Spring 5-14-2020

Analysis of concurrent delays in the construction industry

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ANALYSIS OF CONCURRENT DELAYS IN THE CONSTRUCTION INDUSTRY

A thesis submitted to the School of Sciences and Engineering in partial fulfillment of the requirement for the degree of

Master of Science in Construction Engineering

To

Department of Construction Engineering

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B.Sc. In Construction Engineering, 2013

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SPRING 2020

Acknowledgment

I would like first to thank God for enlightening my path, giving me strength and ability to pursue my studies and finish this research satisfactorily.

I would like to express my sincere appreciation to my advisor Dr. Samer Ezeldin for guiding me throughout my research and giving me support and advice. His valuable knowledge, motivation and mentorship have inspired and helped me through my research.

Sincere gratitude goes to my mother, Dr. Nermin Hatem, for her profound support, love, prayers and passionate encouragement, not only in this research, but in my whole life. Special thanks to my father, Dr. AbdelRahman, for being a role model for us even if he is not with us now. I would like to extend my appreciation to my husband, Eng. Ahmed El Kady, for his keen help, interest, patience and care throughout this research. I would also like to thank my daughter, Nour, for being my source of inspiration and hope. Special thanks to my siblings, Dr. Yomna & Eng. Mahmoud for their continuous support and help.

Finally, I would like to thank my friends and colleagues who gave me support and advice whenever needed.

ABSTRACT

Most of construction projects suffer from delays. These delays could be due to several reasons such as, poor design, poor planning and variation orders. The most controversial type of delays in the construction industry is the concurrent delay. Ambiguity usually surrounds the concurrent delays when they exist in the project because they do not have a unified or agreed upon definition. In addition, there are different remedy theories in terms of time and cost when they arise. Therefore, the aim of this research is to highlight how the Egyptian Law perceive concurrency; in addition to performing a comprehensive literature review for the accepted definitions for concurrent delays. The scope of this literature includes how different countries law define concurrency and its remedy including Egyptian Law, English Law and the US Law. In addition, the literature also includes how different internationally recognized protocols recommends the definition for concurrency and its reimbursement including the Association for the advancement of cost engineering (AACE) 2011, the Society of Construction Law (SCL) 2017, and the American Society of civil engineers (ASCE) 2016. Furthermore, the literature also shows how different standards forms of contracts identify concurrency and its consequences including FIDIC 2017 & NEC3. After that, this research proposes an analytical model that will help the user to identify concurrency and will output the delay responsibility for each party and the extension of time that should be granted to the contractor. The model includes the three internationally accepted standards (i.e.: AACE, SCL Protocol & ASCE) for the user to select from. The model is developed using MS visual basic programming language because of its wide array of functions and availability. Then, it was initially tested using different “what if scenarios” to determine its validity and limitations. After that, it was validated using actual project data where the final result was compared to both the contractor claim and the consultant’s counter claim. After verification & validation, the model proved its validity. Therefore, this model could be considered a useful tool for claim management, as it provides acceptable evidence in case of concurrency allowing the user to choose the best suitable concurrency analysis approach to the project.

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List of Abbreviations:

ASCE: American Society of Civil Engineers

AACE: Association for the Advancement of Cost Engineering

GDP: Gross Domestic Product

SCL: Society of Construction Law

Chapter1: Introduction:

1.1 Background:

Construction industry affects the development process for any country. The industry provides different direct and indirect employment opportunities for skilled and un-skilled labors. It also provides services for different sectors in the country such as governmental, private& public sectors (Wibowo, 2009). It also constitutes a substantial proportion of the Gross Domestic Product (GDP) of both developed and developing countries with a value added in the range of 7% to 10 % for developed countries and 3% to 6% for underdeveloped countries (Lowe, 2003 as cited by (Wibowo, 2009). In Egypt, the construction industry constituted on average 5 % of GDP in 2013/2014 and 11% of total employment for the same period. These numbers are expected to increase because of the huge investments in the construction field adopted by the Egyptian government including mega projects such as Suez Canal, one million housing and other infrastructure projects (Esam et al., 2015).

There are three main elements that constraint any construction project; namely, time, cost and quality. Therefore, the success of any project depends on how balanced these constraints are. These elements are interrelated, as any change in one of them will affect the others (Stojcetovic et al, 2014). Failing to finish the project on time will affect all stakeholders' interests. For the Owner, he will lose profits and benefits from operating the project on the agreed contract date. On the other hand, the Contractor will incur additional costs because of the extended stay on site(Braimah, 2013).There are different causes of delay in construction projects; such as variation orders, inaccurate estimations, fluctuations in prices, weather conditions and financial difficulties (Gajare et al., 2014).

1.2 Delay Analysis Techniques:

There are different techniques to investigate the effects of the delays on the project schedule. These techniques can be grouped under two main umbrellas, which are retrospective and prospective analysis. For prospective delay analysis techniques, the effect of the delays are predicted on the progress of works. Examples of that type of analysis are global impact, net impact, impacted as planned, as planned but for & time impact delay analysis techniques. However, the retrospective techniques demonstrate the actual impact of delay events on the project schedule, so it is done after the effect of delay events is actually felt. Therefore, it should be done at the end of the project. Examples of that type of analysis are as built vs. as planned, as built adjusted, collapsed as built & windows analysis. For each delay analysis technique, there are advantages and disadvantages. However, the technique that the project parties will use if problems arise should be stipulated and agreed upon in the project contract from the beginning of the project. (Gibson, 2008)

1.3 Different Types of Delays:

Delays could be categorized in four main categories. First category is critical or non-critical delays. Critical delays are the delays that affect the project completion date while the non critical delays are delays that don't affect the finish date of the project. Second category is excusable or non-excusable delays, where excusable delays are delays that occur out of the contractor's control such as acts of God, strikes, fire. However, non-excusable delays are the contractor's responsibility. Third category is compensable or non-compensable, where compensable delays are owner responsible delays, so the contractor will be granted an extension of time and cost compensation. However, non-compensable delays are delays that may be excusable for the contractor; however, he will not be entitled for any compensation resulting from them. Such delays are usually out of the contractor and the owner control. The forth category is concurrent or non-concurrent delays (Gajare et al., 2014); where concurrent delays occur when a contractor responsible delay is happening concurrently with an owner responsible delay. This type of delay is the most controversial one.

1.4 Concurrent Delays:

Concurrent delays are two delays happening at the same time that each of them is the responsibility of different parties. These delays are independent of one another and each of them alone postpones the completion date of the project. Although the previous understanding is the common one among expertise in the industry, experts usually debate on implementation. That is due to different interpretations for this definition and its consequences. Some of these differences are because of questions about concurrency. These questions are like if concurrency should be studied on delay causes or effects. Another question is about if delays have to overlap on their whole durations or just part of that duration. Another question is about if delays that are not overlapping in time could be considered concurrent (Livengood, 2017). Therefore, in the presence of concurrent delays and the absence of a unified definition, disputes often arise on which party will be responsible for the delay and whether there will be cost compensation or not (Arif et al., 2013). Therefore, concurrent delays are controversial especially if the parties did not agree on the way of defining and dealing with them from the beginning of the project.

1.5 Problem Statement:

Although most standard forms of contract have clauses for how to deal with delays whether owner's responsibility or contractor's responsibility, the majority of claims are not settled amicably and parties resort to disputes (Braimah, 2013). The case is more crucial when it comes to concurrent delays. That is because, most standard forms of contracts do not specify the definition of concurrency and its consequences. Therefore, courts deal with them based on case law which is not always consistent (Arif et al., 2013)

Literature review shows how different countries' laws are dealing with concurrent delays. In addition, it also shows different good practice standards that give guidance of how to assess concurrency in construction projects and what the compensation should be in terms of time and cost. Moreover, literature also shows how different standard forms of contract deal with concurrent delays. However, a few shows how Egyptian Law addresses the issue of concurrency. In addition, there is a need for a model that guides experts through studying concurrency to track where concurrency is and to determine its consequences. Therefore, this research will clarify how the Egyptian Law deals with concurrency, in addition to including a comprehensive literature review for the different theories, protocols, laws & standard forms of contracts of how to deal with concurrency. Thus, helping any decision maker in choosing the most appropriate technic for the project. In addition, this research will propose an analytical model that will include the most internationally recognized protocols; namely, SCL Protocol, ASCE and AACE for the user to select from to assess concurrency. Then, it will output each party's responsible delay and the extension of time that should be granted to the contractor. Therefore, it could be considered a useful tool for analyzing and supporting concurrency claims with valid evidence.

1.6 Research Objectives:

The main objectives of this research are:

1) Identify how Egyptian Law deals with concurrency, in addition to different countries law; namely, English law and US law
2) Identify how different internationally recognized protocols define concurrency and its consequences; namely, SCL Protocol, ASCE & AACE

3) Identify if different standard forms of contracts specify the way to recognize concurrency and its consequences or not including FIDIC & NEC.
4) Identify the compatibility of the countries laws with the most recognized protocols; namely, SCL Protocol, ASCE & AACE
5) Develop an analytical model that will incorporate the most internationally recognized protocols; namely, SCL Protocol, ASCE and AACE for the user to choose from. Then, the model will highlight concurrency and output the delay responsibility for each party and the extension of time that should be granted to the contractor.

1.7 Research Methodology:

The following figure shows the methodology adopted in this research:

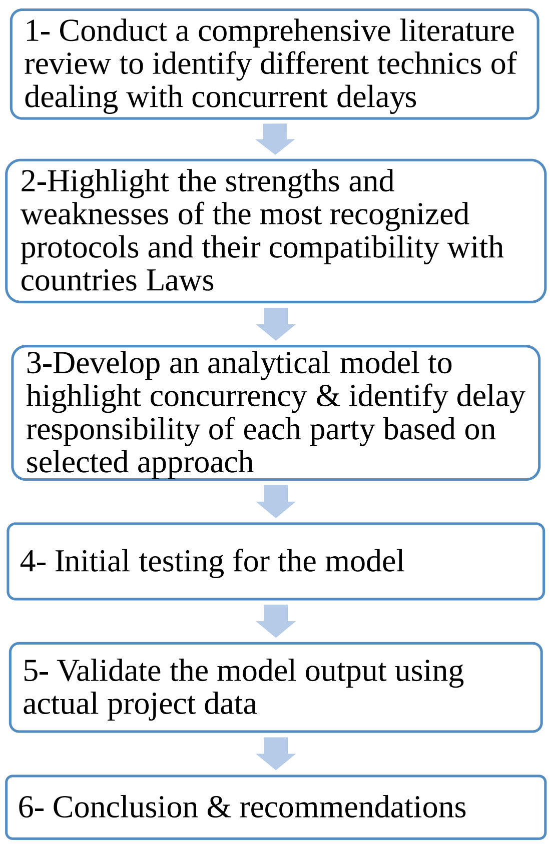


Figure 1: Research Methodology

First, literature review will be done to identify the gap in literature concerning the analysis of concurrent delays. In addition, from comprehensive literature review, how different countries law, different internationally recognized protocols and different standard forms of contracts deal with concurrency will be identified. After that, the compatibility of the most recognized protocols with the countries laws is highlighted. Then, a summary will be included at the end of each chapter summarizing the chapter findings. After that, an analytical model will be developed including the internationally accepted protocols for concurrency definition for the user to select one of them. The model will then identify if there is concurrency or not based on the selected technic. The model will be initially tested to check its output and logic. Then, the model will be validated using actual project data and the result will be compared to the Contractor claim and the Consultant counter claim. After that, reflections on the findings will be highlighted. Finally, conclusions and recommendations for future research will be highlighted.

1.8 Thesis Structure:

This research is composed of seven chapters as follows:

Chapter 1: Introduction:

This chapter includes introduction about different delays in the construction industry and the most controversial delay among them namely concurrent delay. In addition, it includes the problem statement, the main objectives & the main steps followed in this research.

Chapter 2: Literature Review:

This chapter discusses the researches done in the field of concurrency analysis highlighting the gap in literature. Then, the different technics and definitions for concurrency will be clarified. It also shows different court cases, theories involving concurrency and the recommended compensation in terms of cost and time.

Chapter 3: Modeling Methodology:

In this chapter, the compatibility of the different technics discussed in the literature review with the different countries law will be highlighted. In addition, the main steps used in the model will be mentioned; besides explaining the reasons for selecting the programming language used and the selected type of analysis in the proposed model.

Chapter 4: Model Development:

This chapter shows the model interface, the main inputs & outputs for each sheet.

Chapter 5: Model Verification:

This chapter shows initial testing of the model under different scenarios to show its capabilities.

Chapter 6: Model Validation:

In this chapter, the model will be tested using actual project data to validate its results. Then, the model output will be compared to the Contractor's claim and the Consultant's counter claim and the researcher reflections on both will be highlighted.

Chapter 7: Conclusion & Recommendations:

This chapter includes the main conclusions for this research and recommendations for future researches.

Chapter 2: Literature Review:

2.1: Concurrent Delays Overview:

There is no unified or agreed upon definition for concurrent delays in construction projects. Therefore, many conflicts arise while dealing with concurrency and its reimbursement in terms of time and cost. There are different perspectives for concurrency; the following are some of them:

- Concurrent delays occur when separate delay events happen at the same period of time and each of which affects the project finish date.
- Concurrent delays appear when the consequences of the separate delay events overlap.
- Concurrency occur when one of the events is a reason for a delay to the project completion date; however, that delay would have been occurred anyway by the other event even if the first event didn't exist (Peters, 2003).

Therefore, there are different interpretations for the definition for concurrent delays; however, all definitions agree that these delays have to affect the project completion date. Accordingly, they have to be on the critical path. In the following sections, different definitions for concurrent delays will be discussed according to countries Laws, the most internationally accepted protocols and standard forms of contract.

After proving concurrency, it is important to know the remedy resulting from their existence. There are mainly two different approaches for concurrency remuneration. The first one is the "time but not money" approach in which the contractor is entitled for extension of time for the period of concurrency; however, he will not receive any cost compensation. The second approach is apportionment where damages should be apportioned between parties according to each party's liability. Therefore, the contractor is given partial extension of time and partial cost compensation. In addition, the owner applies partial liquidated damages on the contractor (Rankin, et al., 2018).

Because of the uncertain nature of concurrent delays, many researches are done to determine the different perspectives for concurrency and its remedy. A collection of researches done in concurrency is summarized in the following paragraphs.

A paper published in the Buildings Journal by Braimah in 2013 entitled " Construction Delay Analysis Techniques- A Review of Application Issues and Improvement Needs", the researcher identified the major issues related to the delay analysis techniques; in addition, he recognized the major aspects that needs improvements. Among these aspects, he highlighted that the issue of concurrent delays is not well addressed in the delay analysis techniques and needs to be incorporated in future researches.

In a technical article submitted to the AACE International Annual meeting in 2004, Bubshait et al. discussed different concurrency analysis theories and practices. Then, they discussed an assessment example for concurrent delays.

Another paper submitted to the CIB 2016 World Building Congress entitled "Legal Development in Relation to Concurrent Delay: The Position of the English and Scottish Courts", Hughes et al., explored the concurrent delays concepts and identified the doctrinal split between the English and Scots law based on recent court decisions.

The American Society of civil Engineers has published several papers in the topic of concurrency. In their Journal titled "Legal Affairs and Dispute Resolution in Engineering and construction" in 2019, Munvar et al., published a paper entitled "Concurrent Delay Analysis: Methods, Case Law, and Expert Perception" identifying the nature and effects of concurrent delays in the Indian Industry and recommending how to incorporate the advanced global practices in the Indian Industry.

In 2017, in the ASCE Journal titled "Legal Affairs and Dispute Resolution in Engineering and construction", Livengood published a paper entitled "Knowns and Unknowns of Concurrent Delays" discussing the three main recognized technics for concurrent delays which are the SCL Protocol, the AACE and the ASCE. In addition, Livengood discussed three legal approaches to concurrency namely, intertwined delays, apportionment of delays & jury verdict.

In the same journal in 2013, another paper entitled "Concurrent Delays in Construction: International Legal Perspective" by Arif and Morad discussed the different adopted concurrency approaches in courts with different legal systems including, the US, Canada, UK and Australia and how each court judges the remedy in case of concurrent delays.

In another Journal under the ASCE entitled "Journal of Management in Engineering", Chong et al., published a paper named "Revisiting UK Delay and Disruption Protocol: Distinguished Features for Contract Drafting" in 2014. In this paper, the researchers compared the

SCL Protocol main concepts with the references used by the contracting parties. Among these concepts, the issue of concurrency was discussed. In addition, the researchers determined how the SCL protocol could be feasibly used in the Malaysian industry.

A dissertation submitted to the British University in Dubai for the degree of Masters in Construction Law and Dispute Resolution in 2018 entitled "Construction Delays and Concurrent Delays", El Gezery identified the main rules used in the different civil and common law jurisdictions, in addition to the courts approaches to determine the extension of time in case of concurrency. Then, he proposed different options for defining concurrency based on how parties agree on dealing with concurrency and proposed contractual amendments to consider concurrency. In addition, he recommends how the UAE courts could have a more efficient scheme for construction disputes resolution.

Another dissertation submitted to the University of Strathclyde for the degree of Doctor of Philosophy in Law in 2017 entitled "Concurrent Delay Analysis in Public Works Construction Disputes. A cross-jurisdictional study of Egypt, Scotland and England", Abdallal identified the difference between the private and public contracts in civil law countries and explained how that may add to the practical perspective of concurrency. In addition, he identified the issue of concurrent delays from the legal perspective and the construction management perspective. Then, he tested a regulatory framework for concurrency in the context of civilian law and common law that will help in the disputes related to concurrency.

Accordingly, many researches are done to identify the different approaches to analyze concurrency; however, a few addressed the concurrency under the Egyptian Law. In addition, there is a need for a model that guides the user into concurrency identification and remedy. Therefore, the aim of this research is to identify how the Egyptian Law perceives the concurrent delays compared to other countries laws; namely, the English & US Laws. In addition, how the Egyptian Law is compatible with the internationally accepted technics for concurrency analysis; namely, SCL Protocol, ASCE and AACE. Moreover, how the standard form of contracts especially FIDIC -as it is widely accepted in Egypt- recommends dealing with concurrent delays. After that, an analytical model is developed to include the three recognized technics (SCL Protocol, ASCE &AACE) for the user to select one of them, and then the model will identify concurrency and the extension of time that should be granted to the contractor.

2.2 Concurrent Delays In Different Countries Laws:

2.2.1 Concurrent delays in Egyptian Law:

In Egypt, there are two main laws that are used in the construction industry. The first law is the Civil Law (Law 131 for year 1948) which controls the contract when it is between two different parties; the Country represented by the government is **not** one of them. The second one is the administrative law (law 89 for year 1998) which controls the contract when the Country represented by the government is a party to the contract (Yeihia, 2009).

Egypt follows the civil law system where courts implement the articles and principles existed in the law in judging any case. According to Pejov (2000) for each case facts, the courts would interpret the laws and apply it specifically to that case. Accordingly, if there is a case that is not clearly conveyed by the law, the courts should apply the general understanding and concepts of the civil code general principles to fill in the gaps.

Concurrent delays are not directly addressed in the Egyptian civil law (Law 131 for year 1948) according to many researchers; in addition, it doesn't have any judicial authority or persuasive commentary regarding concurrency. However, there are some of the Civil Law articles that could be used in terms of concurrency existence. Al-Sanhoury- who is a legal scholar who drafted the Egyptian civil code 1948 and published a book called "El-Waseet" to explain the civil code in details- in his book El Waseet (as cited by El Nemr, Waleed 2017) defined "the contributory Fault" as a fault where each party has contributed independently to the damage caused. According to El Nemr (2017), this is the most relevant concept to concurrency in the Egyptian Civil Code. According to Azzam (2019), the cases of concurrent delays in Egyptian Civil Law are explained by Al-Sanhoury and could be categorized into two main categories as follows:

- First Category where only one of the parties should be held responsible for the fault, that category includes the following cases:
    - If one of the faults is the main reason for the damage and the second party's fault didn't cause any damage.
    - If one of the faults is the result of the other party's fault.
    - If one of the faults' severity exceeds the other party's fault.
    - If one of the faults is intentional.

- Second Category is based on articles 169 & 216 in the Egyptian Civil Code where the judge may allow cost reimbursement for one of the parties, or apportion the reimbursement equally between parties or apportion damages according to the severity of each fault. That category includes the following cases:
  - Each fault could be distinguished from one another.
  - If one of the faults severity exceeds the other party's fault severity; however, the other party has accepted the fault.

According to EL Nemr (2017), the concept of concurrent delays was derived from article 169 in the Civil Code which states *"When several persons are responsible for damage, they are jointly and severally responsible to make reparation for the damage. The liability will be shared equally between them, unless the judge fixes their individual share in the damage due"*. Moreover, Al Sanhory (as cited by El Nemr. 2017) refers as well to article 216 in Egyptian Civil Code as a specific article that addresses the concept of contributory fault. This article stipulates "*The judge may reduce the amount of damages or may even refuse to allow damages if the creditor, by his own fault, has contributed to the cause of, or increased, the loss"*. Therefore, Al Sanhoury (as cited by El Nemr. 2017) concluded that these two articles no 169 & 216 allow apportionment where the judge would distribute the damages between the parties according to each party's share to the harm. However, if it is hard to allocate each party's responsibility and share of the harm, the judge may assume equal share for each one.

For the administrative law, there are two versions; the old version is Law 89 for year 1998 and the new version is Law 182 for year 2018. Both versions don't have any clauses related to concurrent delays. They only have clauses that organize when the contractor should be entitled to time extension and/or cost compensation and when he shouldn't. It is worth to highlight that the amendments done in the new version of the law (Law 182 for year 2018) includes mostly some modifications to the articles related to cost and time entitlements for the contractor (Azzam, 2019).

2.2.2 Concurrent delays in English Law:

England follows the common law system where the previous judicial decisions are the pillars for judging the succeeding cases. Thus, courts are not only judging in the cases, but they also creating the law. Therefore, lawyers in this system would compare the actual case they have to previous similar cases having related legal background. Then, they could find the binding legal rule from similarities between the present & previous cases (Pejov, 2000).

