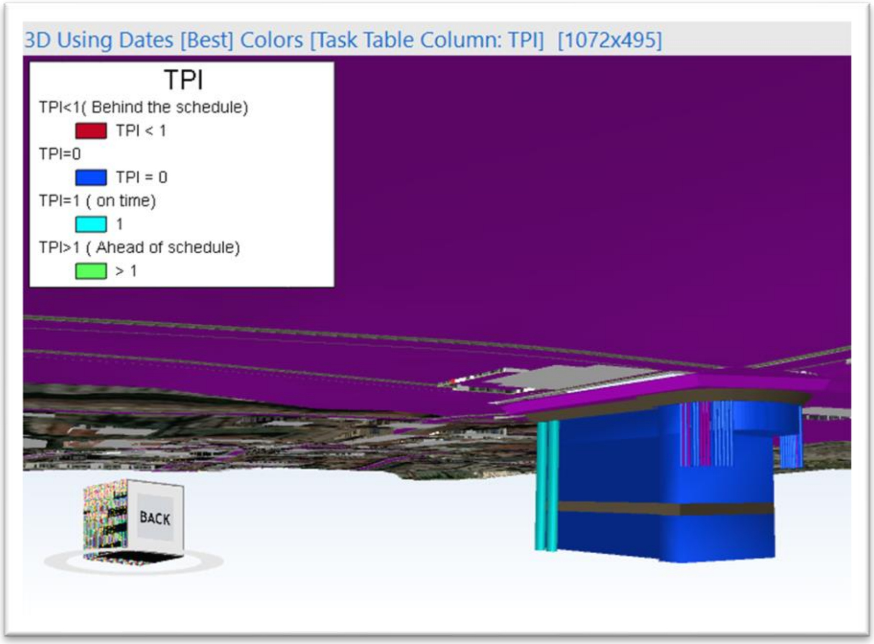


Figure 43- Color code for TPI

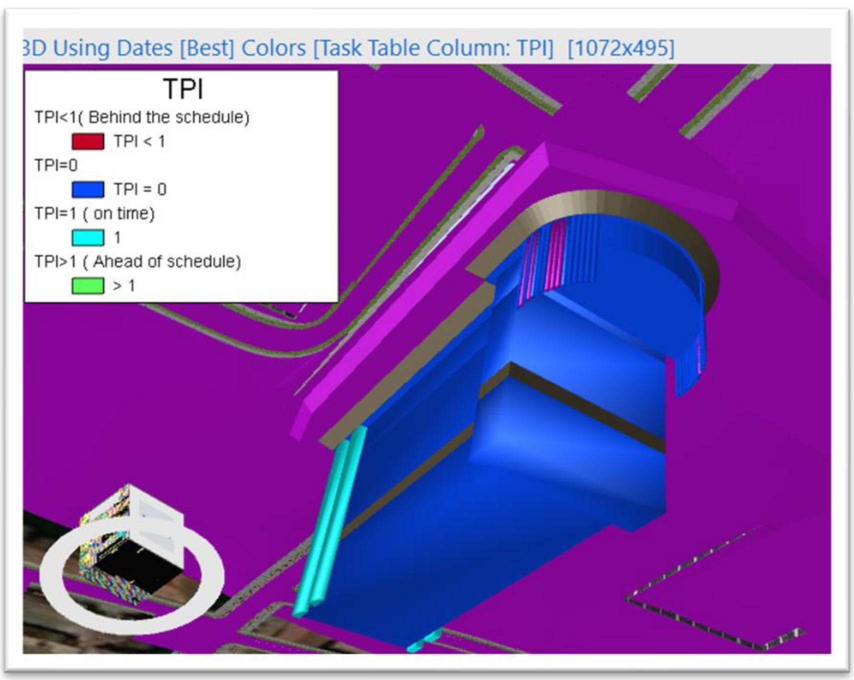
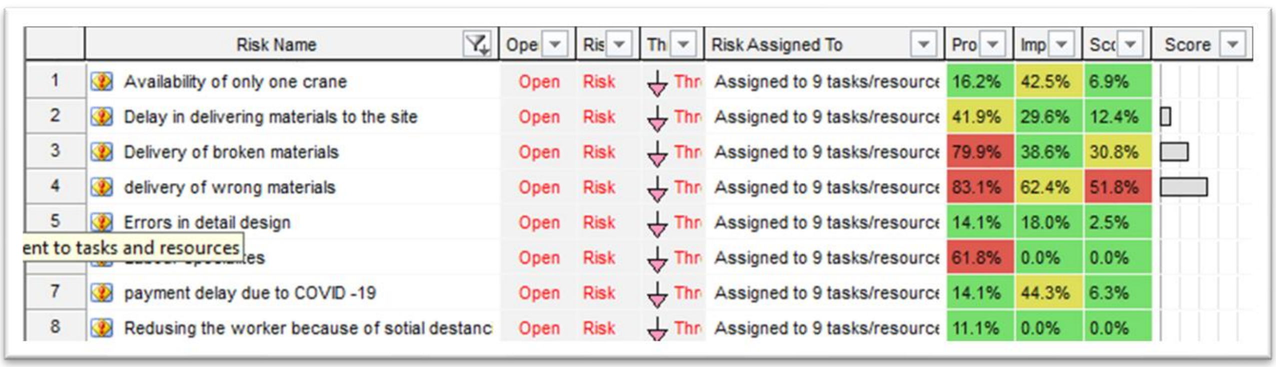