The definition for concurrent delays that is widely accepted in England was proposed by John Marrin in 2002 as "*concurrent delay is used to denote a period of project overrun which caused by two or more effective causes of delay which are of approximately equal causative potency*" as cited by (Hughes et al., 2016). Therefore, based on that definition, the effective causes of delay have to be the responsibility of both the employer and the contractor. In addition, for delays to be concurrent, the causes of delay don't have to overlap in time; however, they have to possess the same effect on the project completion date and that is refered to as "equal causative potency". In the case of equal causative potency, the contractor will be entitled for extension of time for the concurrent delay, and that could be referred to as the "Malmaison Approach". That approach was derived from the case of Henry Boot v Malmaison in 1999 and then used in the following cases (Hughes et al., 2016). This approach is used when none of the delay causes could be considered as the dominant cause of delay (Keating as cited by Long, 2018). In that approach, the contractor is entitled to full extension of time only and no cost compensation for the concurrent delay that is caused by the contractor & the employer if the events have equal causative potency and one of them is a relevant event. That is basically because of two reasons. First one is that rejecting to grant the contractor an extension of time could be considered as an act of prevention. The second justification is that according to JCT contract, the contractor is entitled to an extension of time if there is a relevant event. Accordingly, the JCT didn't mention any exceptions in case there is a relevant event. On the other hand, the contractor is not granted any cost compensation because he would have incurred the same loss and expenses because of the delays he is responsible for (Hughes et al., 2016). Therefore, according to Arif et al. (2013), the Malmaison approach grants the contractor a full extension of time in case there is concurrency and one of the events is an employer responsibility regardless the contractor responsible delay happening at the same time. On the other hand, if the effective causes of delay have unequal effect on the project completion date, the dominant cause concept will be applied. In this concept, the party that is responsible for the dominant cause of delays will take the responsibility for the damage. According to Arif et al. (2013), the dominant cause analysis is a more logical approach instead of the time of occurrence as the event causing the prevailing damage is the one to be studied. In that approach, the dominant cause of delay is the one responsible for the delay in case of concurrency (Long, 2018). However, according to Marrin as cited by to John Hughes, et al., 2016, doubts surround that concept because of lack of judicial support.

There are different other approaches that have been used in UK cases. One of these approaches is the "But for" test, in this test, delays are tested if they would have occurred anyway even if the concurrency doesn't exist. (Long, 2018). However, that approach is not an accurate one as these non-related delays may individually have an effect on the project. Accordingly, courts would not use that approach in these cases (Arif et al., 2013). Another approach is "First in line" in which the delay event that happened first in time is considered the one responsible for the whole project delay regardless the party responsible for it. This approach was used in Royal Brompton Hospital vs Hammond. However, this approach doesn't seem to be a balanced one (Arif et al., 2013). Although there are different approaches to deal with concurrent delays, the most widely accepted ones in UK courts are the Malmaison approach and the dominant cause approach. According to Abdallah (2017), the Malmaison approach is considered the established doctrine when there is concurrency in England.

It is worth to highlight the case of "City Inn versus Shepherd Construction". It is held in Scottish courts and considered a landmark case in the assessment of concurrent delays (Arif et al., 2013). In this case, the court suggested that if there is no single event that could be considered the dominant cause of delays, apportionment between parties could take place. In addition, as the court found the previous cases in Scotland, England & Wales of low assistance, it suggested the following approach while determining extension of time and concurrency. First, it is important to show that the delay is caused by a relevant event. Second, causation of delay should be supported by evidence. Third, critical path method could be used as a supportive tool for analysis of delays but not to be used as indispensable. Forth, if there is an event that could be considered the dominant cause of delays, that event will be responsible for the delay. Fifth, if there is both employer responsible events and contractor responsible events that both are causing delays and none of them could be considered the dominant cause of delay, apportionment could be applied. Sixth, fair and reasonable assessment should be applied (Arif et al., 2013). That principle of apportionment is faced with reluctance in the courts of England and Wales and is not accepted yet. However, according to Arif et al. (2013), the case of “City Inn vs. Shepherd Construction” has opened the path to reform and modify the law to include guidelines to apply apportionment whenever possible.

2.2.3 Concurrent delays in US Law:

Common Law system is the adopted judicial system in US courts similar to England. However, US perceive concurrency in a different way. In this section, how US courts deal with concurrent delays is discussed.

According to Long (2018), there are three main technics for dealing with concurrency according to US courts. The first one is "time but no money" which dated back to 1900s. In this technic, if concurrency is proved, time extension is granted, but no cost compensation. This approach is also termed as "Easy Rule" where neither apportionment nor compensation is granted (Arif et al., 2013). According to Arif at al. (2013), this approach is considered the "Doctrine of concurrent delays" by the courts. It is usually applied if it is difficult to allocate the responsibility of concurrency to each party or when there is lack of evidence to prove each party's share of the damage.

After that, Apportionment is evolved as a tolerant way of dealing with concurrency. This approach is also known as "Fair Rule" or "Comparative negligence" as mentioned by Arif et.al (2013). However, for the courts to be able to apportion each parties' responsibility to the harm, the burden of proof lies on the claimant. If it is difficult to segregate the responsibilities of each party, apportionment should not be used.

As a good alternative to apportionment, critical path method technic could be used. This method gives good evidence and proof for the delays causes & effects from the project schedule, according to Long (2018). Arif et al. (2013) have also highlighted the importance of that technic in providing proof and solid ground for analyzing concurrent delays.

Among countries that follow the common law system, US has a better experience in perceiving concurrency. Therefore, the US Law in regards to concurrency is considered a bench mark according to Arif et al. (2013). Therefore, the main principles used in US Law were summarized by Bramble and Callahan 2000 (as cited by Arif et al., 2013) as follows:

- Time and cost calculations should be provided by the parties involved in the project in order for the courts to analyze concurrency.
- The burden of proof lies on claimant for financial recovery.

- Contractor will be granted time extension if there is a third party that is involved in causing delays.
- Time extension is only granted if concurrent delays are excusable and non-compensable.
- Compensation will be given due to one delay only in case of concurrency and both delays are compensable.

2.3 Concurrent Delays in Different Recognized Protocols:

According to Livengood (2017), there are three recognized guides worldwide for forensic delay analysis; each one of them addresses concurrency in a different way. These three guides are

1. Association for the Advancement of Cost Engineering International (AACE) Recommended Practice on Schedule Delay – RP 29R-03(AACE 2011).
2. The Society of Construction Law's Delay and Disruption Protocol (SCL-DDP 2017).
3. The ASCE Standard Guidelines for Schedule Delay Analysis (ASCE 2016).

In this section, how concurrency is addressed in each one of them will be discussed.

2.3.1 Concurrent Delays in AACE 2011:

According to the Association for the Advancement of Cost Engineering International, there are two definitions for concurrent delays. The first one is "two or more delays that take place or overlap during the same period, either of which occurring alone would have affected the ultimate completion date". The second one is "concurrent delays occurs when there are two or more independent causes of delay during the same time period" (as cited by Livengood, 2017). Accordingly, there are two different theories according to the AACE, namely, Literal theory & Functional Theory. In the Literal Theory delays have to be "literally concurrent in time", so they have to occur at the same time. Therefore, they have to start on the same time to be considered concurrent. That could be justified by the following; if the delays do not start at the same time, the first delay that occurs results in a float that the second delay would absorb. Therefore, the second delay will not remain on the critical path anymore and will not affect the project completion date. That could be illustrated as shown in the following figure.

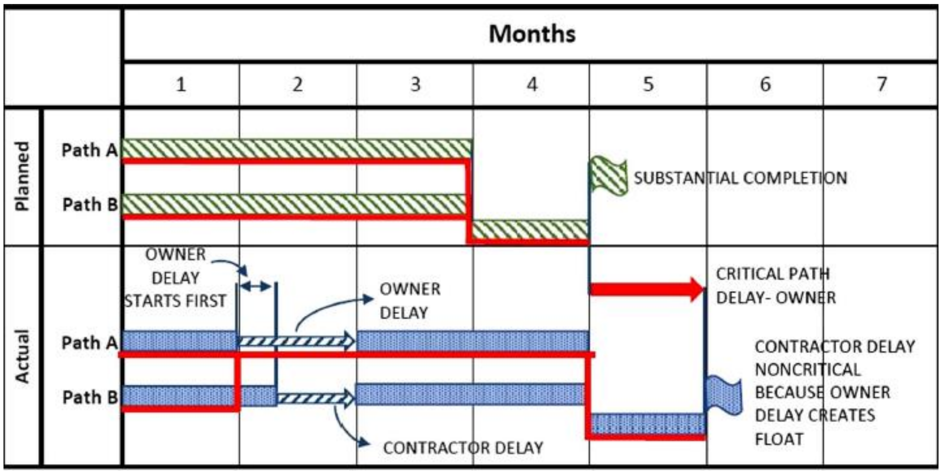


Figure 2 Literal Concurrency
Livengood 2017

However, that exact simultaneity is impossible to happen according to the AACE. On the other hand, in the Functional Theory, delays don't have to start on the same day, but they have to occur in the same analysis period. Accordingly, choosing the evaluation time period is crucial as it affects the identification of concurrency. Therefore, if the delays are within the same analysis period, they are considered concurrent. However, if they are in different analysis windows, they are not concurrent. The following figure shows how the differences in selecting the analysis period would affect the existence of concurrency. Therefore, the selection of analysis period should be precise and should avoid big analysis windows. Therefore, the activities causing delays should start near in time for them to be concurrent. That is to eliminate the possibility of taking a big time period as an analysis window. (Livengood , 2017).

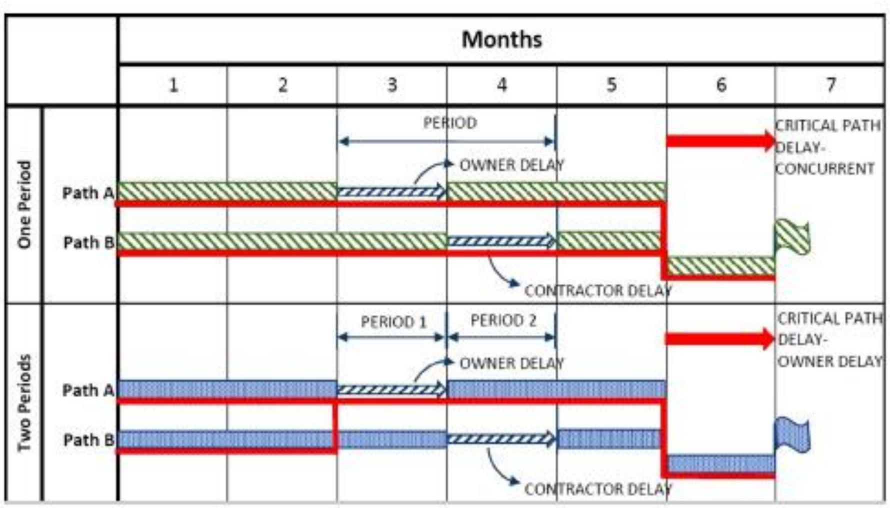


Figure 3 Effect of time period selection
Livengood 2017

In addition to the previous definitions, AACE stated that delays have to possess some characteristics to be considered concurrent. These characteristics are: first, delays should be independent and unrelated to each other. Therefore, if one of the delays is dependent on the other, they are not concurrent delays. Second, each delay should affect the project completion date in absence of the other delay. Therefore, each party's responsible delays should be studied separately to ensure that they are on the project's critical path. Third, different parties should be responsible for the delays to be considered concurrent, but one of them could be a force majeure one. Forth, the delays under consideration have to be involuntary. Accordingly, pacing delays where one of the parties have voluntary delayed his pace of work to cope with the delays by the other party should not be considered concurrent delays. Fifth, the delayed work has to be considerable (Livengood, 2017). Hence, the delays under consideration should affect the project finish date by a considerable amount.

After knowing the main definitions and characteristics of concurrent delays according to the AACE, it is important to know when AACE recommends studying concurrency. Is it better to study them at time of delay causation or at the time when they affect the project schedule? AACE recommends that analyzing concurrency should be consistent with the delay analysis technique that is adopted in the project. Accordingly, if the delay analysis technique analyzes delays at the time of causation, concurrency should follow the same procedure. On the other hand, if delay analysis considers delays when they affect the schedule, concurrency should be analyzed using the same theory. However, generally, AACE recommends that analyzing concurrent delays should be better done when they affect the schedule (Livengood, 2017).

When concurrency is proved, AACE recommends the following remedy in terms of time and cost compensation:

• If the concurrent delays are a force majeure delay and a contractor delay, the contractor is entitled for extension of time only. Therefore, he will not be granted any cost compensation and he will not be asked for liquidated damages

• If the concurrent delays are a force majeure delay and an employer delay, the contractor will be entitled for time extension, but he will not be cost compensated. In addition, no liquidated damages will be applied

• If the concurrent delays are a contractor delay and an owner delay, then the contractor will be entitled for time extension, but he is not granted any cost compensation.

(Long. 2018)

According to the previous cases, it is obvious that AACE considers concurrent delays as excusable non compensable delays. Therefore, the only allowed remedy is time extension because each party's right to be compensated is offset by the other party's right to compensation as well. Therefore, no cost compensation is applied.

2.3.2 Concurrent Delays in SCL DDP 2017:

The Society of Construction Law first published the delay and disruption protocol in 2002 to provide guidance for dealing with delay and disruption matters. Then, a new edition with updates was released in 2017 superseding the previous edition (The society of construction law, 2019). In this section, the definition of concurrency and its remuneration according to the SCL protocol is discussed.

The concurrency definition according to the Society of Construction Law's Delay and Disruption Protocol is "True concurrent delay is the occurrence of two or more delay events at the same time, one an Employer Risk Event, the other a Contractor Risk Event and the effects of which are felt at the same time. True concurrent delay will be a rare occurrence" (as cited by Livengood, 2017). Accordingly, the SCL protocol adopts the literal concurrency theory that was illustrated by the AACE. For the delays to be concurrent, they have to start at the same time and have the same duration. In addition, they have to affect the project completion date, so they have to be in the critical path of the project. Therefore, it is important to conduct CPM analysis for analyzing concurrency (Livengood, 2017). The following figure illustrates the concept of literal concurrency where both the owner delay and the contractor delay start at the same time and have the same duration; therefore, they are considered concurrent (Long. 2018).

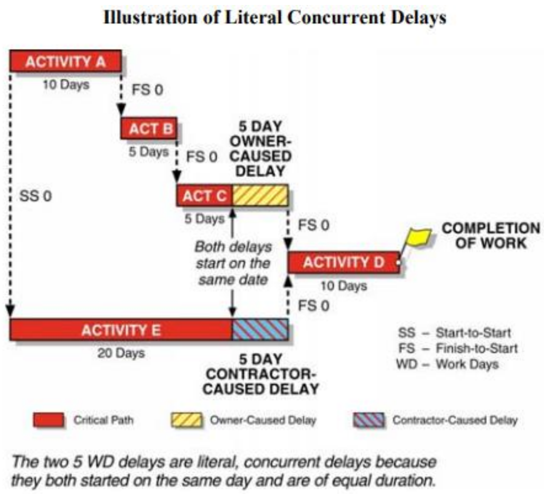


Figure 4 Literal concurrency
Richard, Long. 2018

It is important to understand if the SCL recommends to study the concurrency delays at the occurrence time or when they affect the project schedule. According to the SCL definition for concurrency, if the delay effects are felt at the same time, they are considered concurrent even if the causes occur at different times. Therefore, based on that definition concurrent delays should be studied when they affect the schedule at the same time, not when their causes happen (Livengood, 2017). Therefore, according to Hasan (2013), it is considered concurrent effect of sequential delay events.

After concurrency is proved, it is essential to analyze the allowed remedy for the different parties in the project. According to Hasan (2013) when concurrency is proved, the contractor should be granted a full extension of time regardless of his own delays. That means the contractor delays that is concurrent with the owner's delays shouldn't reduce the due extension of time that the contractor is entitled for. That could be justified by the "Prevention Principle" in the English Law as the SCL Protocol is a British standard. The prevention principle stipulates that one can't take benefit of a situation that his performance has hindered. Accordingly, as the employer has concurrently with the contractor caused delay to the project completion date, the employer shouldn't benefit from his delays. According to El Nemr 2017, for the prevention law to be applicable in the presence of concurrency, the burden of proof lies on the contractor. He should prove that he couldn't finish the work in the agreed upon completion date due to employer's delays.

For the cost compensation, unlike the British law, SCL allows apportionment in case it was possible to separate the contractor delays from the owner delays in concurrency. However, if the contractor-incurred costs were because of his delays, he will not be entitled to any additional costs. Therefore, generally, the contractor could only be entitled to cost compensation in case the employer delays exceed the contractor's delays in duration. (SCL, 2017)

2.3.3 Concurrent Delays in ASCE 2016:

The schedule delay analysis standard committee of the construction institute of the ASCE published the schedule delay analysis 2016. This standard recommends the best practices and principles related to schedule delay analysis. Then, it explains the reasoning for each principle and ways of applying it (ASCE library). In this section, the concurrency definition and its remedy as recommended by the ASCE are discussed.

The ASCE Standard Guidelines for Schedule Delay Analysis defines the concurrent delay as a "situation where two or more critical delays are occurring at the same time during all or portion of the delay time frame in which the delays are occurring" (ASCE 2016 as cited by Livengood 2017). Therefore, delays don't have to start and end on the same time; however, they should overlap in time. Therefore, if delays are separated in time, they are not regarded as concurrent. For concurrent delays to be analyzed and studied, they have to be on the project's critical path, so they have to affect the project completion date.

The first step to analyze concurrency is to figure out if ASCE standard recommends studying concurrency on the time of occurrence or when they affect the schedule, According to Livengood 2017, the ASCE standard did not specify whether concurrency should be studied when delays are initiated or when they affect the schedule. However, he believes that the ASCE language infers that it should be analyzed when it is felt.

After proving concurrency, the ASCE standard considers concurrent delays as excusable non-compensable delays. Therefore, an extension of time is granted, but no cost compensation is allowed to either party. Accordingly, the contractor will not be entitled to cost compensation for an owner delay that is concurrent with his own delay if it is difficult to apportion each party's share of the damage. Similarly, the owner will not be granted liquidated damages for a contractor delay that is concurrent with his own delay if it is hard to segregate each party's responsibility for the harm caused. However, if it is possible to apportion damages of concurrent delays, it should be applied. The ASCE defines some example cases where apportionment is possible as follows; when simultaneous delays overlap on the start or finish or both of either delay. Another case, when simultaneous delays are absorbed by the available float partially before it became critical. The last case mentioned by the ASCE is when simultaneous delays have different dates (start or finish) and they are critical activities (one or more). (ASCE, 2016)

2.4 Concurrent Delays in Different Standard Forms of Contracts:

2.4.1 Concurrent delays in FIDIC 2017:

FIDIC is a widely accepted and used standard form of contract worldwide. As there is no Egyptian standard form of construction contracts, FIDIC is widely used in public and private sectors in Egypt. In the older version of FIDIC, it was silent about concurrency definition and its recommended remuneration. It only included sections for dealing with delays and when the contractor should be entitled for time and/ or cost compensation (Abdalall, 2017). However, according to Mangan, 2019, the new version of FIDIC which is published in 2017 didn't remain silent any more about concurrency. It recommended that parties to the contract should agree from the beginning of the project on how they will deal with concurrency. FIDIC suggested in the guidance to the general conditions, that parties to the contract should select the technic and the way of perceiving concurrency. In addition, FIDIC mentioned that the SCL protocol is an internationally accepted protocol in terms of concurrency analysis, so it can be used as reference for parties to agree about concurrency definition and its remuneration. In Clause 8.5, FIDIC 2017"Extension of time for completion", the cases where the contractor is entitled for extension of time and the ways of assessing them are mentioned in details. Then, the case of concurrency was articulated as follows. "If a delay caused by a matter which is the Employer's responsibility is concurrent with a delay caused by a matter which is the Contractor's responsibility, the Contractor's entitlement to EOT shall be assessed in accordance with the rules and procedures stated in the Special Provisions (if not stated, as appropriate taking due regard of all relevant circumstances)". Therefore, FIDIC didn't give a specific definition or compensation for concurrency. It only attracts parties' attention that they should select the appropriate technic for the project from the beginning and document that in the contract to reduce claims arising from concurrency. Furthermore, in the guidance to general conditions, FIDIC gives a suggestion of using SCL Protocol as a reference.

2.4.2 Concurrent delays in NEC 3:

NEC3 is a widely accepted standard form of contract in UK as the government recommends using it for public construction projects (Abdalall, 2017). NEC didn't recommend definition for concurrency and its remedy. However, it has techniques for the evaluation of time extension and cost compensation (Lowsley et al. 2012 as cited by Abdalall, 2017). Generally, NEC adopts the "early warning system" concept that recommends that once the delay events happen, the contract administrator should agree with the parties on the events consequences in terms of time and cost. Therefore, that approach is aligning with the concept of contemporaneous action that is recommended by the SCL protocol. That concept promotes the idea of dealing with delay events once they arise in the project instead of “wait and see” approach. Accordingly, that contemporaneous action should reduce claims and disputes which could be applied to concurrency delays as well. However, NEC didn’t identify a specific definition for concurrency and its recommended compensation (Abdalall, 2017).

2.5 Chapter Summary:

Delays are inevitable in the construction industry; therefore, it is important to develop tools that mitigate these delays and their consequences. Concurrent delays are the most questionable delay type in the construction industry because of the lack of standardized definition and remedy for its occurrence.

This section highlighted the gap in literature concerning concurrency analysis where there is a need to highlight how the Egyptian law perceive concurrency. In addition, there is a need for a model that helps the user through concurrency analysis.

Moreover, this section identified how different Laws are dealing with concurrency; namely, Egypt Law, English Law & US Law. Egypt Law & US Law supports the apportionment concept whenever possible. However, the English Law doesn't support that concept; instead, it supports the concept of time but no cost where extension of time is only granted when concurrency is proved.

In addition, this section highlighted how different recognized protocols address concurrency; namely, AACE, SCL Protocol & ASCE. AACE defined two theories for concurrency; namely, literal concurrency & functional concurrency. AACE mentioned that true concurrency is difficult to be proved. AACE see that the remedy in case of concurrent delays is extension of time only. SCL protocol adopts the literal concurrency concept. SCL recommends that if apportionment could be proved, it should be applied. ASCE recommends that delays have to overlap in time to be considered concurrent. For the remedy, ASCE recommends extension of time only to be granted if apportionment couldn't be proved.

Moreover, this section discussed how different standard forms of contracts recommends dealing with concurrency; namely, FIDIC 2017 & NEC3. FIDIC recommends that the parties to contract should agree from the beginning of the project on the concurrency definition and its remedy to mitigate conflicts arising from it. It also mentioned that the SCL protocol is a widely accepted one in the topic of concurrency if parties need a recommended reference. For the NEC3, it doesn't address the concurrency specifically; however, it recommends the early warning system when problems arise.

Therefore, from the research done, there is a need to show which technics are compatible with each country's law, in addition to highlight the strengths and weakness of using them. Furthermore, this research will propose an analytical model that will help the user to determine concurrency and its remedy according to one of the most recognized technics namely SCL Protocol, ASCE and AACE that could be selected by the user.

Chapter 3: Modeling Methodology:

In this chapter, the main aspects considered before and while developing the model are discussed in details. These points include:

- Highlight the compatibility of the different recognized technics with the different countries laws.
- Highlight the strengths and weaknesses of each the most recognized technics for concurrency; namely, SCL Protocol, ASCE and AACE.
- Highlight the language and concepts used in developing the model and the reasons for selecting them.

3.1 Compatibility of Different Technics with Different Laws for Concurrency Analysis:

The different approaches of dealing with concurrency are discussed in the literature review. In this section, the ones that will be used in the model will be highlighted and discussed. In the literature, dealing with concurrency was categorized into three main umbrellas which are different laws, different recognized protocols and different standard types of contracts. The model will have the different types of recognized protocols for the user to choose from; namely, AACE, SCL Protocol & ASCE. These protocols abide by the different countries' laws as follows:

- **Egyptian Law**:
    - All the technics can be used and is compatible with the Egyptian Law. That is because the Egyptian law requires the damage to be the responsibility of both parties to be considered concurrent.
    - For the concurrency remedy, the judge has the authority to apportion or to reject reimbursement based on the evidence he has.
    - Therefore, any of the three technics could be used. It is recommended that the parties agree on one of them in the contract as each protocol will give different reimbursement and justification.
- **English Law**:
    - SCL protocol is the most applicable in case of the English Law because it is a British protocol, so it is affected by the British law and concepts.

- SCL protocol follows the Malmaison Approach where delays have to have equal causative potency to be considered concurrent; otherwise, the dominant cause concept will apply.
- However, the British law doesn't support the concept of apportionment unlike the SCL protocol.

- **US Law**:
  - AACE &ASCE are the most compatible technics with the US law because they are American ones, so they are affected by the US law & concepts.
  - For the remedy, US law supports apportionment whenever possible which is aligned with the ASCE. However, the AACE adopts the Easy rule for remedy which recommends time, but not money.

The following figure summarizes which technic is compatible with which country's law:

Table 1: Compatibility of Laws with Recognized Protocols in case of Concurrency

Compatibility	AACE	SCL Protocol	ASCE
Egyptian Law	✓	✓	✓
English Law		✓	
US Law	✓		✓

3.2 Strengths & Weaknesses of Using Each Technic:

As the three protocols could be used according to the Egyptian Law, it is important for the user to understand the strength and weakness of each protocol, in order to be able to choose the best suitable one for his project.

AACE:

In this approach, there are two main theories; the literal concurrency and the functional concurrency. However, the AACE regards the true concurrency as impossible to be identified. Therefore, the following will show the strengths and weaknesses of using functional concurrency.

Strengths:

- It gives a detailed explanation of concurrency and more practical approach for proving its existence.
- Functional concurrency could be proved.

Weaknesses:

- If the analysis period changed, the concurrency analysis will change accordingly.
- Therefore, it is important to agree on the analysis period from the beginning of the project.
- Apportionment is not supported as a remedy. Time extension is only granted in case of concurrency.

SCL Protocol:

This approach adopts the literal concurrency where delays have to start in the same time. The following paragraphs show the strengths and weaknesses of using SCL protocol.

Strengths:

- Analysis period doesn't affect the concurrency.
- The SCL protocol offers detailed approach for analyzing delays and their consequences.
- It is an internationally accepted protocol.

Weaknesses:

- True concurrency is almost impossible to happen or to be proved.

- Therefore, in most cases it is not proved and the party that has dominant delay is the one that takes the delay responsibility.
- One party will take the responsibility for the whole delay period.

ASCE standard:

In this standard, delays have to overlap in time but don't have to have same start and end dates. In the following paragraphs, the strengths and weaknesses of using this standard are highlighted.

Strengths:

- It gives a practical definition for concurrency where overlapping has to exist.
- Can be proved in an easier way.

Weaknesses:

- ASCE standard is not as elaborative as the other approaches

3.3 Model Development:

This research presents an analytical model that is user friendly and covers several computational technics, using MS Excel Visual basic. That specific programming language is used because it allows for macro recording, it is easy to be used, provides wide array of functions, and has many available online tutorials. It also allows for building comprehensive models.

The model is based on the following incremental methodology:

1. Creating baseline schedule based on the critical path method.
2. Creating update schedule based on critical path method.
3. Creating delay analysis based on time impact analysis method.
4. Developing owner responsible delays schedule based on actual dates for owner activities and as sequence dates for contractor activities to see the effect of owner delays only on the schedule.
5. Developing contractor responsible delays schedule based on actual dates for contractor activities and as sequence dated for owner activities to see the effect of contractor delays only on the schedule.
6. Clarifying if concurrency exists based on the concurrency approach selected by the user.
7. Clarifying where concurrency exists, which activities that have contractor responsible critical delays is concurrent with which activities that have owner responsible critical delays.
8. The final output will be the delay responsibility for each party and the extension of time that should be granted to the contractor.

In the following section, the reasons behind using time impact analysis in the model are explained in details.

Time impact delay analysis:

Time impact delay analysis is one of the widely used techniques in analyzing delays in the construction industry. According to Gibson (2008), time impact analysis is a type of prospective analysis in which the analyzer begins with having the as planned schedule and then predict the effects of delay events on it. This type of analysis is different from retrospective analysis in which the analyzer begins with as built program and study the effects of delay events on the schedule. Therefore, the methodology used in time impact analysis is as follows:

- The project baseline is updated with actual data from site to represent the actual progress of work
- That update will show if the contractor is on, behind or ahead of schedule
- Then, create subnet of activities representing the employer's delay event
- Link that subnet with the updated schedule
- The difference in completion date between the updated schedule and the impacted schedule with employer delay event will represent the extension of time that should be granted to the contractor

Therefore, it is important to have a reliable baseline that represents accurately the progress of work on site and reliable actual data from site (Gibson, 2008).

SCL protocol recommends time impact analysis as a type of delay analysis that promotes a contemporaneous action instead of "wait and see" approach. SCL recommends that when delay events happen, they should be dealt with as soon as possible. According to Arcuri et al., 2007, time impact analysis is the most comprehensive delay analysis technique as it incorporates the actual project data to a dynamic schedule. All variations are incorporated in the schedule to examine the effect of each event and quantify its consequences on the schedule. Therefore, the time impact analysis gives full attention to the actual events individually and together and in presence of the ongoing delays. Accordingly, it gives an accurate judging to the effects of events, so it is the least controversial technique. That is why it is used in the model. However, it is the most time-consuming delay analysis technique.

3.4 Equations Used To Analyze Concurrency:

The model will allow the user to select one of the most recognized techniques; namely, SCL Protocol, AACE& ASCE for concurrency analysis. Therefore, the following equations are part of the VB code used for the 3 techniques to identify the concurrent activities.

1- Identifying critical path for owner responsible delays and for contractor responsible delays:

```
Worksheets("Contractor Responsibility").Activate
titles.AutoFilter Field:=totalfloatcolumn, Criteria1:="0n
Range(Range("A6"), Range("A6").End(xlDown).Offset(0, 1)).Copy
Worksheets("Analysis").Activate
Range("A6").Offset(0, 9).PasteSpecial

Worksheets("Owner Responsibility").Activate
titles.AutoFilter Field:=totalfloatcolumn, Criteria1:="0"
Range(Range("A6"), Range("A6").End(xlDown).Offset(0, 1)).Copy
Worksheets("Analysis").Activate
Range("A6").PasteSpecial
```

2- Identifying the selected technique and entering into the related if function

a. If SCL protocol:

```
Worksheets("Start").Activate
If Range("E12") = "SCL Protocol" Then
Worksheets("Analysis").Activate
For check = 0 To numberofactivitiesowner -1
 For contr = 0 To numberofactivitiescontractor - 1

  If startcheck = startcon And endcheck = endcon Then
  endcheck.Offset(0, 1 + count).EntireColumn.Insert
  concurrentactivity = endcon.Offset(0, -7)
  count = count + 1
  End If
 Next
Next
```

b. If ASCE:

```
Worksheets("Start").Activate
If Range("E12") = "ASCE" Then
Worksheets("Analysis").Activate
 For check = 0 To numberofactivitiesowner-1
  For contr = 0 To numberofactivitiescontractor - 1
  If startcheck <= endcon And endcheck >= startcon Then
  endcheck.Offset(0, 1 + count).EntireColumn.Insert
  concurrentactivity = endcon.Offset(0, -7)
count = count + 1
```

```
End If
  Next
Next
```

c. If AACE

```
If Range("E12") = "AACE" Then
Worksheets("Analysis").Activate
startPeriod = InputBox("Please Insert Start of your Analysis Period Date")
 EndPeriod = InputBox("Please Insert End of your Analysis Period Date")
For check = 0 To numberofactivitiesowner - 1
  For contr = 0 To numberofactivitiescontractor - 1
  If startcheck <= EndPeriod And endcheck >= startPeriod And startcon <= EndPeriod And
  endcon >= startPeriod Then
  endcheck.Offset(0, 1 + count).EntireColumn.Insert
  concurrentactivity = endcon.Offset(0, -7)
count = count + 1
   Next
Next
```

Therefore, according to the previous equations, concurrency will be checked in the critical path only. Then, according to the concurrency definition in each technic, the model will apply the related equation and identify if there is concurrency or not. In case of proved concurrency, the model will identify the concurrent activities.

3.5 Chapter Summary

In this chapter, we discussed compatibility of recognized protocols with countries' law. It was found that the three protocols; namely, SCL Protocol, ASCE & AACE are all compatible with the Egyptian law. Therefore, they are all incorporated into an analytical model to help the user selects one of them to analyze and identify concurrency. The model is developed using MS Visual basic programming language. The delay analysis method that is used in the model is time impact analysis because it gives the most acceptable judging for the effect of the claim events. In addition, the main equations used in the VB code to identify the existence of concurrency are mentioned and explained.

Chapter 4: Model Development:

4.1 Model Interface:

In this chapter, the model interface is discussed in details. The model consists of eight sheets. Each sheet inputs & outputs are highlighted. In addition, screen shots for each step are provided to show the user what to expect from each button in the model. The model sheets are (Start, Schedule, Update schedule, Time Impact, Owner Responsibility, Contractor Responsibility, Analysis & Final Result) and are illustrated in details as follows.

- Start: this is the welcoming sheet where the user inputs the basic information about the project; including: name of the project, contractor name, owner name and project budget value.

  In addition, the user will select the concurrency analysis technic he is going to adopt (i.e.: SCL protocol, AACE, ASCE)

  When the user presses the button "Start", he is prompt with the following message.

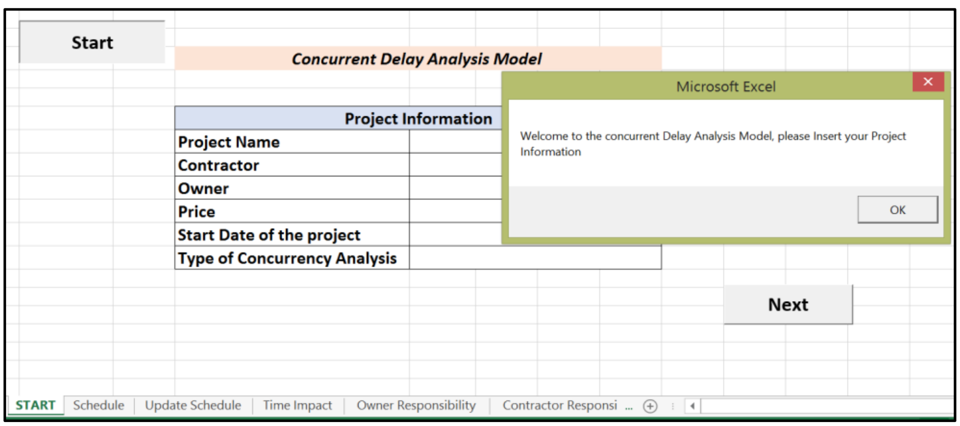


Figure 5: Start Sheet, "Start Button"

Then, he should start to fill in the project information.

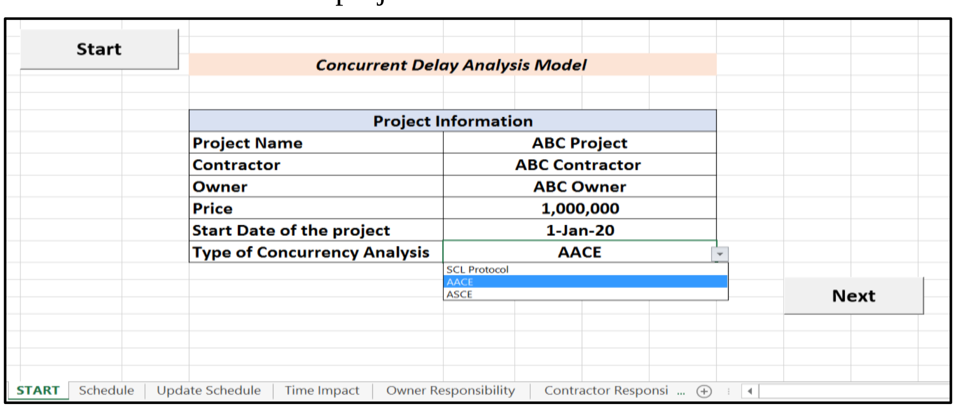


Figure 6: Start Sheet, Concurrency Analysis Approach Selection

To move from this sheet to the next sheet, the user can either choose the “Next” button, or simply select the next sheet from the sheets bar.

- Schedule: in this sheet, the model user inputs the activity IDs, activity names, durations and responsibility for each activity. Then, the model asks for the number of predecessors & number of successors. After that, the model inserts columns for the number of predecessors, lags, relationships (will be equal to the number of predecessors) & number of successors according to the user inputs. Then, the model asks the user to input the predecessors, lags and relationships for each activity. After that, the model identifies the successors’ names, and outputs the early start and early finish dates and late start and late finish dates and the total float. The following is a step by step illustration for this sheet.

When the user presses the button “Insert Data”, he will receive the following message.

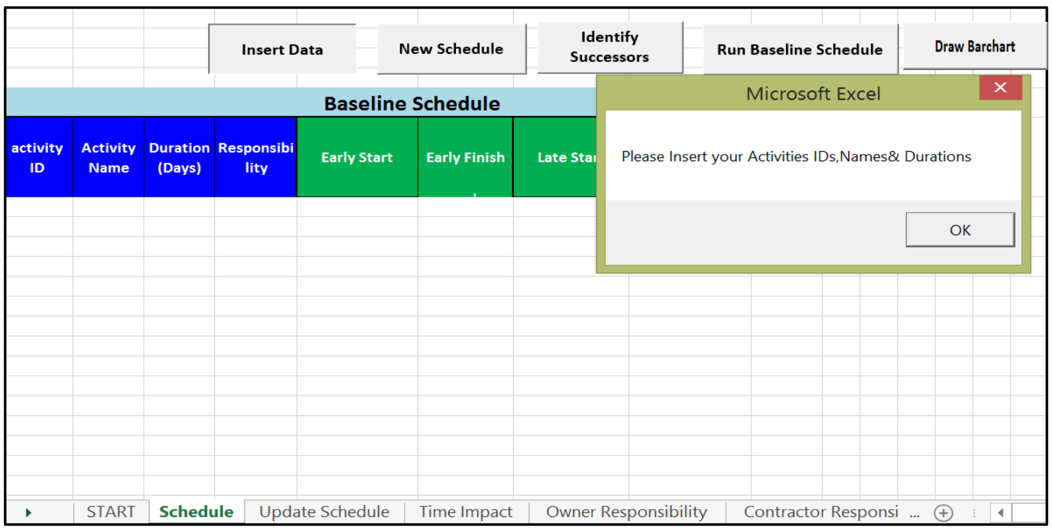


Figure 7: Schedule Sheet, "Insert Data" button

Then, the user should input his project activities, names & durations. After he finishes, he should press the next button which is “New Schedule”. Then, he is prompt with the following messages asking to insert the max number for predecessors & successors.

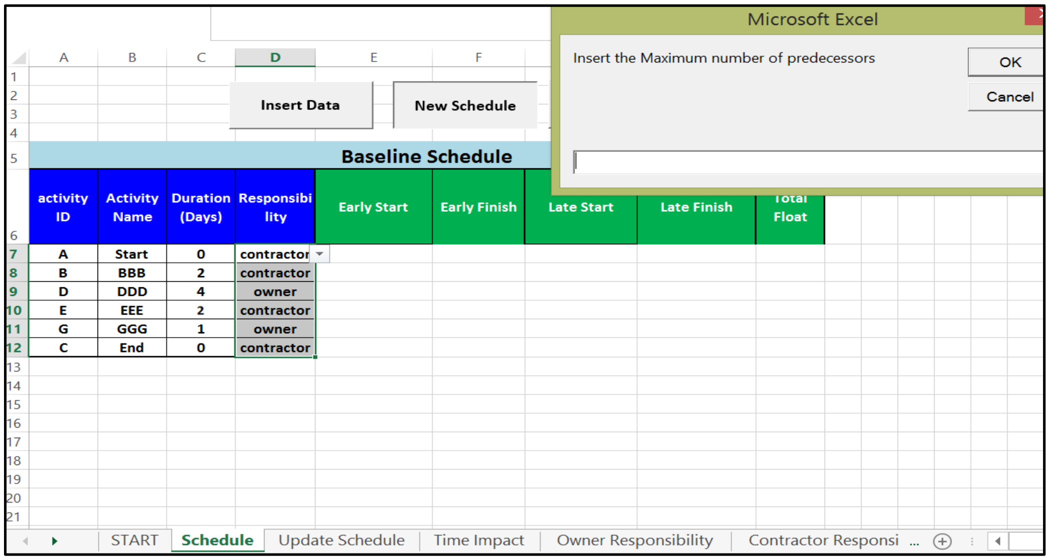


Figure 8: Schedule Sheet, insert number of predecessors

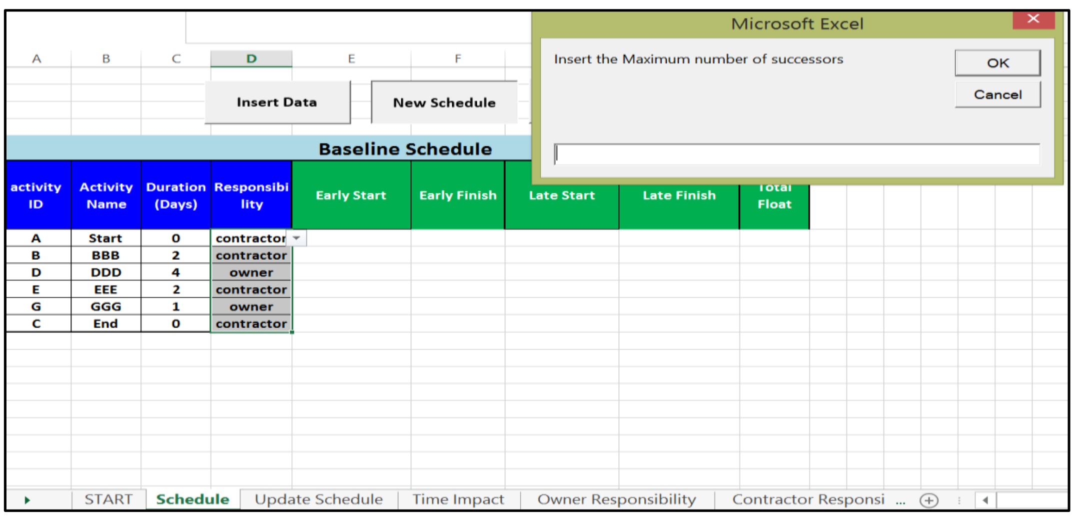


Figure 9 Schedule sheet, insert number of successors

After that, the user will receive the following message.

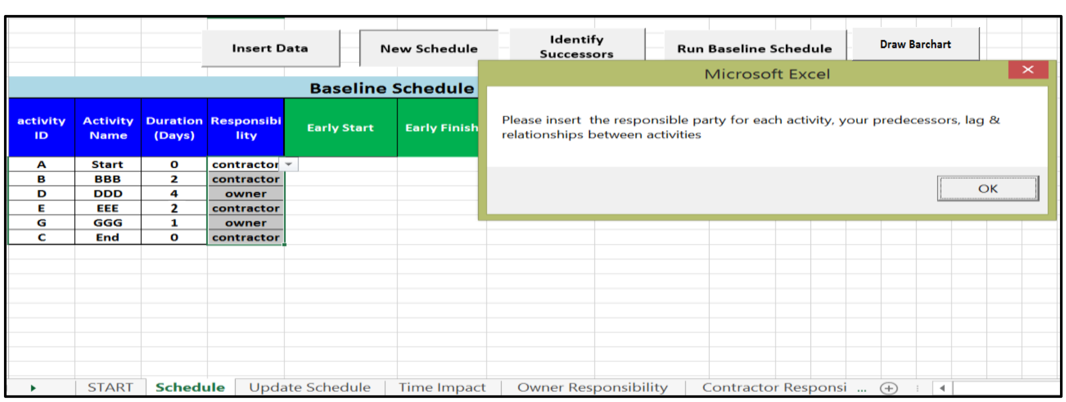


Figure 10: Schedule Sheet, "New Schedule" Button

The schedule will look like the following figure based on the inputted number of predecessors &successors.

Insert Data | New Schedule | Identify Successors | Run Baseline Schedule | Draw Barchart | Clear All | Next

Baseline Schedule

activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Lag1	Lag2	Relationship1	Relationship2	Successor1	Successor2	Early Start	Early Finish	Late Start	Late Finish	Total Float
A	Start	0	contractor													
B	BBB	2	contractor													
D	DDD	4	owner													
E	EEE	2	contractor													
G	GGG	1	owner													
C	End	0	contractor													

Figure 11: Schedule Sheet, Baseline Schedule showing number of predecessors & successors

Then, the user should input predecessors, lags and relationships between each activity and its predecessors. After that, the user should press the button "Identify Successors" for the model to determine the successors for each activity as presented in the following figure.