Figure 44- Color code for TPI

As mention in the risk management chapter after going through the process of exporting , converting and importing the model between the software the final model has been exported from Rriskyproject professional updated with the new duration and new cost with the worst case scenario from the process of risk assessment and imported to Synchro pro again .

Results from Risk analysis:



	Risk Name	Ope	Ris	Th	Risk Assigned To	Pro	Imp	Sco	Score
1	Availability of only one crane	Open	Risk	Thr	Assigned to 9 tasks/resource	16.2%	42.5%	6.9%	
2	Delay in delivering materials to the site	Open	Risk	Thr	Assigned to 9 tasks/resource	41.9%	29.6%	12.4%	
3	Delivery of broken materials	Open	Risk	Thr	Assigned to 9 tasks/resource	79.9%	38.6%	30.8%	
4	delivery of wrong materials	Open	Risk	Thr	Assigned to 9 tasks/resource	83.1%	62.4%	51.8%	
5	Errors in detail design	Open	Risk	Thr	Assigned to 9 tasks/resource	14.1%	18.0%	2.5%	
	ent to tasks and resources [illegible]es	Open	Risk	Thr	Assigned to 9 tasks/resource	61.8%	0.0%	0.0%	
7	payment delay due to COVID -19	Open	Risk	Thr	Assigned to 9 tasks/resource	14.1%	44.3%	6.3%	
8	Redusing the worker because of sotial destanc	Open	Risk	Thr	Assigned to 9 tasks/resource	11.1%	0.0%	0.0%	