Insert Data | New Schedule | Identify Successors | Run Baseline Schedule | Draw Barchart | Clear All | Next

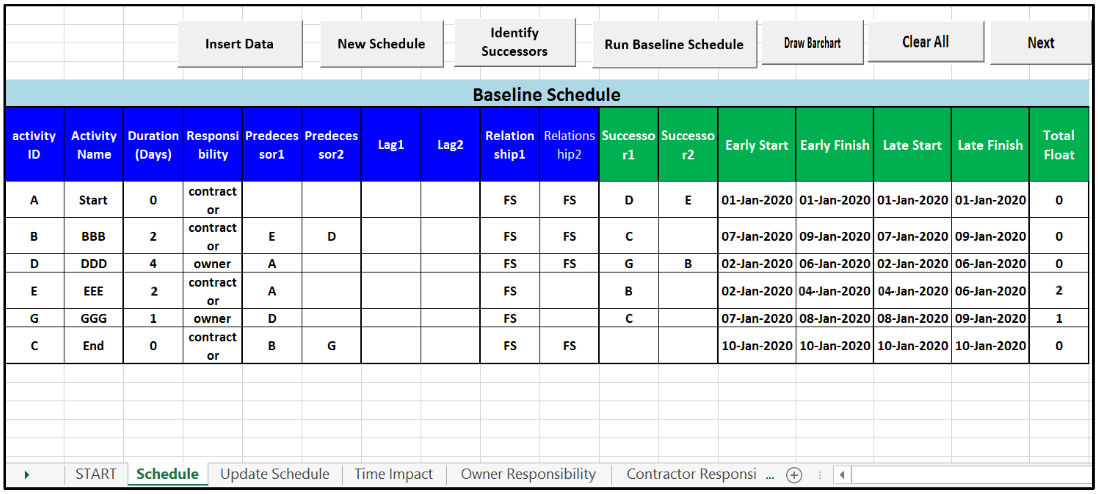
Baseline Schedule

activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Lag1	Lag2	Relationship1	Relationship2	Successor1	Successor2	Early Start	Early Finish	Late Start	Late Finish	Total Float
A	Start	0	contractor					FS	FS	D	E					
B	BBB	2	contractor	E	D			FS	FS	C						
D	DDD	4	owner	A				FS	FS	G	B					
E	EEE	2	contractor	A				FS		B						
G	GGG	1	owner	D				FS		C						
C	End	0	contractor	B	G			FS	FS							

START | Schedule | Update Schedule | Time Impact | Owner Responsibility | Contractor Responsi ...

Figure 12: Schedule Sheet, "identify Successors" Button

Then, the user has to press the button “Run Baseline Schedule” to run early dates, late dates and identify total float for each activity. The following figure shows the final output in this sheet.



Baseline Schedule

activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Lag1	Lag2	Relationship1	Relationship2	Successor1	Successor2	Early Start	Early Finish	Late Start	Late Finish	Total Float
A	Start	0	contractor					FS	FS	D	E	01-Jan-2020	01-Jan-2020	01-Jan-2020	01-Jan-2020	0
B	BBB	2	contractor	E	D			FS	FS	C		07-Jan-2020	09-Jan-2020	07-Jan-2020	09-Jan-2020	0
D	DDD	4	owner	A				FS	FS	G	B	02-Jan-2020	06-Jan-2020	02-Jan-2020	06-Jan-2020	0
E	EEE	2	contractor	A				FS		B		02-Jan-2020	04-Jan-2020	04-Jan-2020	06-Jan-2020	2
G	GGG	1	owner	D				FS		C		07-Jan-2020	08-Jan-2020	08-Jan-2020	09-Jan-2020	1
C	End	0	contractor	B	G			FS	FS			10-Jan-2020	10-Jan-2020	10-Jan-2020	10-Jan-2020	0

Figure 13: Schedule Sheet, "Run Baseline Schedule" Button Output

If the user needs to re-input all his data, he could press the “Clear All” button. In addition, to move to the next sheet, he should either press the “Next” button or choose the next sheet from the sheets bar.

To display the bar chart of the schedule, the user should press on the “Draw bar chart” button. Then, the bar chart will be shown as follows;

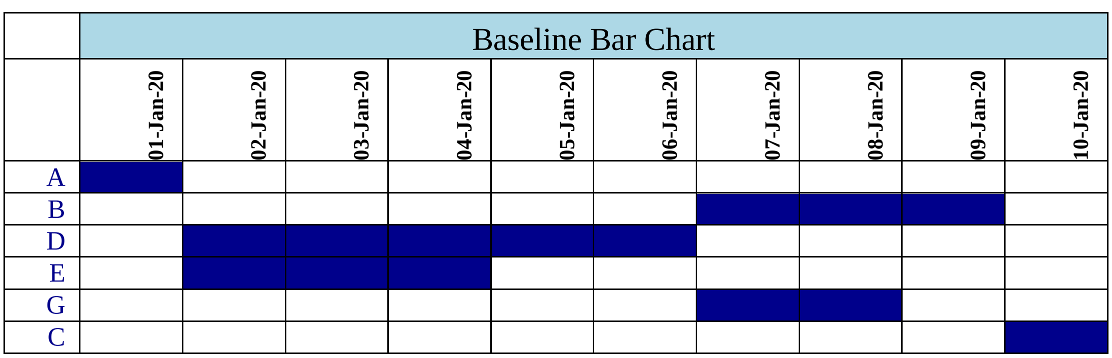


Figure 14: Baseline Bar Chart

- Update Schedule: in this sheet, the model asks the user to insert any new activities, the new number of predecessors, new number of successors and to update the relationships and lags according to new activities. Then, the model defines the new successors. After that, the model asks the user to insert the actual data, and the data date. Then, the model runs the updated schedule and outputs the start and finish dates for each activity. The following figures show step by step illustration for this sheet.

When the user presses the button “Insert Actual New Activities & Relations”, the model copies the baseline data into the “Update Schedule Sheet”. Then, the user is prompt with the following messages asking for the new number of predecessors & successors.

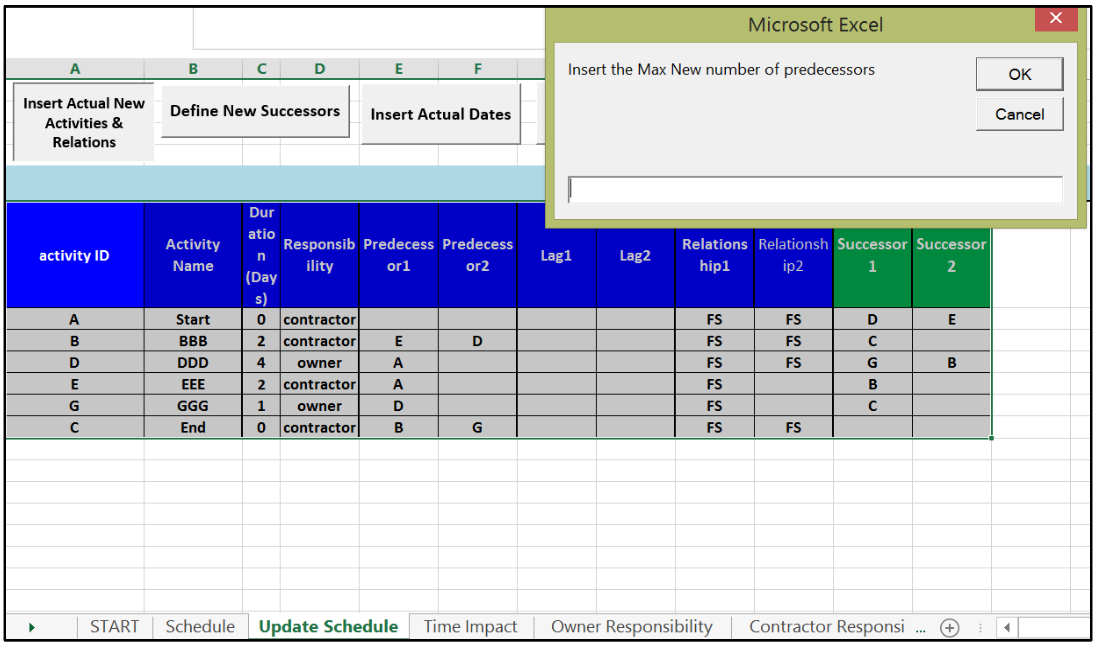


Figure 15: Update Schedule Sheet, Insert New Number of Predecessors

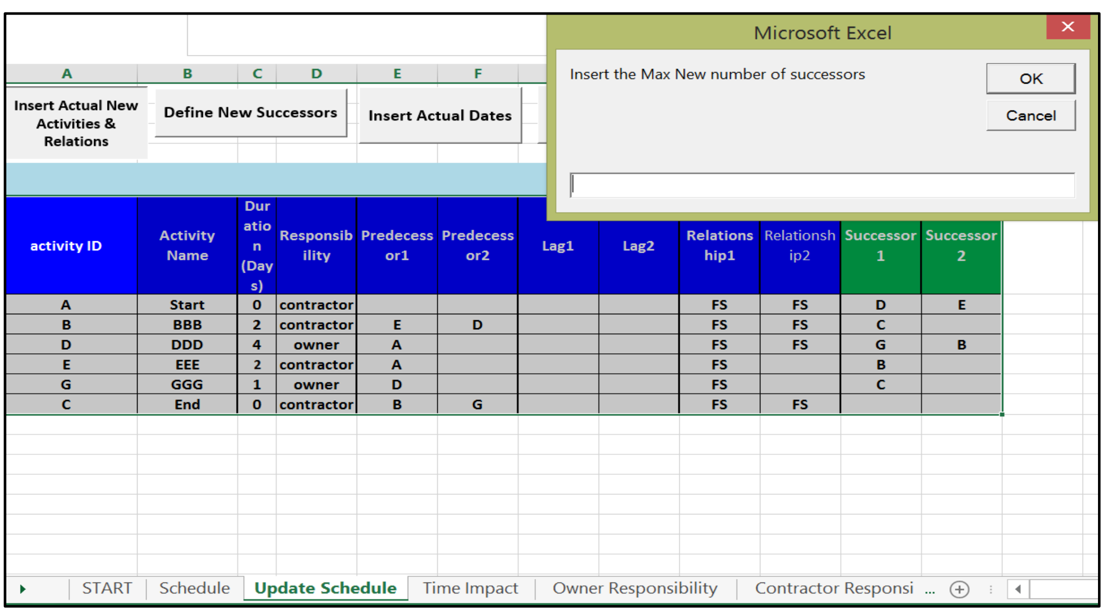


Figure 16: Update Schedule Sheet, Insert New Number of Successors

Then, the following message will appear.

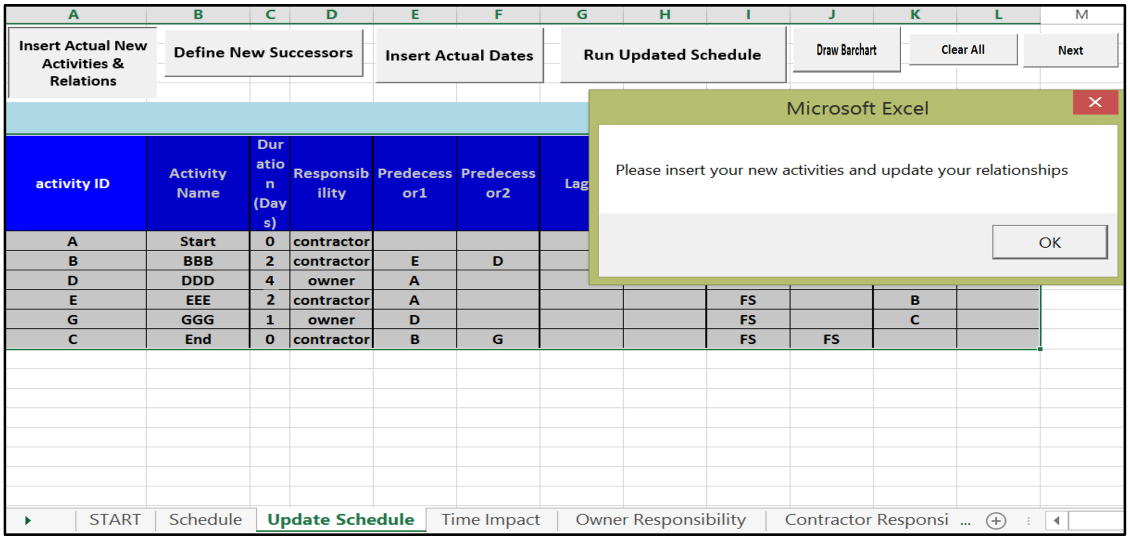


Figure 17: Update Schedule Sheet, Insert New activities

The user then should input his new activities and update the required data. After that, he should press the button "Define New Successors", so the model will update the successors depending on the added activities. Then, in order to enter the actual dates and % complete, the user should press the button "Insert Actual Dates" and the following message will appear.

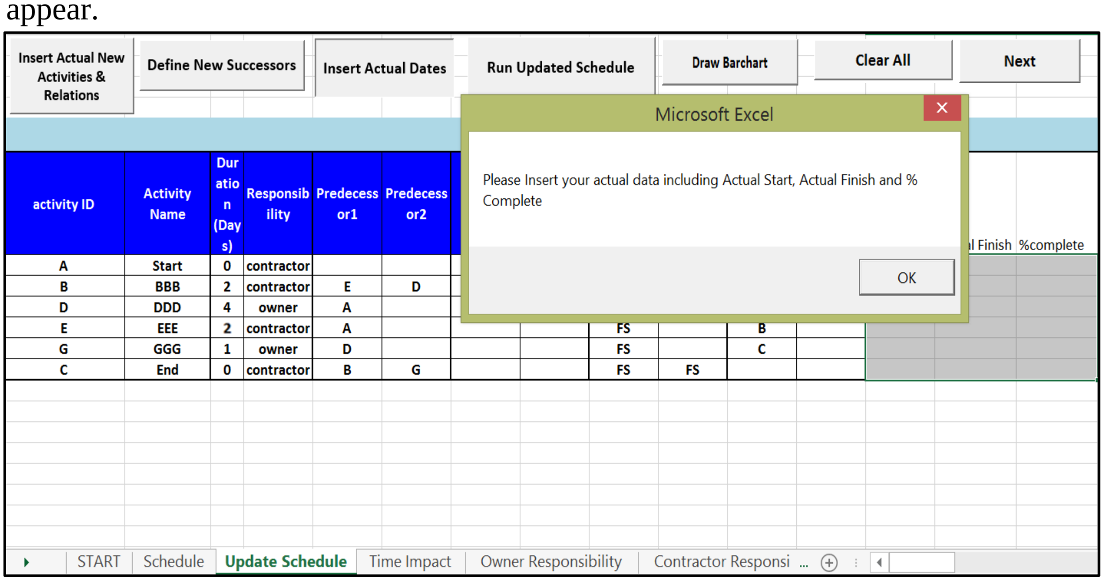
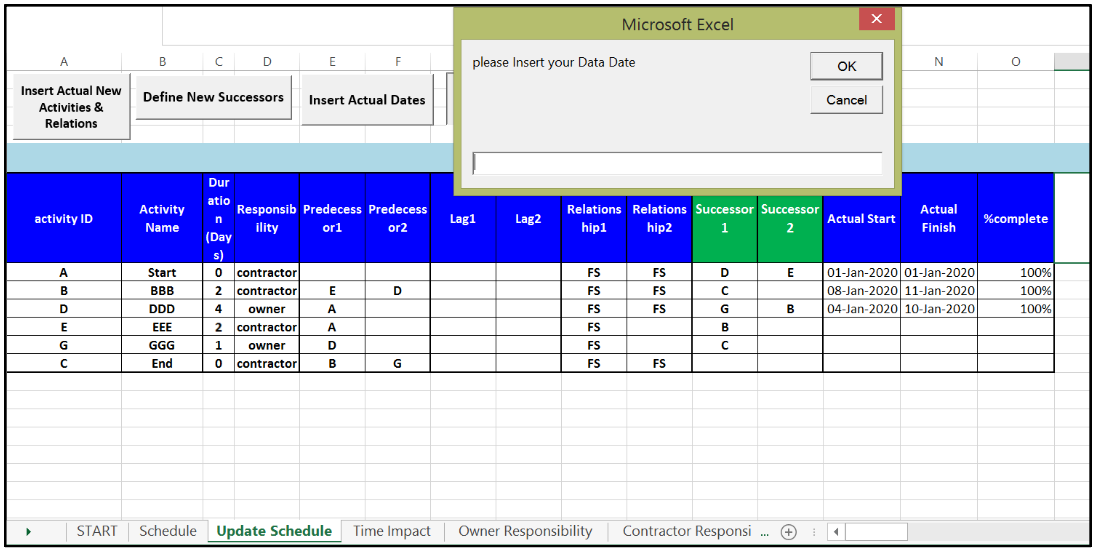


Figure 18: Update Schedule Sheet, Insert Actuals

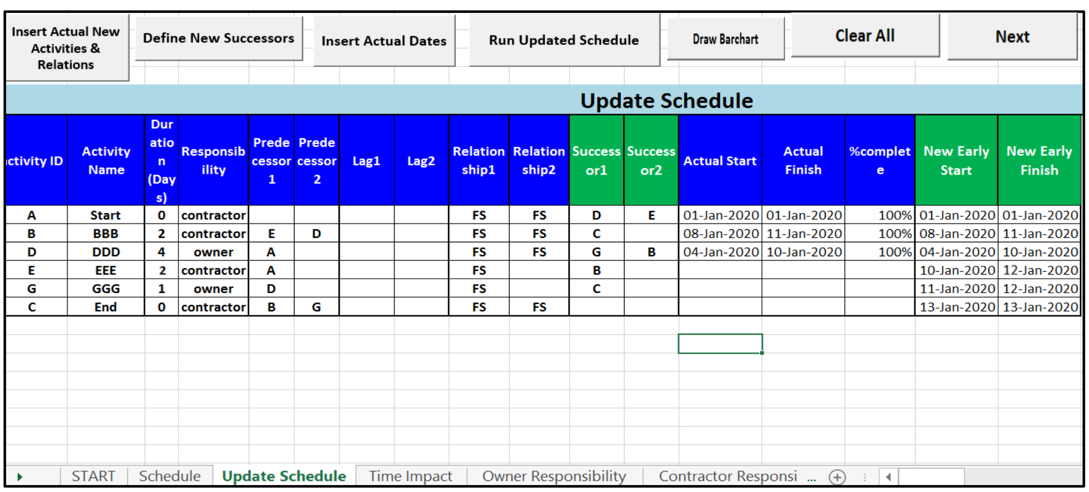
After inserting the actuals, the user should press the "Run Updated Schedule" in order to run the new dates based on the updated schedule. The model asks the user to insert the data date as shown in the following figure.



activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Lag1	Lag2	Relationship1	Relationship2	Successor 1	Successor 2	Actual Start	Actual Finish	%complete
A	Start	0	contractor					FS	FS	D	E	01-Jan-2020	01-Jan-2020	100%
B	BBB	2	contractor	E	D			FS	FS	C		08-Jan-2020	11-Jan-2020	100%
D	DDD	4	owner	A				FS	FS	G	B	04-Jan-2020	10-Jan-2020	100%
E	EEE	2	contractor	A				FS		B				
G	GGG	1	owner	D				FS		C				
C	End	0	contractor	B	G			FS	FS					

Figure 19: Update Schedule Sheet, Insert Data Date

Then, the schedule runs and outputs the new dates as follows.



ctivity ID	Activity Name	Duration (Days)	Responsibility	Predecessor 1	Predecessor 2	Lag1	Lag2	Relationship1	Relationship2	Successor1	Successor2	Actual Start	Actual Finish	%complete	New Early Start	New Early Finish
A	Start	0	contractor					FS	FS	D	E	01-Jan-2020	01-Jan-2020	100%	01-Jan-2020	01-Jan-2020
B	BBB	2	contractor	E	D			FS	FS	C		08-Jan-2020	11-Jan-2020	100%	08-Jan-2020	11-Jan-2020
D	DDD	4	owner	A				FS	FS	G	B	04-Jan-2020	10-Jan-2020	100%	04-Jan-2020	10-Jan-2020
E	EEE	2	contractor	A				FS		B					10-Jan-2020	12-Jan-2020
G	GGG	1	owner	D				FS		C					11-Jan-2020	12-Jan-2020
C	End	0	contractor	B	G			FS	FS						13-Jan-2020	13-Jan-2020

Figure 20: Update Schedule Sheet, Final Output

If the user needs to re-input all his data, he could press the "Clear All" button. In addition, to move to the next sheet, he should either press the "Next" button or choose the next sheet from the sheets bar.

To display the bar chart, the user should press the button "Draw Bar Chart", then it will be shown as follows.

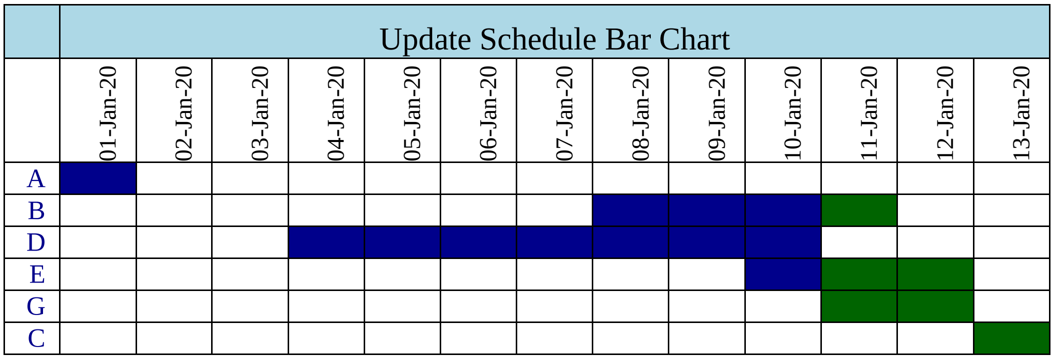
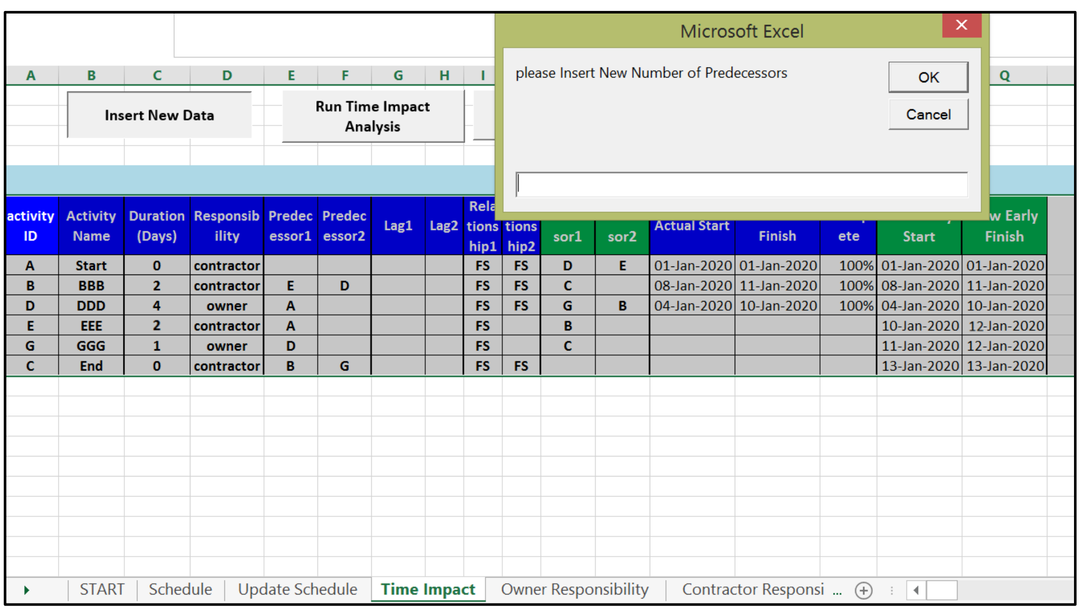


Figure 21: Update Schedule Bar chart

- Time impact analysis: in this sheet, the model asks the user to insert the claim event subnet of activities, the new number of predecessors, new number of successors, relationships and lags. Then, the model defines the new successors. After that, the model asks the user to insert the actual data, and the data date. Then, the model runs the time impact analysis and outputs the start and finish dates for each activity, late start and late finish for each activity and total float. The following figures show step by step illustration for this sheet.

  When the user presses the button "Insert New Data", the model copies the activities baseline data and the actual update dates into the "Time impact sheet". Then, the model asks for the new number of predecessors & successors as shown in the following figures.



activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Lag1	Lag2	Relationship1	Relationship2	sor1	sor2	Actual Start	Finish	ete	Start	w Early Finish
A	Start	0	contractor					FS	FS	D	E	01-Jan-2020	01-Jan-2020	100%	01-Jan-2020	01-Jan-2020
B	BBB	2	contractor	E	D			FS	FS	C		08-Jan-2020	11-Jan-2020	100%	08-Jan-2020	11-Jan-2020
D	DDD	4	owner	A				FS	FS	G	B	04-Jan-2020	10-Jan-2020	100%	04-Jan-2020	10-Jan-2020
E	EEE	2	contractor	A				FS		B					10-Jan-2020	12-Jan-2020
G	GGG	1	owner	D				FS		C					11-Jan-2020	12-Jan-2020
C	End	0	contractor	B	G			FS	FS						13-Jan-2020	13-Jan-2020

Figure 22: Time Impact Sheet, Insert New Number of Predecessors

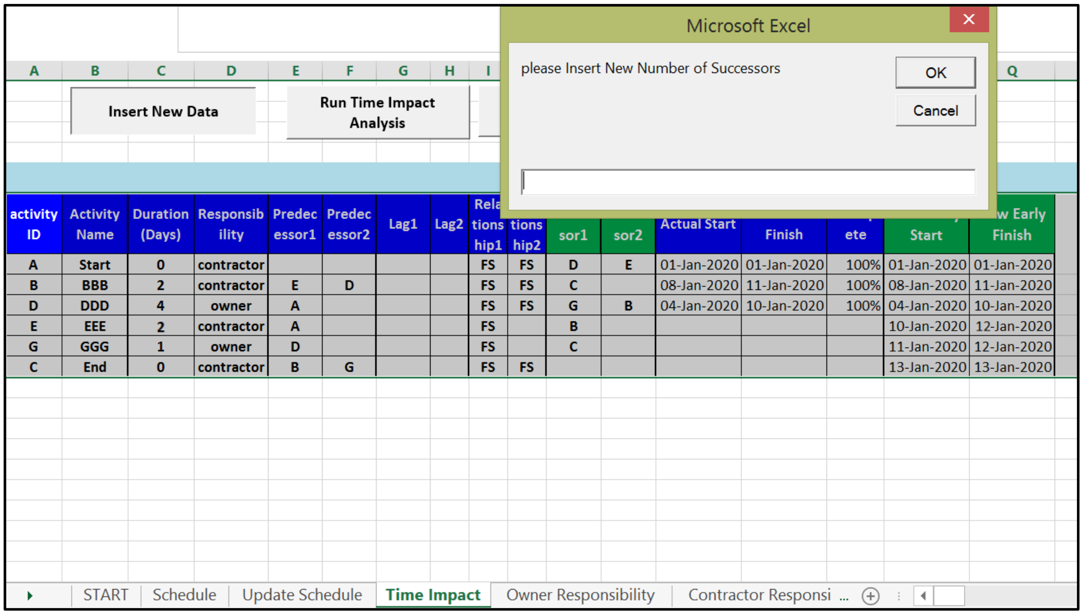


Figure 23: Time Impact Sheet, Insert New Number of Successors

Then, the user receives the following message.

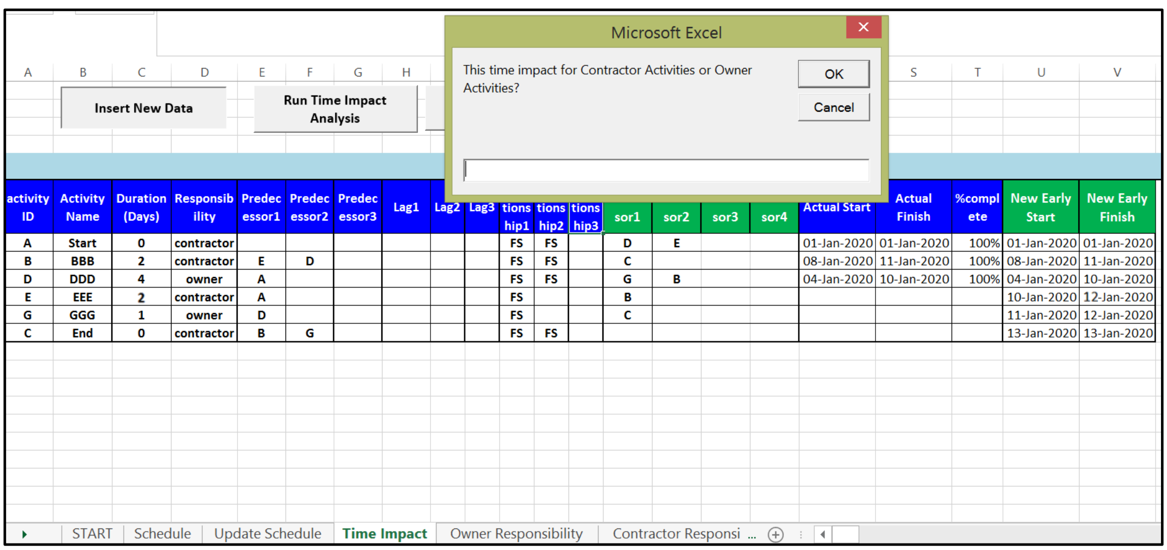
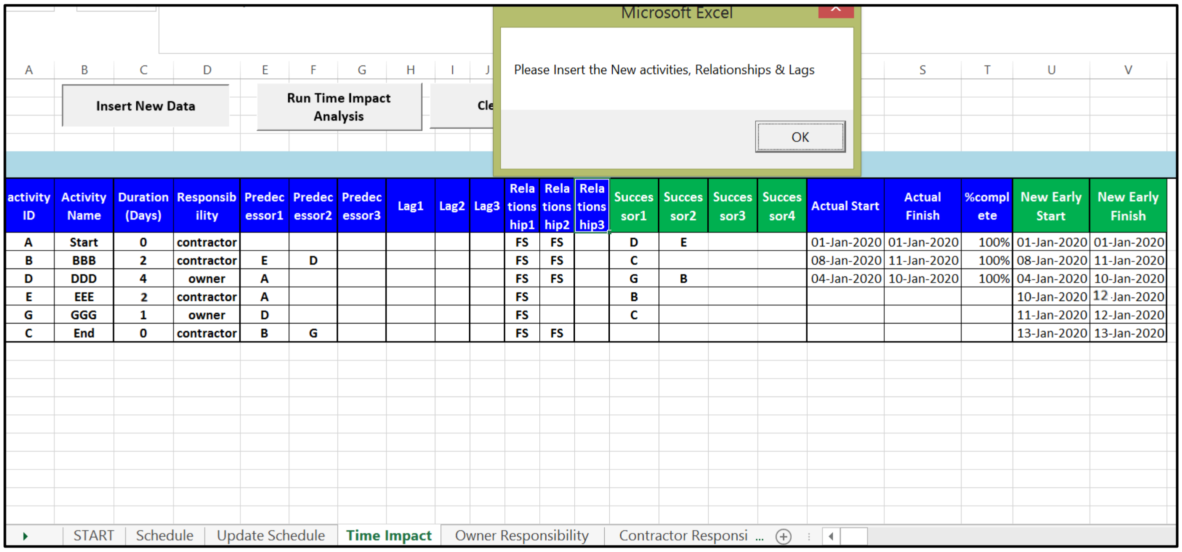


Figure 24: Time Impact Sheet, Define New Activities Responsibility

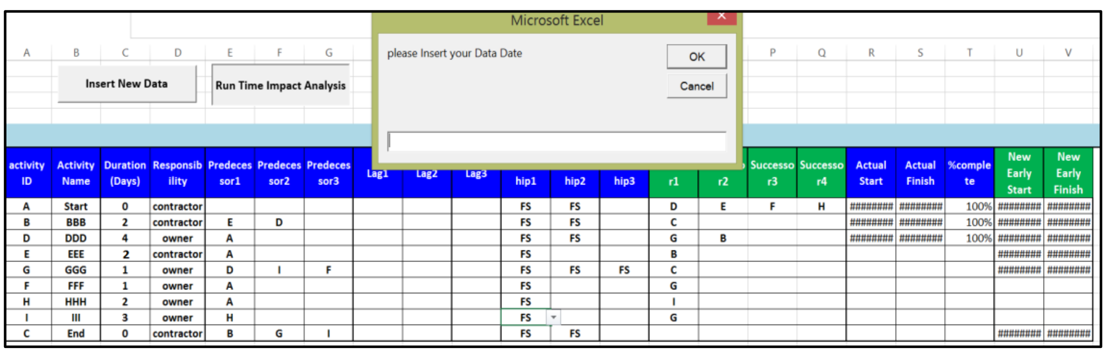
Then, the user is asked to insert his new activities.



activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Predecessor3	Lag1	Lag2	Lag3	Relationship1	Relationship2	Relationship3	Successor1	Successor2	Successor3	Successor4	Actual Start	Actual Finish	%complete	New Early Start	New Early Finish
A	Start	0	contractor							FS	FS		D	E			01-Jan-2020	01-Jan-2020	100%	01-Jan-2020	01-Jan-2020
B	BBB	2	contractor	E	D					FS	FS		C				08-Jan-2020	11-Jan-2020	100%	08-Jan-2020	11-Jan-2020
D	DDD	4	owner	A						FS	FS		G	B			04-Jan-2020	10-Jan-2020	100%	04-Jan-2020	10-Jan-2020
E	EEE	2	contractor	A						FS			B							10-Jan-2020	12-Jan-2020
G	GGG	1	owner	D						FS			C							11-Jan-2020	12-Jan-2020
C	End	0	contractor	B	G					FS	FS									13-Jan-2020	13-Jan-2020

Figure 25: Time Impact Sheet, Insert New Activities

After inputting the new activities and update the relations, lags and predecessors accordingly, the user should press the “Run Time Impact Analysis” button. Then, the model updates the successors and asks for the data date as shown in the following image.



activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Predecessor3	Lag1	Lag2	Lag3	hip1	hip2	hip3	r1	r2	Successor3	Successor4	Actual Start	Actual Finish	%complete	New Early Start	New Early Finish
A	Start	0	contractor							FS	FS		D	E	F	H	########	########	100%	########	########
B	BBB	2	contractor	E	D					FS	FS		C				########	########	100%	########	########
D	DDD	4	owner	A						FS	FS		G	B			########	########	100%	########	########
E	EEE	2	contractor	A						FS			B							########	########
G	GGG	1	owner	D	I	F				FS	FS	FS	C							########	########
F	FFF	1	owner	A						FS			G								
H	HHH	2	owner	A						FS			I								
I	III	3	owner	H						FS			G								
C	End	0	contractor	B	G	I				FS	FS									########	########

Figure 26: Time Impact Sheet, Insert Data Date

After that, the schedule shows the new start & finish dates according to the impacted schedule as follows.

Insert New Data | Run Time Impact Analysis | Draw Barchart | Clear All | Next

Time Impact Analysis

activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Predecessor3	Lag1	Lag2	Lag3	Relationship1	Relationship2	Relationship3	Successor1	Successor2	Successor3	Successor4	Actual Start	Actual Finish	%complete	New Early Start	New Early Finish
A	Start	0	contractor							FS	FS		D	E	F	H	01-Jan-2020	01-Jan-2020	100%	01-Jan-2020	01-Jan-2020
B	BBB	2	contractor	E	D					FS	FS		C				08-Jan-2020	11-Jan-2020	100%	08-Jan-2020	11-Jan-2020
D	DDD	4	owner	A						FS	FS		G	B			04-Jan-2020	10-Jan-2020	100%	04-Jan-2020	10-Jan-2020
E	EEE	2	contractor	A						FS			B							10-Jan-2020	12-Jan-2020
G	GGG	1	owner	D	I	F				FS	FS	FS	C							17-Jan-2020	18-Jan-2020
F	FFF	1	owner	A						FS			G							10-Jan-2020	11-Jan-2020
H	HHH	2	owner	A						FS			I							10-Jan-2020	12-Jan-2020
I	III	3	owner	H						FS			G							13-Jan-2020	16-Jan-2020
C	End	0	contractor	B	G	I				FS	FS									19-Jan-2020	19-Jan-2020

Figure 27: Time Impact Sheet, Final Output

If the user needs to re-input all his data, he could press the "Clear All" button. In addition, to move to the next sheet, he should either press the "Next" button or choose the next sheet from the sheets bar.

In order to display the bar chart, the user should press on the "Draw Bar chart" button. Then, it will appear as follows.

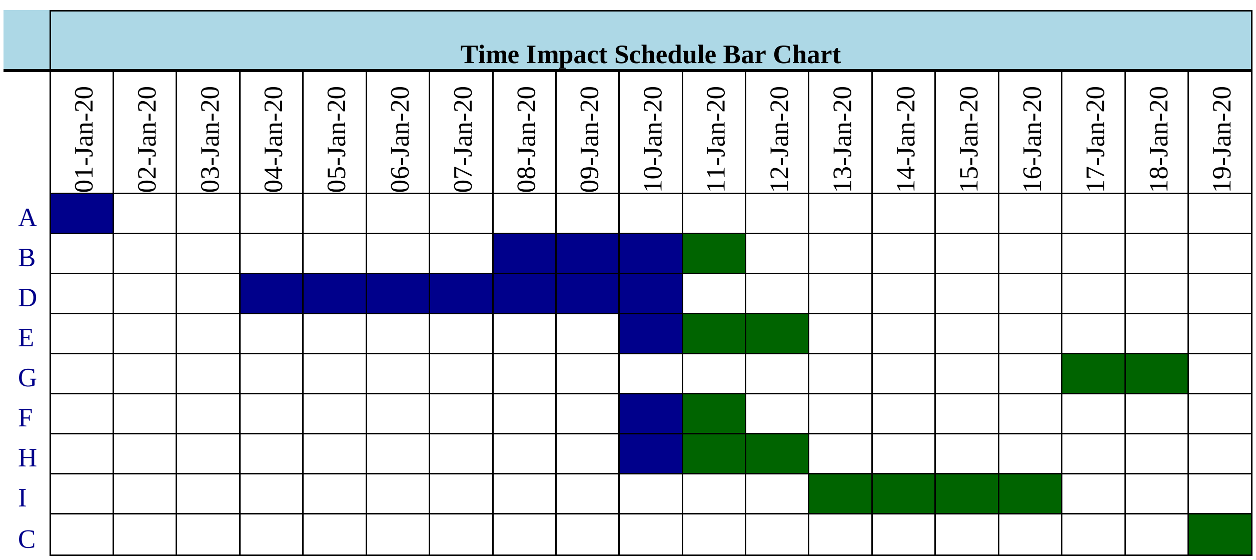


Figure 28: Time Impact Bar chart

- Owner Responsibility: In this sheet, the model will run the owner responsible delays only to give the finish date of the project according to the owner responsible delays alone. In addition, the model will output the early dates, late dates and the total float. The following figures show step by step illustration for this sheet.

When the user presses the button "Run Owner Responsible Delays Early Dates", the model copies the baseline data and any new activities that is owner responsibility in the "time impact" or "update schedule" sheets into the sheet "Owner Responsibility"; in addition to actual dates as well. Then, the following message appears asking for the data date.

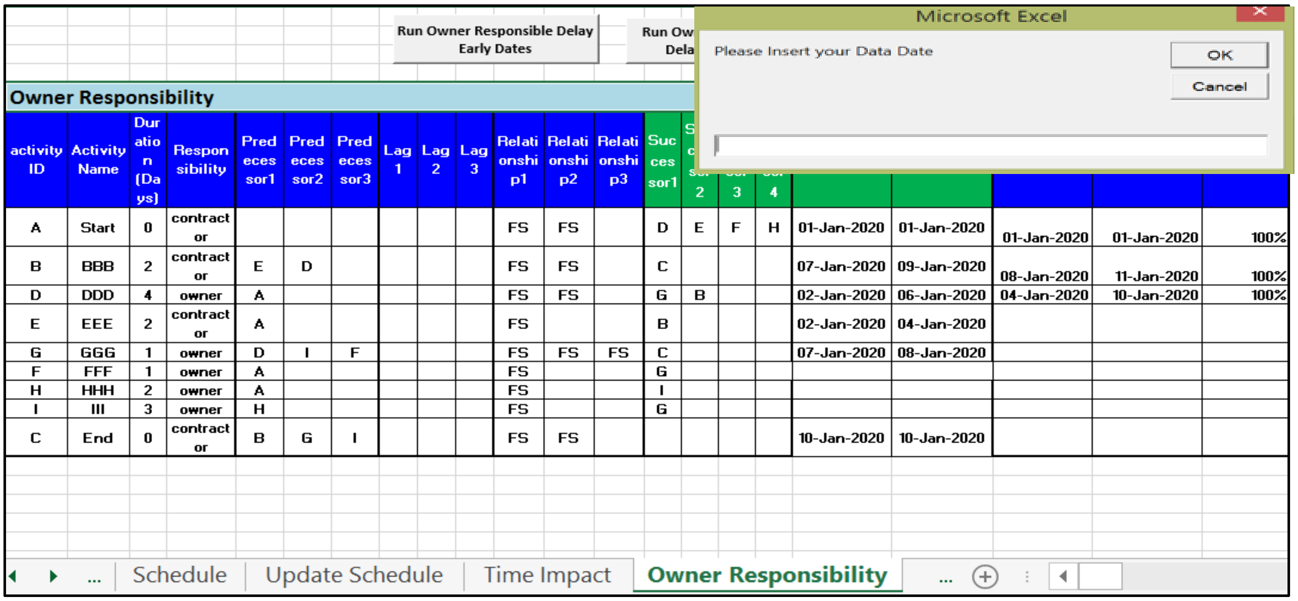


Figure 29: Owner Responsibility Sheet, Insert Data Date

Then, the early dates are generated based on actual dates for owner responsible activities and as sequence for contractor responsible activities

Then, to run the late dates, the user should press the button "Run Owner Responsible Delay Late Dates". After that to obtain the total float, the user should press the button "Total float". The following figure shows the final output of this sheet.

Run Owner Responsible Delay Early Dates | Run Owner Responsible Delay Late Dates | Total Float | Draw Barchart | Clear All | Next

Owner Responsibility

activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor 1	Predecessor 2	Predecessor 3	Lag1	Lag2	Lag3	Relationship 1	Relationship 2	Relationship 3	Successor1	Successor2	Successor3	Successor4	Early Start	Early Finish	Actual Start	Actual Finish	%complete	Start	Finish	Late Start	Late Finish	Total Float
A	Start	0	contractor							FS	FS		D	E	F	H	01-Jan-2020	01-Jan-2020	01-Jan-2020	01-Jan-2020	100%	01-Jan-2020	01-Jan-2020	09-Jan-2020	09-Jan-2020	8
B	BBB	2	contractor	E	D					FS	FS		C				07-Jan-2020	09-Jan-2020	08-Jan-2020	11-Jan-2020	100%	11-Jan-2020	13-Jan-2020	16-Jan-2020	18-Jan-2020	5
D	DDD	4	owner	A						FS	FS		G	B			02-Jan-2020	06-Jan-2020	04-Jan-2020	10-Jan-2020	100%	04-Jan-2020	10-Jan-2020	11-Jan-2020	15-Jan-2020	5
E	EEE	2	contractor	A						FS			B				02-Jan-2020	04-Jan-2020				02-Jan-2020	04-Jan-2020	13-Jan-2020	15-Jan-2020	11
G	GGG	1	owner	D	I	F				FS	FS	FS	C				07-Jan-2020	08-Jan-2020				17-Jan-2020	18-Jan-2020	17-Jan-2020	18-Jan-2020	0
F	FFF	1	owner	A						FS			G									10-Jan-2020	11-Jan-2020	15-Jan-2020	16-Jan-2020	5
H	HHH	2	owner	A						FS			I									10-Jan-2020	12-Jan-2020	10-Jan-2020	12-Jan-2020	0
I	III	3	owner	H						FS			G									13-Jan-2020	16-Jan-2020	13-Jan-2020	16-Jan-2020	0
C	End	0	contractor	B	G	I				FS	FS						10-Jan-2020	10-Jan-2020				19-Jan-2020	19-Jan-2020	19-Jan-2020	19-Jan-2020	0

Figure 30: Owner Responsibility Sheet, Final Output

If the user needs to clear all the data, he could press the button “Clear All”. In addition, to move to the next sheet, he should either press the “Next” button or choose the next sheet from the sheets bar.

To display the bar chart, the user should press the button “Draw Bar chart”.

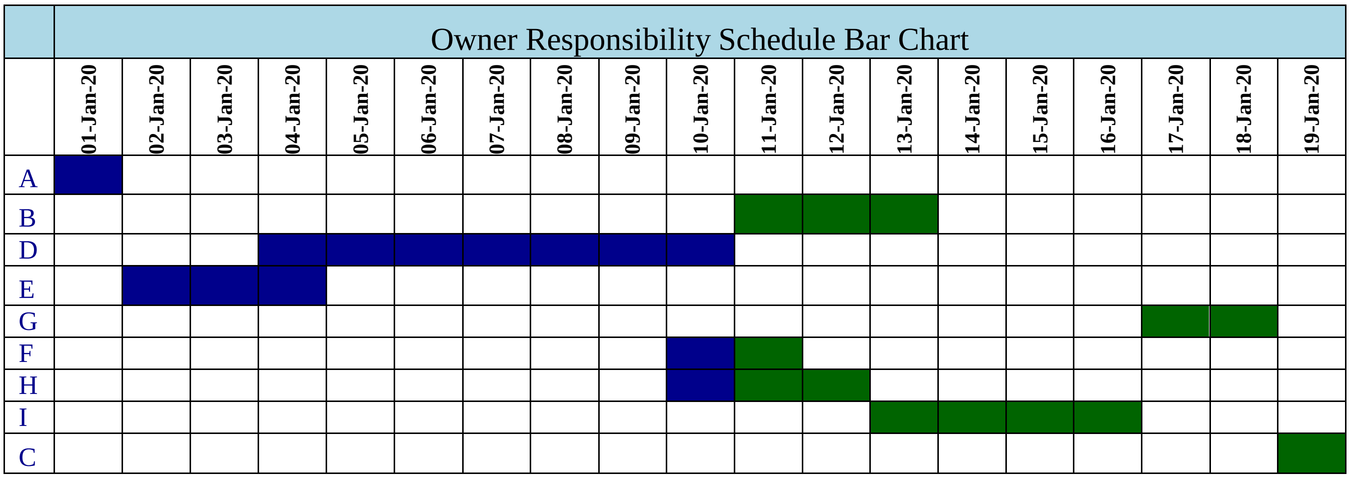


Figure 31: Owner Responsibility Schedule Bar chart

- Contractor Responsibility: In this sheet, the model will run the contractor responsible delays only to give the finish date of the project according to the contractor responsible delays alone. In addition, the model will output the early dates, late dates and the total float. The following figures show step by step illustration for this sheet.