Figure 45- Probability and impact for risks

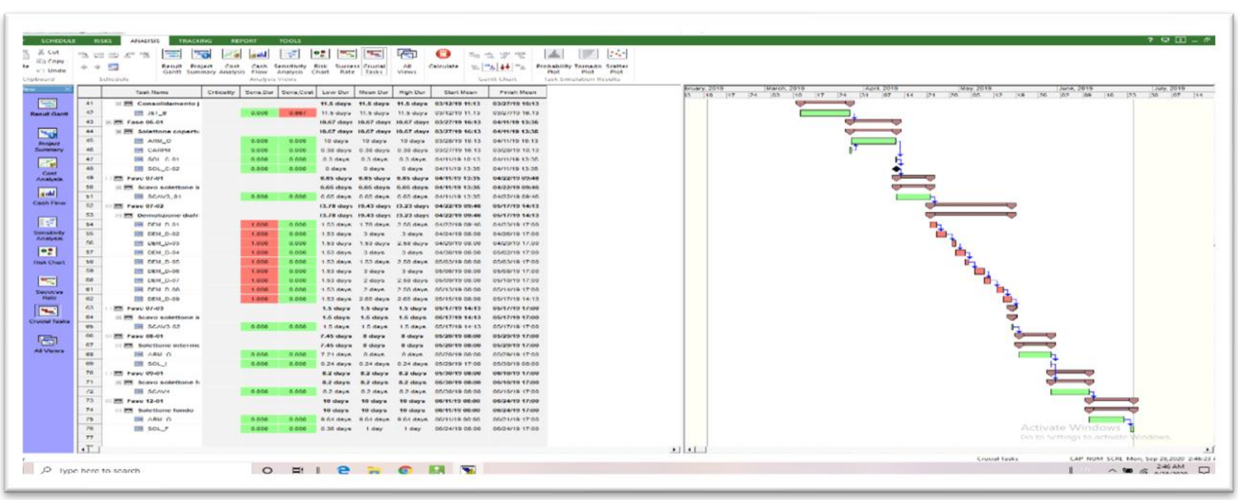


Figure 46- Critical Risks

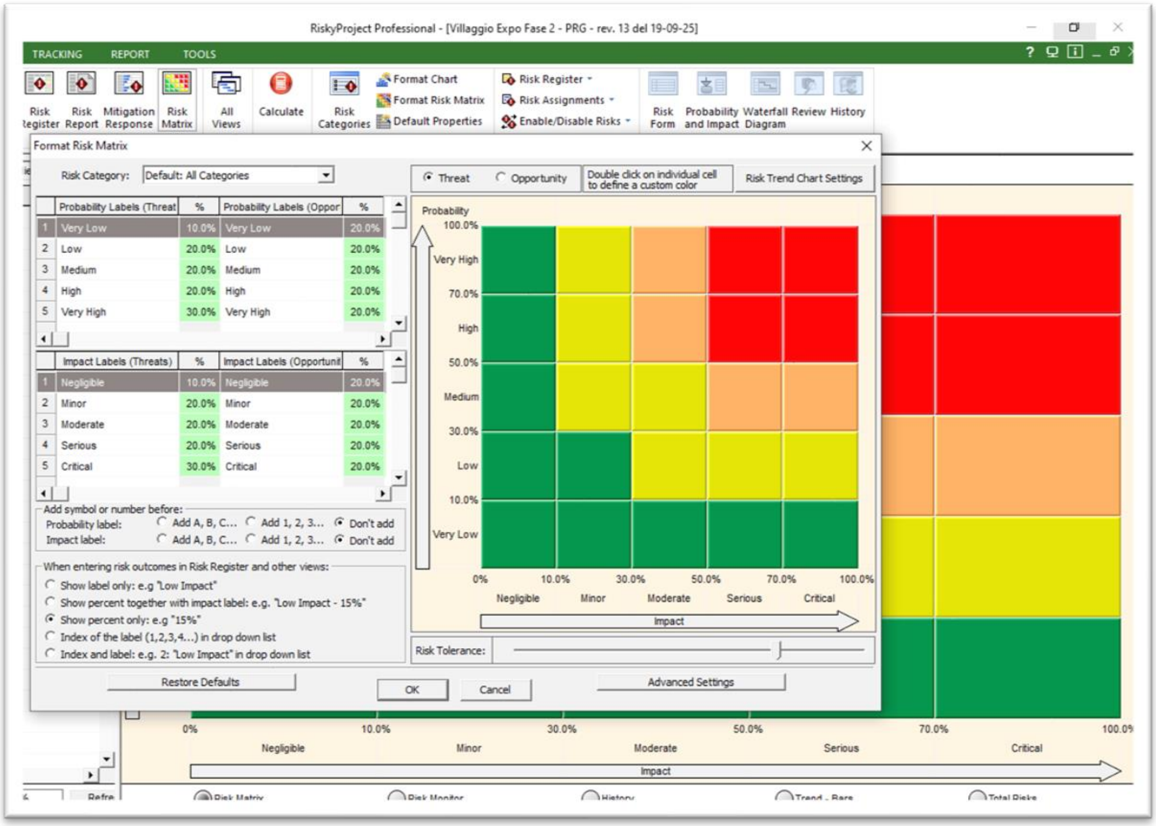


Figure 47- Risk matrex

Three main project parameters			
		Without risks (Current Schedule)	With risks and uncertainties
1	Total Project Cost	$2,494,608	$2,576,512
2	Project Finish Time	06/10/19 10:02	06/24/19 17:00
3	Project Duration	85.25 days	96 days