  When the user presses the button “Run Contractor Responsible Delays Early Dates”, the model copies the baseline data and any new activities that is contractor responsibility in the “time impact” or “update schedule” sheets to the “Contractor Responsibility” sheet. Then, the following message appears asking for the data date.

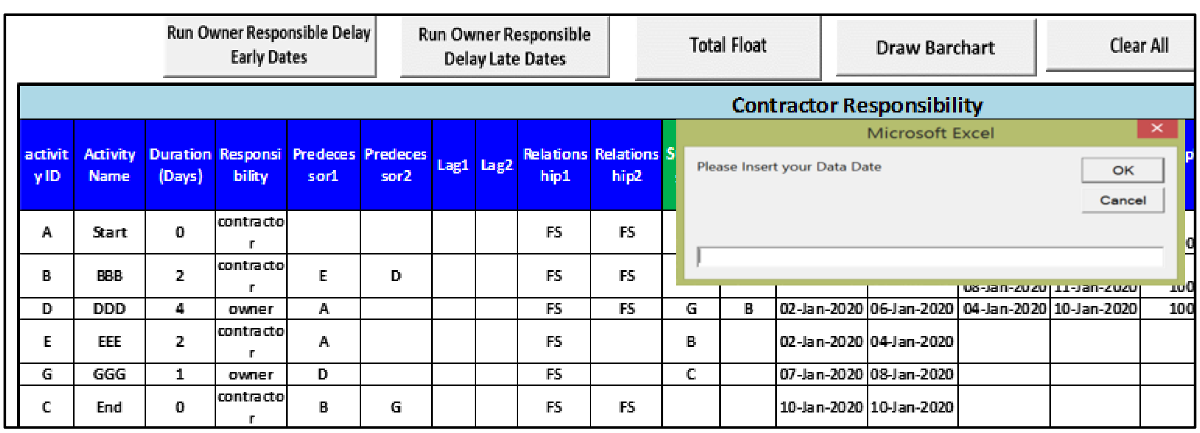


Figure 32: Contractor Responsibility Sheet, Insert Data Date

Then, the early dates are generated based on actual dates for contractor responsible activities and as sequence for the owner responsible activities.

Then, to run the late dates, the user should press the button “Run Contractor Responsible Delay Late Dates”. After that to obtain the total float, the user should press the button “Total float”. The following figure shows the final output for this sheet.

Run Owner Responsible Delay Early Dates | Run Owner Responsible Delay Late Dates | Total Float | Draw Barchart | Clear All | Next

Contractor Responsibility

activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Lag1	Lag2	Relationship1	Relationship2	Successor1	Successor2	Early Start	Early Finish	Actual Start	Actual Finish	%complete	Start	Finish	Late Start	Late Finish	Total Float
A	Start	0	contractor					FS	FS	D	E	01-Jan-2020	01-Jan-2020	01-Jan-2020	01-Jan-2020	100%	01-Jan-2020	01-Jan-2020	03-Jan-2020	03-Jan-2020	2
B	BBB	2	contractor	E	D			FS	FS	C		07-Jan-2020	09-Jan-2020	08-Jan-2020	11-Jan-2020	100%	08-Jan-2020	11-Jan-2020	09-Jan-2020	11-Jan-2020	0
D	DDD	4	owner	A				FS	FS	G	B	02-Jan-2020	06-Jan-2020	04-Jan-2020	10-Jan-2020	100%	02-Jan-2020	06-Jan-2020	04-Jan-2020	08-Jan-2020	2
E	EEE	2	contractor	A				FS		B		02-Jan-2020	04-Jan-2020				10-Jan-2020	12-Jan-2020	06-Jan-2020	08-Jan-2020	-4
G	GGG	1	owner	D				FS		C		07-Jan-2020	08-Jan-2020				07-Jan-2020	08-Jan-2020	10-Jan-2020	11-Jan-2020	3
C	End	0	contractor	B	G			FS	FS			10-Jan-2020	10-Jan-2020				12-Jan-2020	12-Jan-2020	12-Jan-2020	12-Jan-2020	0

Figure 33: Contractor Responsibility Sheet, Final Output

If the user needs to clear all the data, he could press the button “Clear All”. In addition, to move to the next sheet, he should either press the “Next” button or choose the next sheet from the sheets bar.

To display the bar chart, the user should press the button “Draw Bar chart”.

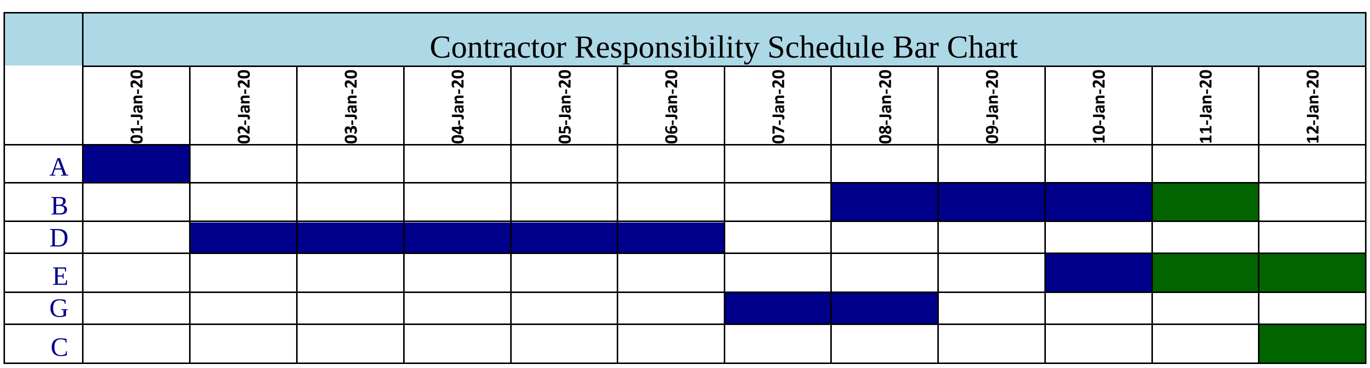


Figure 34 Contractor Responsibility Bar chart

- Analysis: In this sheet, the model analyzes concurrency based on the approach selected in the first sheet "Start". The model shows which critical activities with owner responsible delays are concurrent with which critical activities with contractor responsible delays. In case the selected approach is "AACE", the model will ask the user to insert the start and the end of his analysis period. If the selected approach is not "AACE", then the model runs without any inputs from the user.

  The following figure shows the messages that appear in case of "AACE".

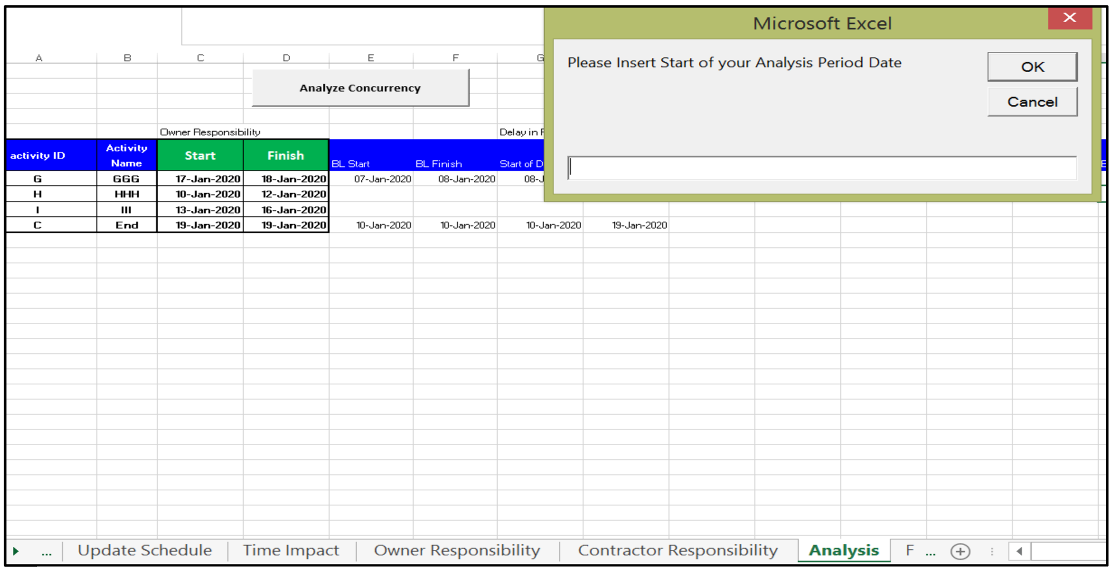


Figure 35 Analysis Sheet, Insert Start of Analysis Period

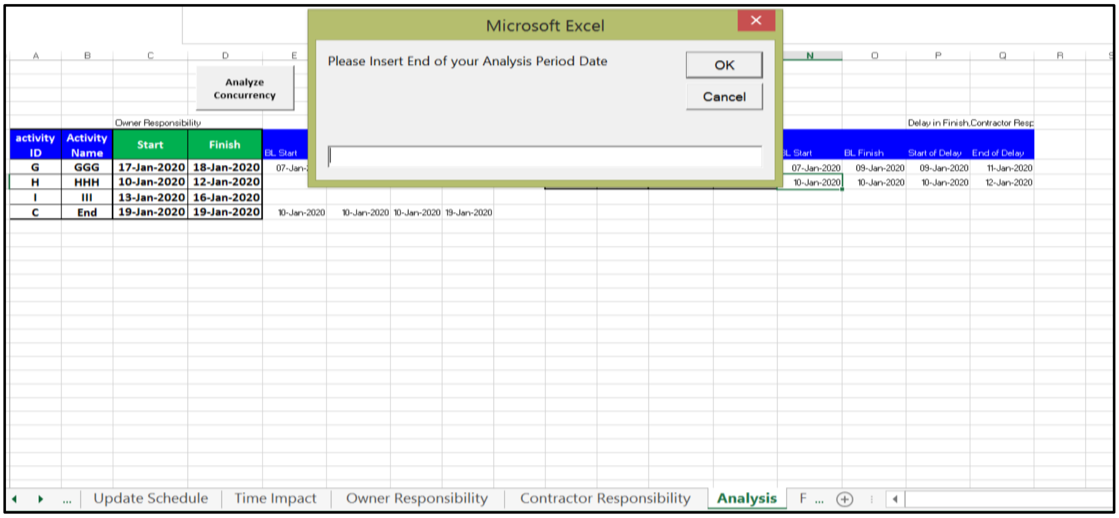
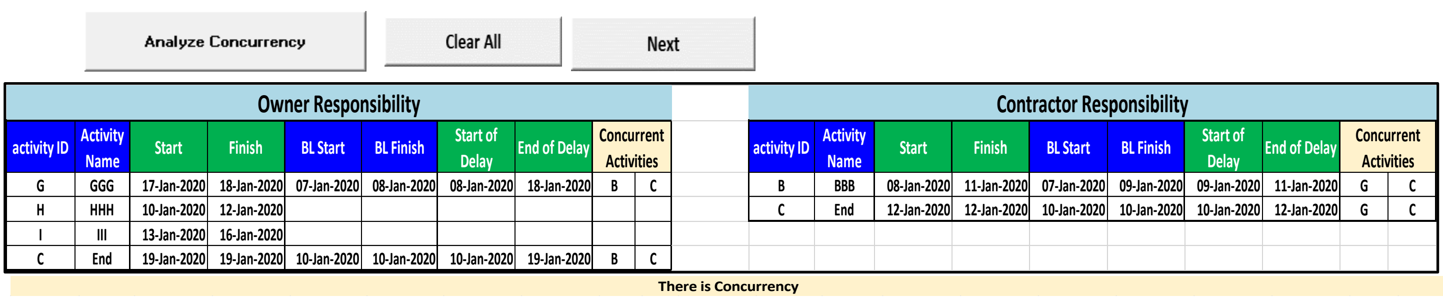


Figure 36 Analysis Sheet, Insert End of Analysis Period

The following figure shows the final output of this sheet. The model outputs the critical delays that is owner responsibility & contractor responsibility. Then, it highlights the concurrent activities.



Owner Responsibility									
activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay	Concurrent Activities	
G	GGG	17-Jan-2020	18-Jan-2020	07-Jan-2020	08-Jan-2020	08-Jan-2020	18-Jan-2020	B	C
H	HHH	10-Jan-2020	12-Jan-2020						
I	III	13-Jan-2020	16-Jan-2020						
C	End	19-Jan-2020	19-Jan-2020	10-Jan-2020	10-Jan-2020	10-Jan-2020	19-Jan-2020	B	C

Contractor Responsibility									
activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay	Concurrent Activities	
B	BBB	08-Jan-2020	11-Jan-2020	07-Jan-2020	09-Jan-2020	09-Jan-2020	11-Jan-2020	G	C
C	End	12-Jan-2020	12-Jan-2020	10-Jan-2020	10-Jan-2020	10-Jan-2020	12-Jan-2020	G	C

There is Concurrency

Figure 37: Analysis Sheet, Final Output

If the user needs to restart this sheet, he could press the button “Clear All”. In addition, to move to the next sheet, he can either press the button “Next” or select the next sheet from the sheets bar.

- Final Result: In this sheet, the model outputs based on the previous sheets; the total delay, concurrent delay, contractor responsible delays, owner responsible delay and the extension of time granted to the contractor.

  As this analysis may involve cumulative effect of several events, the model asks the user to insert the previous event data including finish date, concurrency days, any previously recognized contractor delays & owner delays as follows. The user can insert it as zero, if there is no cumulative effect and this analysis is based on only one event.

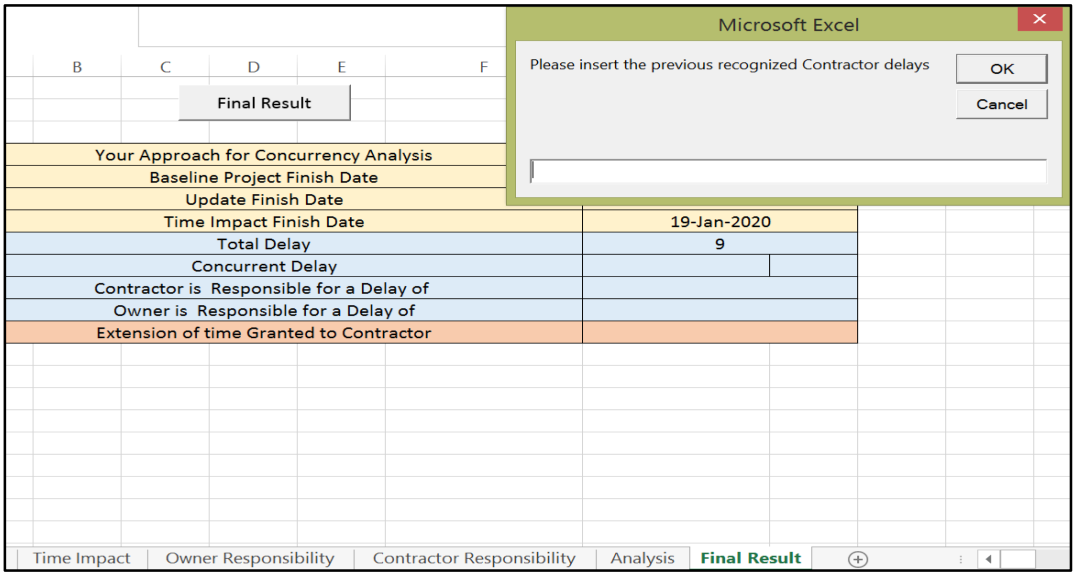


Figure 38: Final Result Sheet, Insert Previous Recognized Contractor Delays

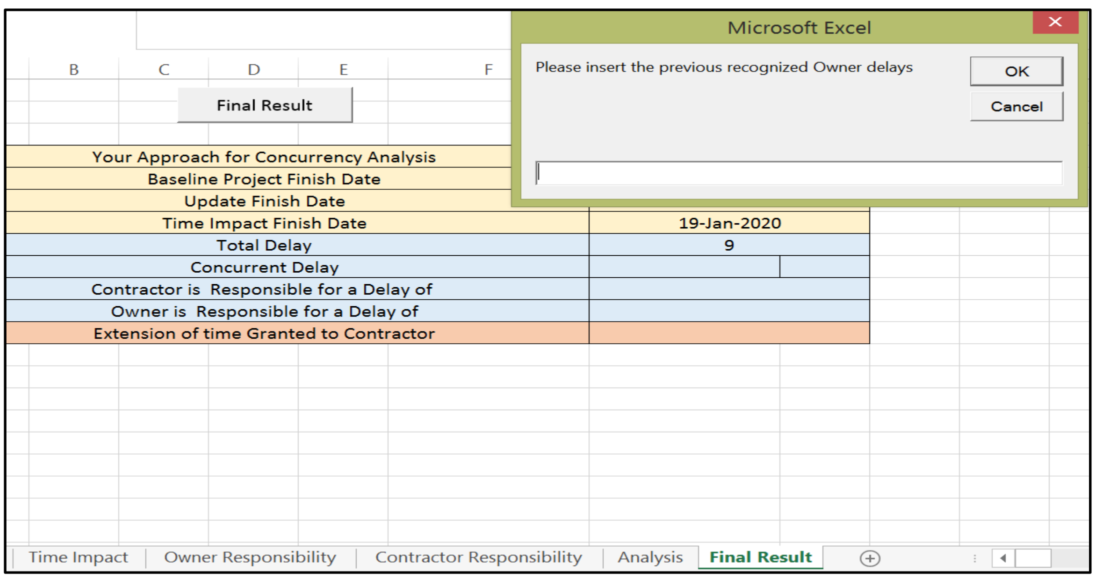
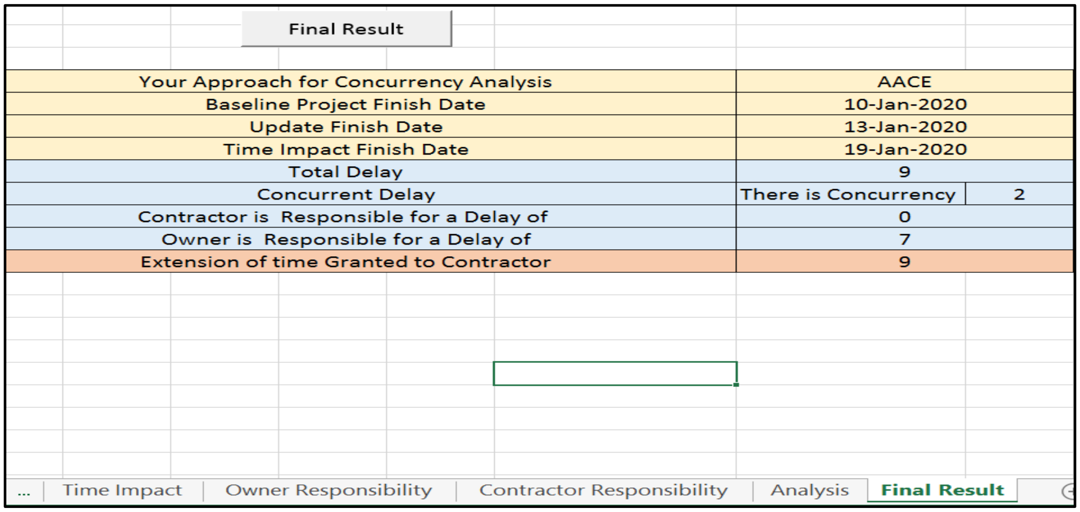


Figure 39: Final Result Sheet, Insert Previous Recognized Owner Delays

Then, the final output of this sheet is as follows.



Final Result

Your Approach for Concurrency Analysis	AACE	
Baseline Project Finish Date	10-Jan-2020	
Update Finish Date	13-Jan-2020	
Time Impact Finish Date	19-Jan-2020	
Total Delay	9	
Concurrent Delay	There is Concurrency	2
Contractor is Responsible for a Delay of	0	
Owner is Responsible for a Delay of	7	
Extension of time Granted to Contractor	9	

... | Time Impact | Owner Responsibility | Contractor Responsibility | Analysis | **Final Result**

Figure 40: Final Result Sheet, Final Output

4.2 Chapter Summary:

The proposed model requires the user to input the basic information about his project. Then, the model outputs two schedules; one is the owner responsible delays alone taking into consideration the actual dates for the owner responsible activities while the contractor responsible activities will run as sequence. The other one is the contractor responsible delays alone taking into consideration the actual dates for the contractor responsible activities while the owner responsible activities will run as sequence. Then, the model performs the concurrency analysis based on the selected approach and determine if there is concurrency or not. Finally, the model determines delay responsibility and final remedy in terms of the extension of time that should be granted to the contractor. The following table summarizes each sheet inputs and outputs:

Table 2: Summary of Model Inputs & Outputs

Sheet Name	**Inputs**	**Outputs**
Start	-Project Basic Information (Name, budget, contractor name, owner name, start of the project, Concurrency Analysis Type)	
Schedule	-Number of (Successors, Predecessors) -Responsible Party of each activity -Predecessors, lags & relationships between each activity and its predecessors	-Identify successors -Early dates -Late dates -Total Float
Update Schedule	-Max new number of (predecessors & successors) - New activities - New Relationships& lags -Actual data (actual start, actual finish & % Complete)	- New Dates (new start & new finish)

	-Data Date	
Time Impact	-Event data(New activities, New relations, lags & actual data) -New number of (predecessors & successors) -Data Date -If this time impact for contractor event or for owner event	-New Dates (new start & new finish)
Owner Responsibility	- Data date	- Early & Late dates for owner responsible delays - Total float
Contractor Responsibility	- Data date	-Early & Late dates for contractor responsible delays - Total float
Analysis	- If the concurrency analysis is AACE, proposed analysis period(start & end)	- If there is concurrency or not -In case there is, the concurrent activities
Final Result	-The previous event data including finish date, concurrent days, recognized owner & contractor delays	- Total delay -Concurrent delay -Contractor responsible delay -Owner responsible delay -Extension of time granted to the contractor

Chapter 5: Model Verification:

5.1 Model Initial Testing & Verification

In this section, the model will be initially tested to ensure that it could work under different scenarios to examine its capabilities and its limitations. The tests used in each sheet are as follows:

Schedule Sheet: The model is tested under different conditions as follows:

• Using equal number of predecessors and successors.