Figure 48- New schedule and cost with worst case scenario

Figure 49- probability for each scenario

Figure 50- schedule finishing time with and without risk

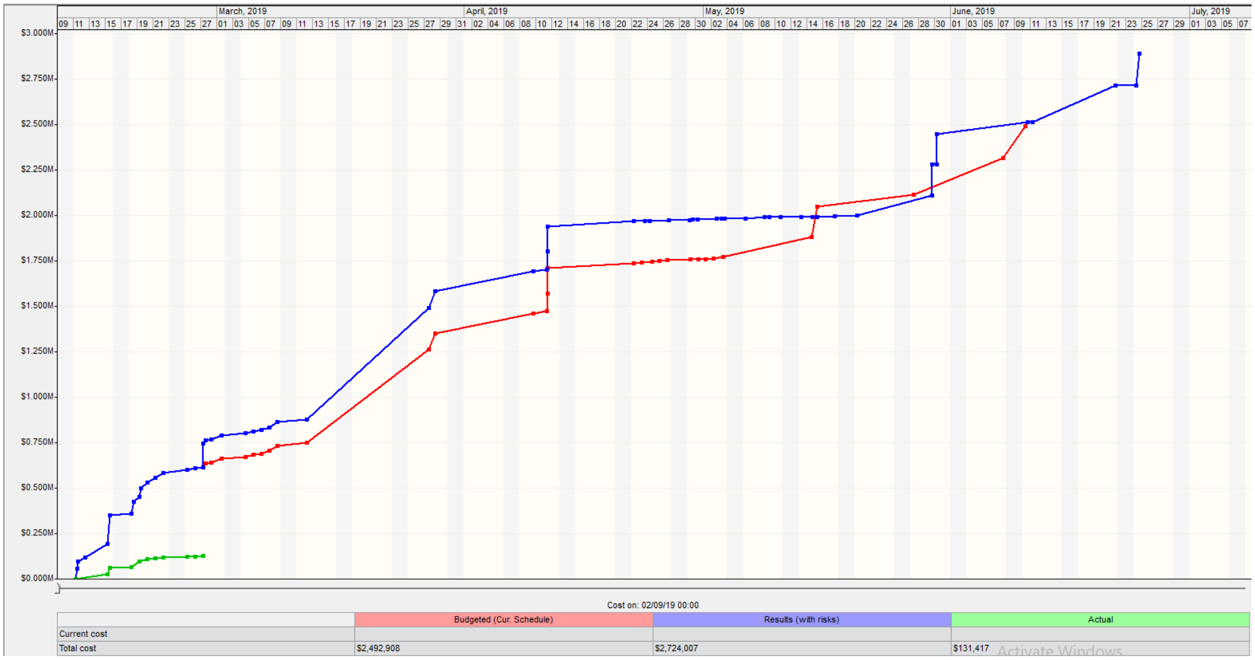


Figure 51- tracking budgeted cost with and without risk

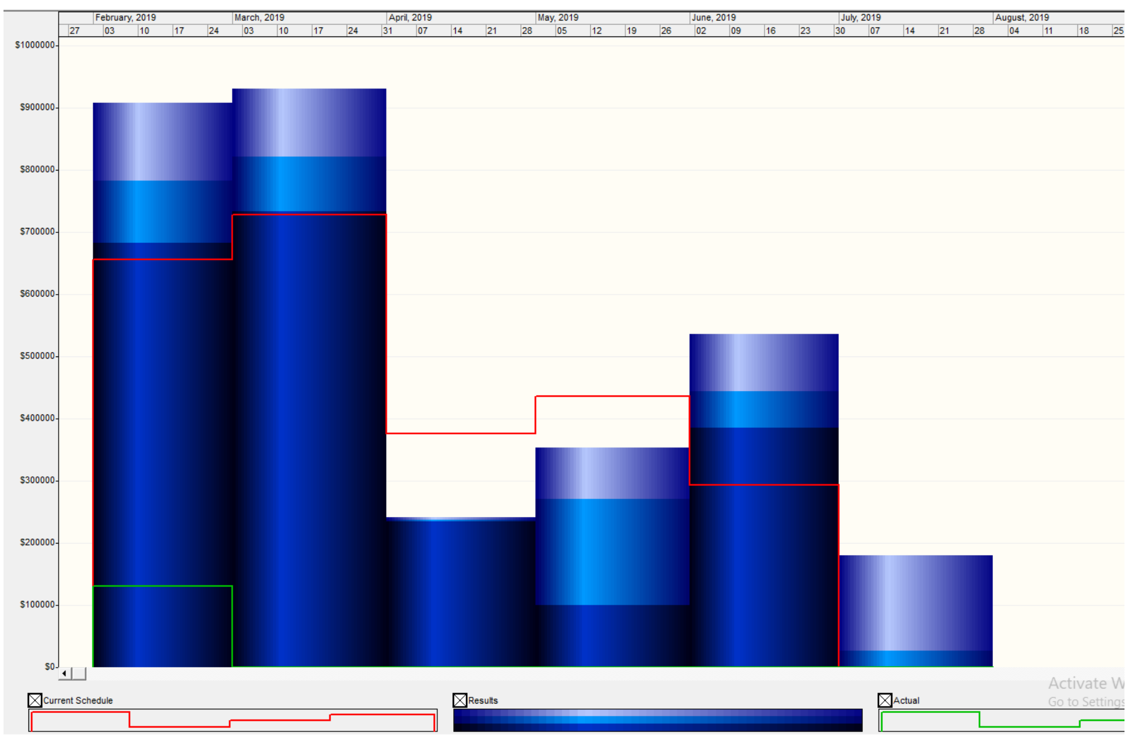
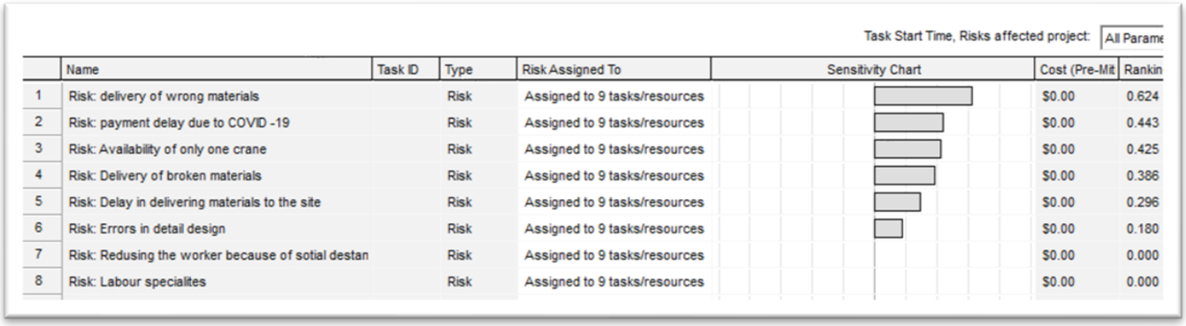