• Using number of successors different from the numbers of predecessors. Then, determine if the model works in both cases and gives valid results or not.

• Different relationships with different lags are assigned to the activities to ensure the logic runs accurately.

• Different number of activities is used to ensure the model can run large as well as small number of activities.

Update Schedule Sheet: The model is tested under the following conditions:

• Using number of activities equals to that in the baseline.

• Using different number of activities than that of the baseline to ensure that the user could add new activities in this sheet.

• Using number of predecessors and successors as same as baseline schedule

• Using different number of predecessors and successors than the baseline.

Time Impact: The model is tested under the following conditions:

• Using different number of activities, number of predecessors, number of successors than the baseline schedule and updated schedule.

• Using different party's responsibility for the new activities.

In the following sections, each test is illustrated in details and is supported with screenshots from the model.

Schedule Sheet:

In this sheet, we need to ensure that the schedule could run accurately regardless the number of successors, predecessors, activities and the type of relationships between activities. Therefore, these different parameters were tested by running the model with different inputs as the below figures will show. Then, the results were tested against the expected manually calculated dates. To ensure accurate results, the first activity in the schedule should be the start activity and the last activity is the finish activity. However, the activities in between don't have to be in any order. The following figures show the model output according to the different inputs in this sheet.

- The following figure depends on the following inputs:
  - Number of activities=6
  - Number of predecessors=Number of successors=2
  - No lags in all activities
  - All relationships were Finish to Start

Insert Data | New Schedule | Identify Successors | Run Baseline Schedule | Draw Barchart | Clear All | Next

Baseline Schedule																
activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Lag1	Lag2	Relationship1	Relationship2	Successor1	Successor2	Early Start	Early Finish	Late Start	Late Finish	Total Float
A	Start	0	contractor					FS	FS	D	E	01-Jan-2020	01-Jan-2020	01-Jan-2020	01-Jan-2020	0
B	BBB	2	contractor	E	D			FS	FS	C		07-Jan-2020	09-Jan-2020	07-Jan-2020	09-Jan-2020	0
D	DDD	4	owner	A				FS	FS	G	B	02-Jan-2020	06-Jan-2020	02-Jan-2020	06-Jan-2020	0
E	EEE	3	contractor	A				FS		B		02-Jan-2020	05-Jan-2020	03-Jan-2020	06-Jan-2020	1
G	GGG	1	owner	D				FS		C		07-Jan-2020	08-Jan-2020	08-Jan-2020	09-Jan-2020	1
C	End	0	contractor	B	G			FS	FS			10-Jan-2020	10-Jan-2020	10-Jan-2020	10-Jan-2020	0

Figure 41: Schedule Sheet Verification, Case#1

All outputs were compared to expected calculated dates and they were all as expected.

- The following figure depends on the following inputs:
  - Number of activities=12
  - Number of predecessors=2
  - Number of successors=3
  - There are lags between activities
  - Relationships are different; there are finish to start, finish to finish and start to start relationships between different activities

Insert Data | New Schedule | Identify Successors | Run Baseline Schedule | Draw Barchart | Clear All | Next

Baseline Schedule																	
activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Lag1	Lag2	Relationship1	Relationship2	Successor1	Successor2	Successor3	Early Start	Early Finish	Late Start	Late Finish	Total Float
A	Start	0	contractor							B	C	J	01-Jan-2020	01-Jan-2020	01-Jan-2020	01-Jan-2020	0
B	BBB	2	owner	A				FS		D	F		02-Jan-2020	04-Jan-2020	10-Jan-2020	12-Jan-2020	8
C	CCC	3	owner	A		2		FS		E	F		04-Jan-2020	07-Jan-2020	04-Jan-2020	07-Jan-2020	0
D	DDD	4	contractor	B		1		SS		I			03-Jan-2020	07-Jan-2020	22-Jan-2020	26-Jan-2020	19
E	EEE	2	owner	C		2		FS		G			10-Jan-2020	12-Jan-2020	10-Jan-2020	12-Jan-2020	0
F	FFF	3	owner	B	C		3	FS	FF	G			07-Jan-2020	10-Jan-2020	13-Jan-2020	16-Jan-2020	6
G	GGG	4	contractor	F	E			SS	FS	H			13-Jan-2020	17-Jan-2020	13-Jan-2020	17-Jan-2020	0
H	HHH	5	contractor	G				FS		I			18-Jan-2020	23-Jan-2020	18-Jan-2020	23-Jan-2020	0
I	III	2	contractor	H	D	3		FS	FS	L			27-Jan-2020	29-Jan-2020	27-Jan-2020	29-Jan-2020	0
J	JJJ	3	contractor	A				FS		K			02-Jan-2020	05-Jan-2020	21-Jan-2020	24-Jan-2020	19
K	KKK	4	contractor	J				FS		L			06-Jan-2020	10-Jan-2020	25-Jan-2020	29-Jan-2020	19
L	End	0	contractor	K	I			FS	FS				30-Jan-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	0

Figure 42: Schedule Sheet Verification, Case #2

All outputs were compared to expected calculated dates and they were all as expected.

Therefore, from the previous what if scenarios, the model proved that it could run accurately regardless the number of activities, the number of predecessors, number of successors and the different relationships and lags between activities.

Update Schedule Sheet:

In this sheet, we need to ensure that the model could run accurately whether the update schedule was just the same as the baseline schedule activities and relationships with different actual dates or in case the updated schedule includes some new activities and relationships. Therefore, according to the definition of update schedule in the contract, the inputs will differ. Some contracts require that the update schedule should be just as the baseline schedule activities and relationship with only updated dates while others may accept changes to represent the actual sequence on site. Accordingly, we need to ensure that in both cases, the model will run accurately. The following figures will show the model output in both cases.

- The following figure depends on the following inputs:
    - The update schedule has the data as the baseline schedule with different actual dates.
    - The data date is 15 Jan 2020

Insert Actual New Activities & Relations | Define New Successors | Insert Actual Dates | Run Updated Schedule | Draw Barchart | Clear All | Next

Update Schedule																	
activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Lag1	Lag2	Relationship1	Relationship2	Successor 1	Successor 2	Successor 3	Actual Start	Actual Finish	%complete	New Early Start	New Early Finish
A	Start	0	contractor							B	C	J	01-Jan-2020	01-Jan-2020	100%	01-Jan-2020	01-Jan-2020
B	BBB	2	owner	A				FS		D	F		03-Jan-2020	07-Jan-2020	100%	03-Jan-2020	07-Jan-2020
C	CCC	3	owner	A		2		FS		E	F		08-Jan-2020	14-Jan-2020	100%	08-Jan-2020	14-Jan-2020
D	DDD	4	contractor	B		1		SS		I			04-Jan-2020	10-Jan-2020	100%	04-Jan-2020	10-Jan-2020
E	EEE	2	owner	C		2		FS		G			12-Jan-2020	15-Jan-2020	100%	12-Jan-2020	15-Jan-2020
F	FFF	3	owner	B	C		3	FS	FF	G						15-Jan-2020	18-Jan-2020
G	GGG	4	contractor	F	E			SS	FS	H						16-Jan-2020	20-Jan-2020
H	HHH	5	contractor	G				FS		I						21-Jan-2020	26-Jan-2020
I	III	2	contractor	H	D	3		FS	FS	L						30-Jan-2020	01-Feb-2020
J	JJJ	3	contractor	A				FS		K			02-Jan-2020	05-Jan-2020	100%	02-Jan-2020	05-Jan-2020
K	KKK	4	contractor	J				FS		L						15-Jan-2020	19-Jan-2020
L	End	0	contractor	K	I			FS	FS							02-Feb-2020	02-Feb-2020

Figure 43: Update Schedule Sheet Verification, Case #1

All outputs were compared to expected calculated dates and they were all as expected.

- The following figure depends on the following inputs:
  - The update schedule has new activities (M & N) and different number of successors and predecessors(4 & 3) than the baseline schedule(3 & 2)
  - The data date is 15 Jan 2020

Insert Actual New Activities & Relations | Define New Successors | Insert Actual Dates | Run Updated Schedule | Draw Barchart | Clear All | Next

Update Schedule																					
activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Predecessor3	Lag1	Lag2	Lag3	Relationship1	Relationship2	Relationship3	Successor1	Successor2	Successor3	Successor4	Actual Start	Actual Finish	%complete	New Early Start	New Early Finish
A	Start	0	contractor										B	C	J	M	01-Jan-2020	01-Jan-2020	100%	01-Jan-2020	01-Jan-2020
B	BBB	2	owner	A						FS			D	F			03-Jan-2020	07-Jan-2020	100%	03-Jan-2020	07-Jan-2020
C	CCC	3	owner	A			2			FS			E	F			08-Jan-2020	14-Jan-2020	100%	08-Jan-2020	14-Jan-2020
D	DDD	4	contractor	B			1			SS			I				04-Jan-2020	10-Jan-2020	100%	04-Jan-2020	10-Jan-2020
E	EEE	2	owner	C			2			FS			G				12-Jan-2020	15-Jan-2020	100%	12-Jan-2020	15-Jan-2020
F	FFF	3	owner	B	C	M		3		FS	FF	FS	G							18-Jan-2020	21-Jan-2020
G	GGG	4	contractor	F	E					SS	FS		H							18-Jan-2020	22-Jan-2020
H	HHH	5	contractor	G						FS			I							23-Jan-2020	28-Jan-2020
I	III	2	contractor	H	D		3			FS	FS		L							01-Feb-2020	03-Feb-2020
J	JJJ	3	contractor	A						FS			K				02-Jan-2020	05-Jan-2020	100%	02-Jan-2020	05-Jan-2020
K	KKK	4	contractor	J						FS			L							15-Jan-2020	19-Jan-2020
M	MMM	2	owner	A						FS			N	F			15-Jan-2020		5%	15-Jan-2020	17-Jan-2020
N	NNN	2	owner	M						FS			L							18-Jan-2020	20-Jan-2020
L	End	0	contractor	K	I	N				FS	FS									04-Feb-2020	04-Feb-2020

Figure 44: Update Schedule Sheet Verification, Case #2

All outputs were compared to expected calculated dates and they were all as expected.

Accordingly, the model proved that it could run accurately whether the update schedule includes new activities and relationships or not.

Time Impact Sheet:

In this sheet, we impact the updated schedule with the claim event activities to see their effect on the project finish date. Therefore, this is done on an updated schedule that has the same activities and relationships as the baseline with different actual dates. Then, the new activities and relationships resulted from the event will be added to this sheet. We need to ensure that the schedule run accurately with new added activities. In addition, we need to have two scenarios; the first one is that the added activities are owner responsibility. The second one is the added activities are contractor responsibility as that will affect the final result for each party's reimbursement.

- The following figure depends on the following inputs:
  - The impact schedule has new activities (M & N) and different number of successors and predecessors(4 & 3) than the updated schedule(3 & 2)
  - The new activities are the owner responsibility

Insert New Data | Run Time Impact Analysis | Draw Barchart | Clear All | Next

Time Impact Analysis																					
activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Predecessor3	Lag1	Lag2	Lag3	Relationship1	Relationship2	Relationship3	Successor1	Successor2	Successor3	Successor4	Actual Start	Actual Finish	%complete	New Early Start	New Early Finish
A	Start	0	contractor										B	C	J	M	01-Jan-2020	01-Jan-2020	100%	01-Jan-2020	01-Jan-2020
B	BBB	2	owner	A						FS			D	F			03-Jan-2020	07-Jan-2020	100%	03-Jan-2020	07-Jan-2020
C	CCC	3	owner	A			2			FS			E	F			08-Jan-2020	14-Jan-2020	100%	08-Jan-2020	14-Jan-2020
D	DDD	4	contractor	B			1			SS			I				04-Jan-2020	10-Jan-2020	100%	04-Jan-2020	10-Jan-2020
E	EEE	2	owner	C			2			FS			G				12-Jan-2020	15-Jan-2020	100%	12-Jan-2020	15-Jan-2020
F	FFF	3	owner	B	C	M		3		FS	FF	FS	G							18-Jan-2020	21-Jan-2020
G	GGG	4	contractor	F	E					SS	FS		H							18-Jan-2020	22-Jan-2020
H	HHH	5	contractor	G						FS			I							23-Jan-2020	28-Jan-2020
I	III	2	contractor	H	D		3			FS	FS		L							01-Feb-2020	03-Feb-2020
J	JJJ	3	contractor	A						FS			K				02-Jan-2020	05-Jan-2020	100%	02-Jan-2020	05-Jan-2020
K	KKK	4	contractor	J						FS			L							15-Jan-2020	19-Jan-2020
M	MMM	2	owner	A						FS			N	F			15-Jan-2020		5%	15-Jan-2020	17-Jan-2020
N	NNN	2	owner	M						FS			L							18-Jan-2020	20-Jan-2020
L	End	0	contractor	K	I	N				FS	FS									04-Feb-2020	04-Feb-2020

Figure 45: Time Impact Sheet Verification, Case #1

All outputs were compared to expected calculated dates and they were all as expected.

- The following figure depends on the following inputs:
    - The impact schedule has new activities (M & N) and different number of successors and predecessors(4 & 3) than the updated schedule(3 & 2)
    - The new activities are the contractor responsibility

Insert New Data | Run Time Impact Analysis | Draw Barchart | Clear All | Next

Time Impact Analysis																					
activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Predecessor3	Lag1	Lag2	Lag3	Relationship1	Relationship2	Relationship3	Successor1	Successor2	Successor3	Successor4	Actual Start	Actual Finish	%complete	New Early Start	New Early Finish
A	Start	0	contractor										B	C	J	M	01-Jan-2020	01-Jan-2020	100%	01-Jan-2020	01-Jan-2020
B	BBB	2	owner	A						FS			D	F			03-Jan-2020	07-Jan-2020	100%	03-Jan-2020	07-Jan-2020
C	CCC	3	owner	A			2			FS			E	F			08-Jan-2020	14-Jan-2020	100%	08-Jan-2020	14-Jan-2020
D	DDD	4	contractor	B			1			SS			I				04-Jan-2020	10-Jan-2020	100%	04-Jan-2020	10-Jan-2020
E	EEE	2	owner	C			2			FS			G				12-Jan-2020	15-Jan-2020	100%	12-Jan-2020	15-Jan-2020
F	FFF	3	owner	B	C	M		3		FS	FF	FS	G							18-Jan-2020	21-Jan-2020
G	GGG	4	contractor	F	E					SS	FS		H							18-Jan-2020	22-Jan-2020
H	HHH	5	contractor	G						FS			I							23-Jan-2020	28-Jan-2020
I	III	2	contractor	H	D		3			FS	FS		L							01-Feb-2020	03-Feb-2020
J	JJJ	3	contractor	A						FS			K				02-Jan-2020	05-Jan-2020	100%	02-Jan-2020	05-Jan-2020
K	KKK	4	contractor	J						FS			L							15-Jan-2020	19-Jan-2020
M	MMM	2	contractor	A						FS			N	F			15-Jan-2020		5%	15-Jan-2020	17-Jan-2020
N	NNN	2	contractor	M						FS			L							18-Jan-2020	20-Jan-2020
L	End	0	contractor	K	I	N				FS	FS	FS								04-Feb-2020	04-Feb-2020

Figure 46: Time Impact Sheet Verification, Case #2

All outputs were compared to expected calculated dates and they were all as expected.

It is clear that the output dates in this test is the same as the previous one; however, it differs in interpretation and will differ in each party's responsibility. As in this iteration, the contractor is the one responsible for the new activities and the delay while in the previous one the owner was the responsible for that delay. Accordingly, the model could run accurately regardless the new activities were owner or contractor responsibility.

Owner Responsibility Sheet:

In this sheet, we need to ensure that the schedule will run the owner activities as actual and the contractor activities as sequence. Therefore, the finish date will give the impact of the owner delays only on the finish date of the project, taking into consideration any new activities added or any relationships adjusted.

- The following figure depends on :
    - The owner is responsible for new activities

Run Owner Responsible Delay Early Dates | Run Owner Responsible Delay Late Dates | Total Float | Draw Barchart | Clear All | Next

Owner Responsibility

activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Predecessor3	Lag1	Lag2	Lag3	Relationship1	Relationship2	Relationship3	Successor1	Successor2	Successor3	Successor4	Early Start	Early Finish	Actual Start	Actual Finish	%complete	Start	Finish	Late Start	Late Finish	Total Float
A	Start	0	contractor										B	C	J	M	01-Jan-2020	01-Jan-2020	01-Jan-2020	01-Jan-2020	100%	01-Jan-2020	01-Jan-2020	06-Jan-2020	06-Jan-2020	5
B	BBB	2	owner	A						FS			D	F			02-Jan-2020	04-Jan-2020	03-Jan-2020	07-Jan-2020	100%	03-Jan-2020	07-Jan-2020	15-Jan-2020	17-Jan-2020	10
C	CCC	3	owner	A			2			FS			E	F			04-Jan-2020	07-Jan-2020	08-Jan-2020	14-Jan-2020	100%	08-Jan-2020	14-Jan-2020	09-Jan-2020	12-Jan-2020	-2
D	DDD	4	contractor	B			1			SS			I				03-Jan-2020	07-Jan-2020	04-Jan-2020	10-Jan-2020	100%	04-Jan-2020	08-Jan-2020	27-Jan-2020	31-Jan-2020	23
E	EEE	2	owner	C			2			FS			G				10-Jan-2020	12-Jan-2020	12-Jan-2020	15-Jan-2020	100%	12-Jan-2020	15-Jan-2020	15-Jan-2020	17-Jan-2020	2
F	FFF	3	owner	B	C	M		3		FS	FF	FS	G				07-Jan-2020	10-Jan-2020				18-Jan-2020	21-Jan-2020	18-Jan-2020	21-Jan-2020	0
G	GGG	4	contractor	F	E					SS	FS		H				13-Jan-2020	17-Jan-2020				18-Jan-2020	22-Jan-2020	18-Jan-2020	22-Jan-2020	0
H	HHH	5	contractor	G						FS			I				18-Jan-2020	23-Jan-2020				23-Jan-2020	28-Jan-2020	23-Jan-2020	28-Jan-2020	0
I	III	2	contractor	H	D		3			FS	FS		L				27-Jan-2020	29-Jan-2020				01-Feb-2020	03-Feb-2020	01-Feb-2020	03-Feb-2020	0
J	JJJ	3	contractor	A						FS			K				02-Jan-2020	05-Jan-2020	02-Jan-2020	05-Jan-2020	100%	02-Jan-2020	05-Jan-2020	26-Jan-2020	29-Jan-2020	24
K	KKK	4	contractor	J						FS			L				06-Jan-2020	10-Jan-2020				06-Jan-2020	10-Jan-2020	30-Jan-2020	03-Feb-2020	24
M	MMM	2	owner	A						FS			N	F					15-Jan-2020		5%	15-Jan-2020	17-Jan-2020	15-Jan-2020	17-Jan-2020	0
N	NNN	2	owner	M						FS			L									18-Jan-2020	20-Jan-2020	01-Feb-2020	03-Feb-2020	14
L	End	0	contractor	K	I	N				FS	FS	FS					30-Jan-2020	30-Jan-2020				04-Feb-2020	04-Feb-2020	04-Feb-2020	04-Feb-2020	0

Figure 47: Owner Responsibility Sheet Verification, Case #1

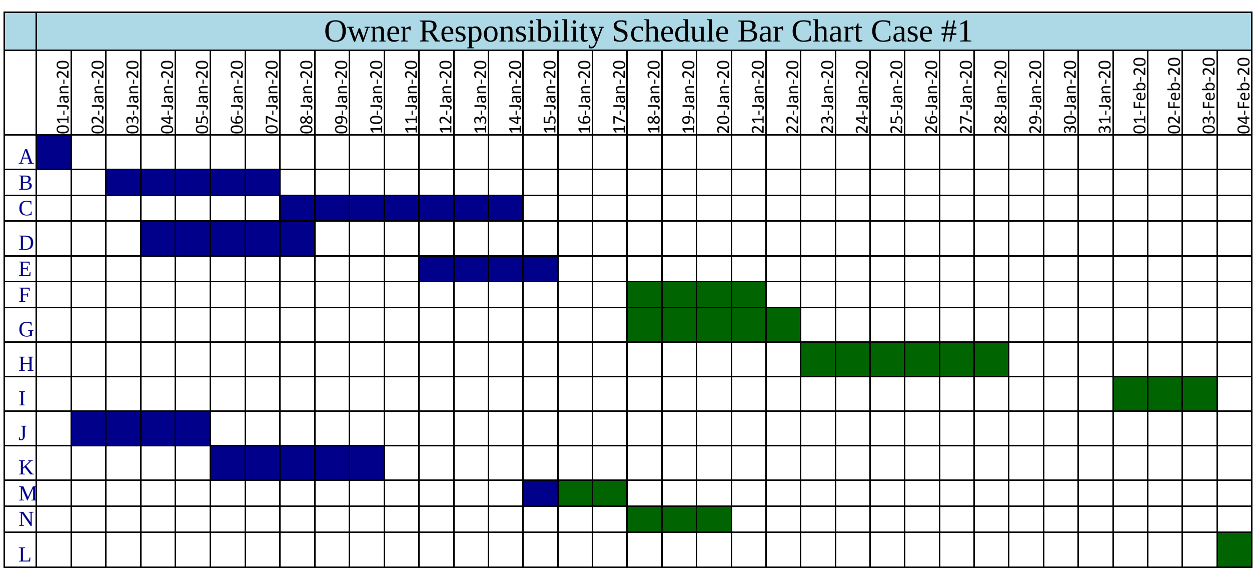


Figure 48: Owner Responsibility Sheet Verification, Case #1 Bar Chart

All outputs were compared to expected calculated dates and they were all as expected.