Figure 52- tracking overrun cost with and without risk



Task Start Time, Risks affected project: All Parame

	Name	Task ID	Type	Risk Assigned To	Sensitivity Chart	Cost (Pre-Mit	Rankin
1	Risk: delivery of wrong materials		Risk	Assigned to 9 tasks/resources		$0.00	0.624
2	Risk: payment delay due to COVID -19		Risk	Assigned to 9 tasks/resources		$0.00	0.443
3	Risk: Availability of only one crane		Risk	Assigned to 9 tasks/resources		$0.00	0.425
4	Risk: Delivery of broken materials		Risk	Assigned to 9 tasks/resources		$0.00	0.386
5	Risk: Delay in delivering materials to the site		Risk	Assigned to 9 tasks/resources		$0.00	0.296
6	Risk: Errors in detail design		Risk	Assigned to 9 tasks/resources		$0.00	0.180
7	Risk: Redusing the worker because of sotial destan		Risk	Assigned to 9 tasks/resources		$0.00	0.000
8	Risk: Labour specialites		Risk	Assigned to 9 tasks/resources		$0.00	0.000

Figure 53- Result of sensitivity analysis

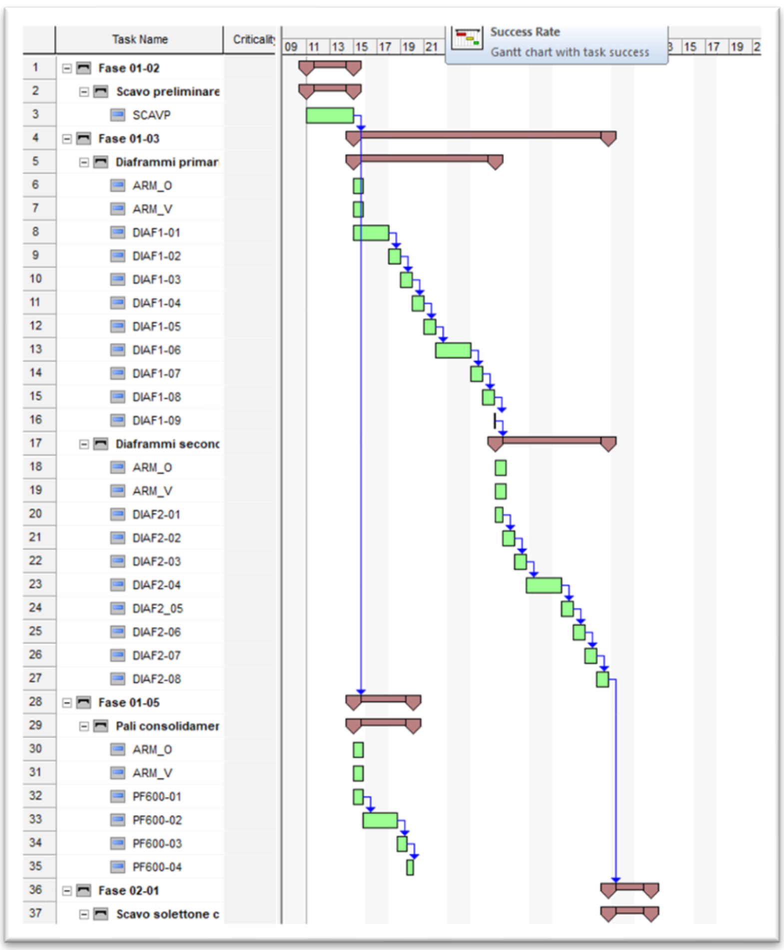


Figure 54- Effect of critical tasks on the project

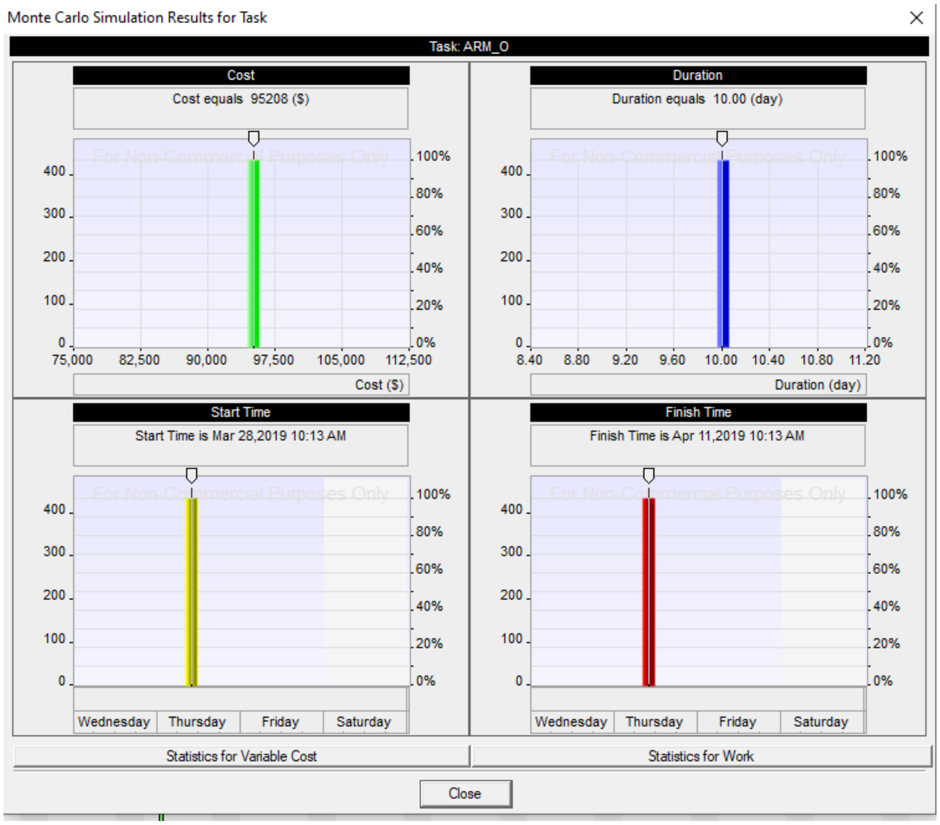


Figure 55- task analysis

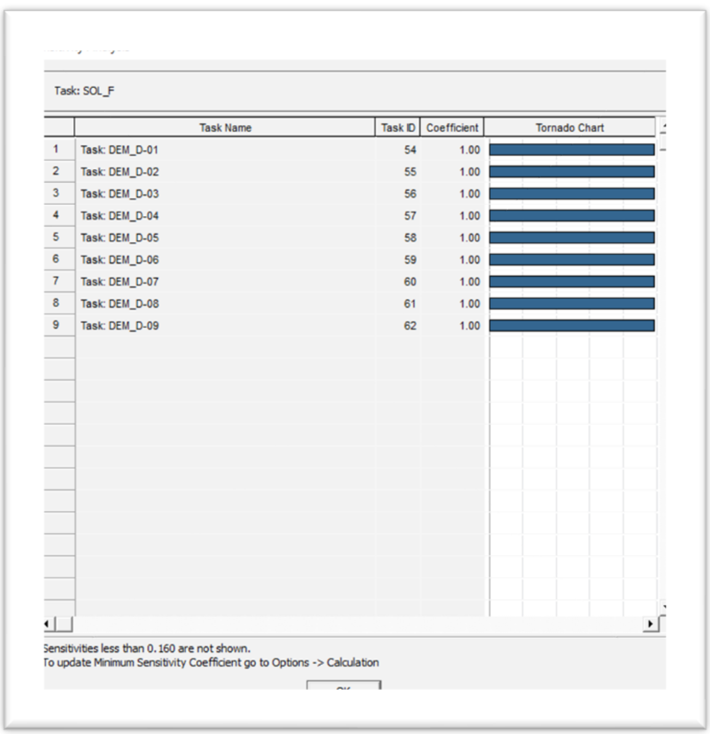


Figure 56- Tornado chart

After importing the new model from SYNCHRO Pro, new baseline schedule has been created which is the new model updated from Riskyproject to compare the old model with the new model including result shows the effect of different risks in duration and budget.

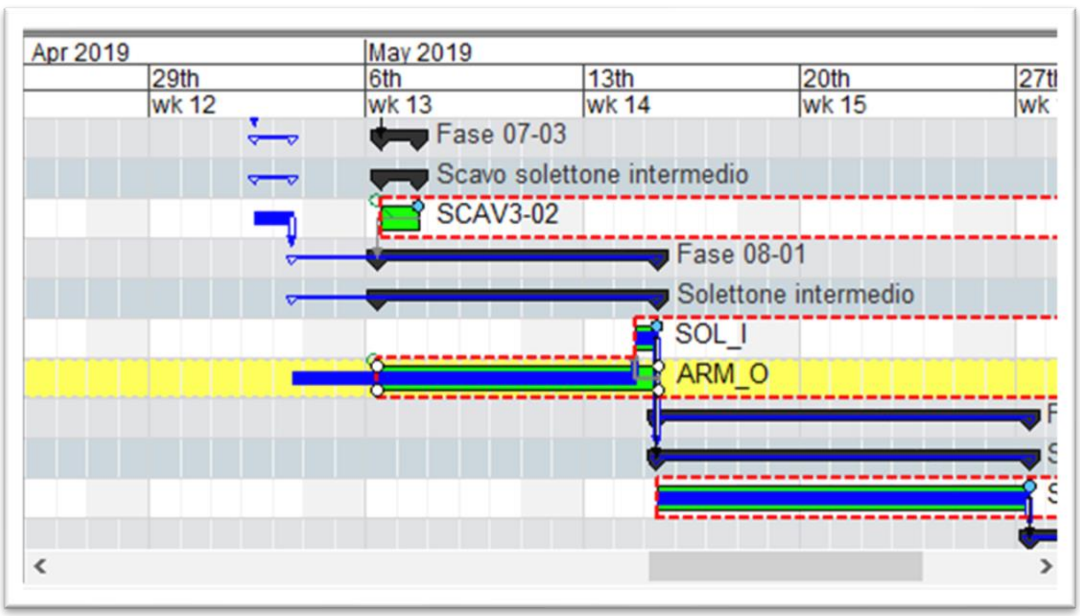
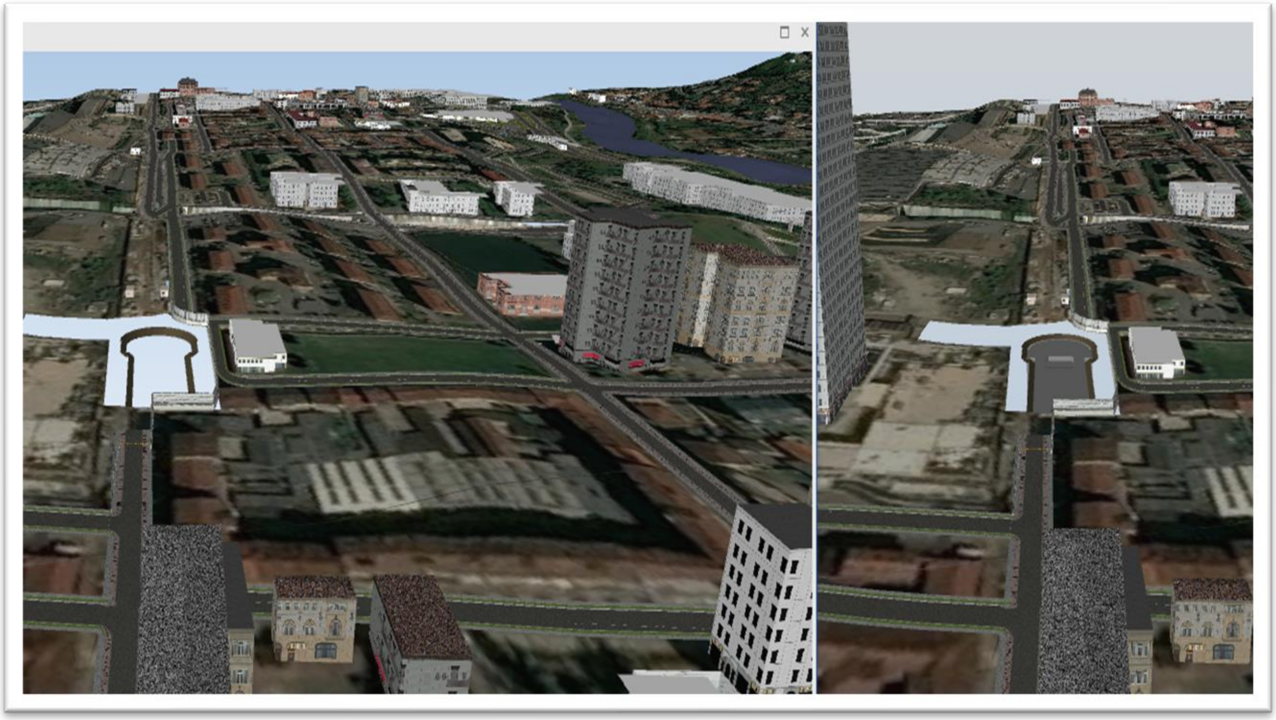


Figure 57- comparing schedules

After comparing schedules we want to see the visual effect of the risks in the 3D model ,by creating two 3D windows and link them together then let the first window follow the first schedule without risk and second one to apply effect of risk in the project , the result as following :

Figure 58- No risk VS Risk in 57 days



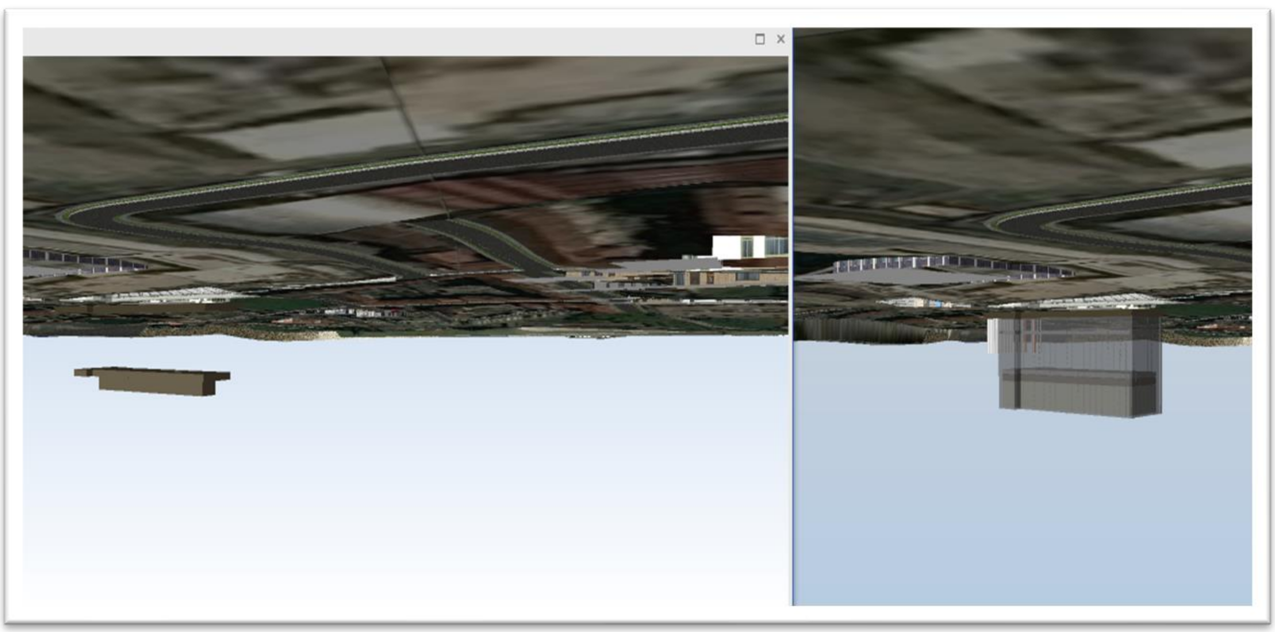


Figure 59- No risk VS Risk in 43 days

CHAPTER SIX: CONCLUSIONS

FINAL CONSIDERATIONS

- The implementation process is long process and BIM coordinator should distribute the responsibilities of the model editing between the engineers, architectures, and managers to ensure the accuracy and guarantee no data losses in the process.

- To speed up the implementation process it is better to include all detail about the schedule and cost and earn value calculation in one file of Microsoft project to reduce the transformation process between Synchro Pro and Riskyproject software.

- Risk management plan should be made before starting the project by meeting with all shareholder of the project to identify all risk elements and to make a foundation of tracing the cost and schedule.

- Risk management and EVM are powerful tools in BIM process and to get the best benefit the process should be updated on every stage of the project to ensure accurate result.

CHALLENGES

- Data loss is the most critical point of the BIM process, since the process of importing and exporting the model expose it to grate Risk of data loss. That is why distrusting the responsibilities may be solution of this problem.

- Conversion of the files from format to another may be critical in case the conversion process made with not authorize providers

- Many steps in BIM process has been made manually which make the process more time consuming, automatic process need to be discovered to make BIM process more attractive.

- The type of contract, delivery method, collaboration between contractor and subcontractor and degree of complexity of the project, all these factors may affect the success of implementation process.

- Advanced knowledge of the technology is essential to make perfect execution of the process.

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