- The following figure depends on :
  - The owner was not responsible for new activities

Owner Responsibility																							
activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor 1	Predecessor 2	Lag1	Lag2	Relationship1	Relationship2	Successor 1	Successor 2	Successor 3	Early Start	Early Finish	Actual Start	Actual Finish	%complete	Start	Finish	Late Start	Late Finish	Total Float
A	Start	0	contractor							B	C	J	01-Jan-2020	01-Jan-2020	01-Jan-2020	01-Jan-2020	100%	01-Jan-2020	01-Jan-2020	04-Jan-2020	04-Jan-2020	3
B	BBB	2	owner	A				FS		D	F		02-Jan-2020	04-Jan-2020	03-Jan-2020	07-Jan-2020	100%	03-Jan-2020	07-Jan-2020	13-Jan-2020	15-Jan-2020	8
C	CCC	3	owner	A		2		FS		E	F		04-Jan-2020	07-Jan-2020	08-Jan-2020	14-Jan-2020	100%	08-Jan-2020	14-Jan-2020	07-Jan-2020	10-Jan-2020	-4
D	DDD	4	contractor	B		1		SS		I			03-Jan-2020	07-Jan-2020	04-Jan-2020	10-Jan-2020	100%	04-Jan-2020	08-Jan-2020	25-Jan-2020	29-Jan-2020	21
E	EEE	2	owner	C		2		FS		G			10-Jan-2020	12-Jan-2020	12-Jan-2020	15-Jan-2020	100%	12-Jan-2020	15-Jan-2020	13-Jan-2020	15-Jan-2020	0
F	FFF	3	owner	B	C		3	FS	FF	G			07-Jan-2020	10-Jan-2020				15-Jan-2020	18-Jan-2020	16-Jan-2020	19-Jan-2020	1
G	GGG	4	contractor	F	E			SS	FS	H			13-Jan-2020	17-Jan-2020				16-Jan-2020	20-Jan-2020	16-Jan-2020	20-Jan-2020	0
H	HHH	5	contractor	G				FS		I			18-Jan-2020	23-Jan-2020				21-Jan-2020	26-Jan-2020	21-Jan-2020	26-Jan-2020	0
I	III	2	contractor	H	D	3		FS	FS	L			27-Jan-2020	29-Jan-2020				30-Jan-2020	01-Feb-2020	30-Jan-2020	01-Feb-2020	0
J	JJJ	3	contractor	A				FS		K			02-Jan-2020	05-Jan-2020	02-Jan-2020	05-Jan-2020	100%	02-Jan-2020	05-Jan-2020	24-Jan-2020	27-Jan-2020	22
K	KKK	4	contractor	J				FS		L			06-Jan-2020	10-Jan-2020				06-Jan-2020	10-Jan-2020	28-Jan-2020	01-Feb-2020	22
L	End	0	contractor	K	I			FS	FS				30-Jan-2020	30-Jan-2020				02-Feb-2020	02-Feb-2020	02-Feb-2020	02-Feb-2020	0

Figure 49: Owner Responsibility Sheet Verification, Case #2

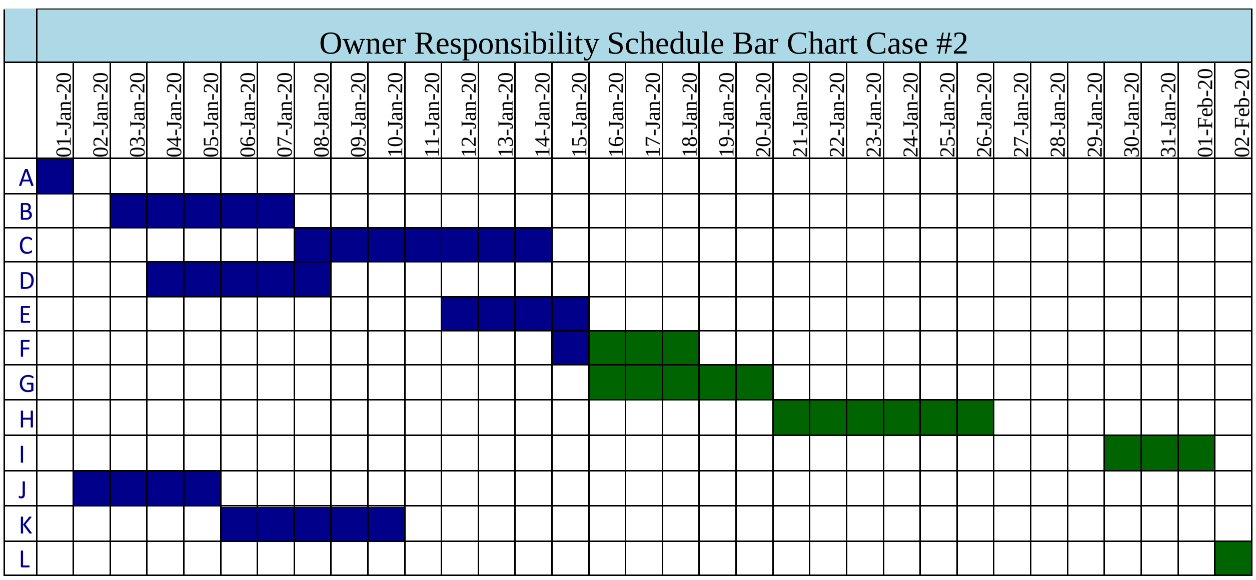


Figure 50: Owner Responsibility Sheet Verification, Case #2 Bar Chart

All outputs were compared to expected calculated dates and they were all as expected. Therefore, the model gives valid results in both cases.

Contractor Responsibility Sheet:

In this sheet, we need to ensure that the schedule runs the contractor activities as actual and the owner activities as sequence. Therefore, the finish date will give the impact of the contractor delays only on the finish date of the project, taking into consideration any new activities added or any relationships adjusted.

- The Following figure depends on:
  - The contractor is responsible for the new activities

Run Contractor Responsible Delay Early Dates | Run Contractor Responsible Late Dates | Total Float | Draw Barchart | Clear All | Next

Contractor Responsibility																										
activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Predecessor3	Lag1	Lag2	Lag3	Relationship	Relationship	Relationship	Successor1	Successor2	Successor3	Successor4	Early Start	Early Finish	Actual Start	Actual Finish	%complete	Start	Finish	Late Start	Late Finish	Total Float
A	Start	0	contractor										B	C	J	M	01-Jan-2020	01-Jan-2020	01-Jan-2020	01-Jan-2020	100%	01-Jan-2020	01-Jan-2020	06-Jan-2020	06-Jan-2020	5
B	BBB	2	owner	A						FS			D	F			02-Jan-2020	04-Jan-2020	03-Jan-2020	07-Jan-2020	100%	02-Jan-2020	04-Jan-2020	15-Jan-2020	17-Jan-2020	13
C	CCC	3	owner	A			2			FS			E	F			04-Jan-2020	07-Jan-2020	08-Jan-2020	14-Jan-2020	100%	04-Jan-2020	07-Jan-2020	09-Jan-2020	12-Jan-2020	5
D	DDD	4	contractor	B			1			SS			I				03-Jan-2020	07-Jan-2020	04-Jan-2020	10-Jan-2020	100%	04-Jan-2020	10-Jan-2020	27-Jan-2020	31-Jan-2020	21
E	EEE	2	owner	C			2			FS			G				10-Jan-2020	12-Jan-2020	12-Jan-2020	15-Jan-2020	100%	10-Jan-2020	12-Jan-2020	15-Jan-2020	17-Jan-2020	5
F	FFF	3	owner	B	C	M		3		FS	FF	FS	G				07-Jan-2020	10-Jan-2020				18-Jan-2020	21-Jan-2020	18-Jan-2020	21-Jan-2020	0
G	GGG	4	contractor	F	E					SS	FS		H				13-Jan-2020	17-Jan-2020				18-Jan-2020	22-Jan-2020	18-Jan-2020	22-Jan-2020	0
H	HHH	5	contractor	G						FS			I				18-Jan-2020	23-Jan-2020				23-Jan-2020	28-Jan-2020	23-Jan-2020	28-Jan-2020	0
I	III	2	contractor	H	D		3			FS	FS		L				27-Jan-2020	29-Jan-2020				01-Feb-2020	03-Feb-2020	01-Feb-2020	03-Feb-2020	0
J	JJJ	3	contractor	A						FS			K				02-Jan-2020	05-Jan-2020	02-Jan-2020	05-Jan-2020	100%	02-Jan-2020	05-Jan-2020	26-Jan-2020	29-Jan-2020	24
K	KKK	4	contractor	J						FS			L				06-Jan-2020	10-Jan-2020				15-Jan-2020	19-Jan-2020	30-Jan-2020	03-Feb-2020	15
M	MMM	2	contractor	A									N	F					15-Jan-2020		5%	15-Jan-2020	17-Jan-2020	15-Jan-2020	17-Jan-2020	0
N	NNN	2	contractor	M						FS			L									18-Jan-2020	20-Jan-2020	01-Feb-2020	03-Feb-2020	14
L	End	0	contractor	K	I	N				FS	FS	FS					30-Jan-2020	30-Jan-2020				04-Feb-2020	04-Feb-2020	04-Feb-2020	04-Feb-2020	0

Figure 51: Contractor Responsibility Sheet Verification, Case A

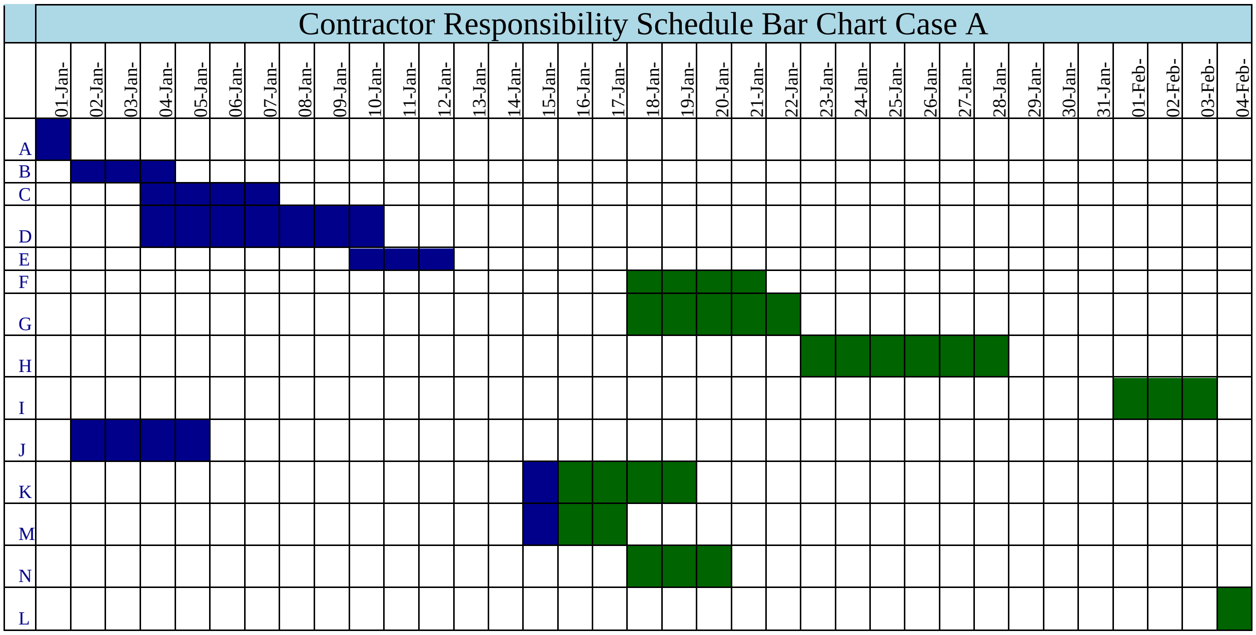


Figure 52: Contractor Responsibility Sheet Verification, Case A Bar Chart

All outputs were compared to expected calculated dates and they were all as expected

- The Following figure depends on:
    - The contractor is not responsible for the new activities

Run Contractor Responsible Delay Early Dates | Run Contractor Responsible Late Dates | Total Float | Draw Barchart | Clear All | Next

Contractor Responsibility																						
activity ID	Activity Name	Duration (Days)	Responsibility	Predecessor1	Predecessor2	Lag1	Lag2	Relationship1	Relationship2	Successor1	Successor2	Successor3	Early Start	Early Finish	Actual Start	Actual Finish	%complete	Start	Finish	Late Start	Late Finish	Total Float
A	Start	0	contractor							B	C	J	01-Jan-2020	01-Jan-2020	01-Jan-2020	01-Jan-2020	100%	01-Jan-2020	01-Jan-2020	03-Jan-2020	03-Jan-2020	2
B	BBB	2	owner	A				FS		D	F		02-Jan-2020	04-Jan-2020	03-Jan-2020	07-Jan-2020	100%	02-Jan-2020	04-Jan-2020	12-Jan-2020	14-Jan-2020	10
C	CCC	3	owner	A		2		FS		E	F		04-Jan-2020	07-Jan-2020	08-Jan-2020	14-Jan-2020	100%	04-Jan-2020	07-Jan-2020	06-Jan-2020	09-Jan-2020	2
D	DDD	4	contractor	B		1		SS		I			03-Jan-2020	07-Jan-2020	04-Jan-2020	10-Jan-2020	100%	04-Jan-2020	10-Jan-2020	24-Jan-2020	28-Jan-2020	18
E	EEE	2	owner	C		2		FS		G			10-Jan-2020	12-Jan-2020	12-Jan-2020	15-Jan-2020	100%	10-Jan-2020	12-Jan-2020	12-Jan-2020	14-Jan-2020	2
F	FFF	3	owner	B	C		3	FS	FF	G			07-Jan-2020	10-Jan-2020				07-Jan-2020	10-Jan-2020	15-Jan-2020	18-Jan-2020	8
G	GGG	4	contractor	F	E			SS	FS	H			13-Jan-2020	17-Jan-2020				15-Jan-2020	19-Jan-2020	15-Jan-2020	19-Jan-2020	0
H	HHH	5	contractor	G				FS		I			18-Jan-2020	23-Jan-2020				20-Jan-2020	25-Jan-2020	20-Jan-2020	25-Jan-2020	0
I	III	2	contractor	H	D	3		FS	FS	L			27-Jan-2020	29-Jan-2020				29-Jan-2020	31-Jan-2020	29-Jan-2020	31-Jan-2020	0
J	JJJ	3	contractor	A				FS		K			02-Jan-2020	05-Jan-2020	02-Jan-2020	05-Jan-2020	100%	02-Jan-2020	05-Jan-2020	23-Jan-2020	26-Jan-2020	21
K	KKK	4	contractor	J				FS		L			06-Jan-2020	10-Jan-2020				15-Jan-2020	19-Jan-2020	27-Jan-2020	31-Jan-2020	12
L	End	0	contractor	K	I			FS	FS				30-Jan-2020	30-Jan-2020				01-Feb-2020	01-Feb-2020	01-Feb-2020	01-Feb-2020	0

Figure 53: Contractor Responsibility Sheet Verification, Case B

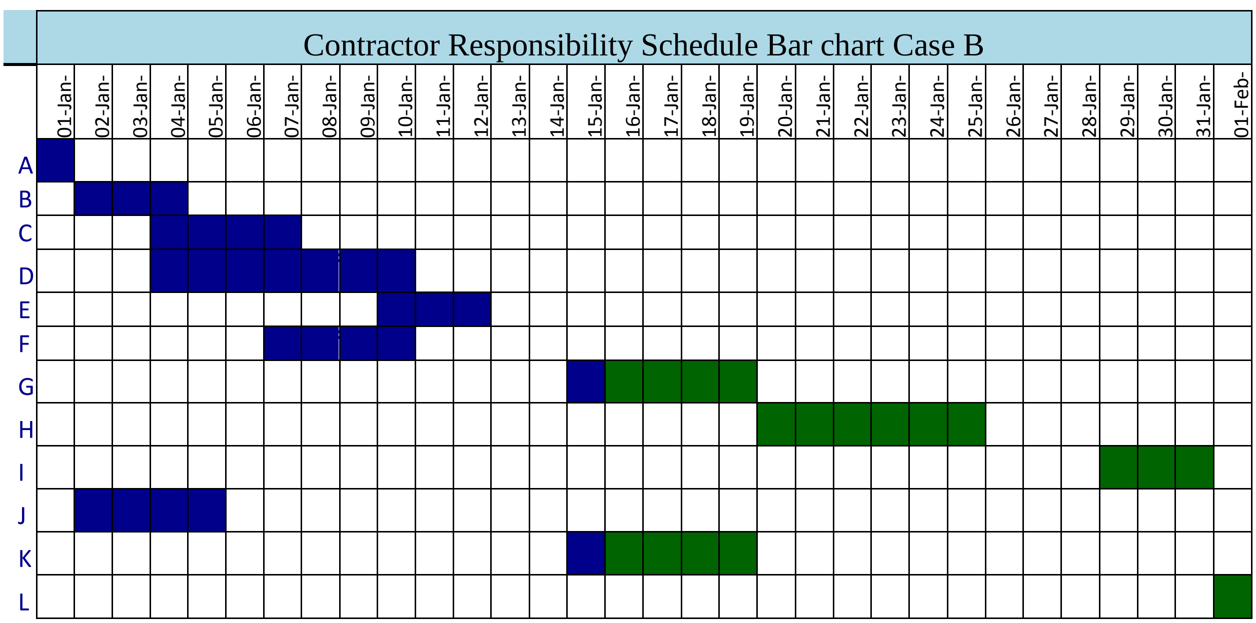


Figure 54: Contractor Responsibility Sheet Verification, Case B Bar Chart

All outputs were compared to expected calculated dates and they were all as expected.

Therefore, the model gives valid results in both cases.

Analysis Sheet:

In this sheet, we analyze where concurrent activities exist based on the selected approach in the first sheet named "Start". We need to ensure that the model runs as expected and detect concurrent activities in the three approaches namely SCL protocol, ASCE and AACE. In addition, under each approach, we have two cases; the first one is the owner is responsible for the new activities and the second one is that the contractor is responsible for the new activities. The following figures will ensure that each of these cases will run accurately on the model.

- The following figure depends on the following:
  - Selected approach: SCL Protocol
  - New activities are the Owner Responsibility

Analyze Concurrency | Clear All | Next

Owner Responsibility							
activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay
F	FFF	18-Jan-2020	21-Jan-2020	07-Jan-2020	10-Jan-2020	10-Jan-2020	21-Jan-2020
G	GGG	18-Jan-2020	22-Jan-2020	13-Jan-2020	17-Jan-2020	17-Jan-2020	22-Jan-2020
H	HHH	23-Jan-2020	28-Jan-2020	18-Jan-2020	23-Jan-2020	23-Jan-2020	28-Jan-2020
I	III	01-Feb-2020	03-Feb-2020	27-Jan-2020	29-Jan-2020	29-Jan-2020	03-Feb-2020
M	MMM	15-Jan-2020	17-Jan-2020				
L	End	04-Feb-2020	04-Feb-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	04-Feb-2020

Contractor Responsibility							
activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay
G	GGG	15-Jan-2020	19-Jan-2020	13-Jan-2020	17-Jan-2020	17-Jan-2020	19-Jan-2020
H	HHH	20-Jan-2020	25-Jan-2020	18-Jan-2020	23-Jan-2020	23-Jan-2020	25-Jan-2020
I	III	29-Jan-2020	31-Jan-2020	27-Jan-2020	29-Jan-2020	29-Jan-2020	31-Jan-2020
L	End	01-Feb-2020	01-Feb-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	01-Feb-2020

There is No Concurrency

Figure 55: Analysis Sheet Verification, SCL Protocol, Owner is responsible for the new activities Case 1&B

The outputs were compared to the expected results and they proved valid.

- The following figure depends on the following:
  - Selected approach: SCL Protocol

- New activities are the contractor responsibility

Analyze Concurrency | Clear All | Next

Owner Responsibility							
activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay
E	EEE	12-Jan-2020	15-Jan-2020	10-Jan-2020	12-Jan-2020	12-Jan-2020	15-Jan-2020
G	GGG	16-Jan-2020	20-Jan-2020	13-Jan-2020	17-Jan-2020	17-Jan-2020	20-Jan-2020
H	HHH	21-Jan-2020	26-Jan-2020	18-Jan-2020	23-Jan-2020	23-Jan-2020	26-Jan-2020
I	III	30-Jan-2020	01-Feb-2020	27-Jan-2020	29-Jan-2020	29-Jan-2020	01-Feb-2020
L	End	02-Feb-2020	02-Feb-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	02-Feb-2020

Contractor Responsibility							
activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay
F	FFF	18-Jan-2020	21-Jan-2020	07-Jan-2020	10-Jan-2020	10-Jan-2020	21-Jan-2020
G	GGG	18-Jan-2020	22-Jan-2020	13-Jan-2020	17-Jan-2020	17-Jan-2020	22-Jan-2020
H	HHH	23-Jan-2020	28-Jan-2020	18-Jan-2020	23-Jan-2020	23-Jan-2020	28-Jan-2020
I	III	01-Feb-2020	03-Feb-2020	27-Jan-2020	29-Jan-2020	29-Jan-2020	03-Feb-2020
M	MMM	15-Jan-2020	17-Jan-2020				
L	End	04-Feb-2020	04-Feb-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	04-Feb-2020

There is No Concurrency

Figure 56: Analysis Sheet Verification, SCL Protocol, Contractor is responsible for the new activities Case 2&A

The outputs were compared to the expected results and they proved valid.

Therefore, the model proved that it could run in both cases whether the owner is the responsible party for the new activities or the contractor under the SCL protocol.

- The following figure depends on the following:
  - Selected approach: ASCE
  - New activities are the owner responsibility

Analyze Concurrency | Clear All | Next

Owner Responsibility									
activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay	Concurrent Activities	
F	FFF	18-Jan-2020	21-Jan-2020	07-Jan-2020	10-Jan-2020	10-Jan-2020	21-Jan-2020	G	
G	GGG	18-Jan-2020	22-Jan-2020	13-Jan-2020	17-Jan-2020	17-Jan-2020	22-Jan-2020	G	
H	HHH	23-Jan-2020	28-Jan-2020	18-Jan-2020	23-Jan-2020	23-Jan-2020	28-Jan-2020	H	
I	III	01-Feb-2020	03-Feb-2020	27-Jan-2020	29-Jan-2020	29-Jan-2020	03-Feb-2020	I	L
M	MMM	15-Jan-2020	17-Jan-2020						
L	End	04-Feb-2020	04-Feb-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	04-Feb-2020	I	L

Contractor Responsibility									
activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay	Concurrent Activities	
G	GGG	15-Jan-2020	19-Jan-2020	13-Jan-2020	17-Jan-2020	17-Jan-2020	19-Jan-2020	F	G
H	HHH	20-Jan-2020	25-Jan-2020	18-Jan-2020	23-Jan-2020	23-Jan-2020	25-Jan-2020	H	
I	III	29-Jan-2020	31-Jan-2020	27-Jan-2020	29-Jan-2020	29-Jan-2020	31-Jan-2020	I	L
L	End	01-Feb-2020	01-Feb-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	01-Feb-2020	I	L

There is Concurrency

Figure 57: Analysis Sheet Verification, ASCE, Owner is responsible for new activities Case 1&B

The outputs were compared to the expected results and they proved valid.

- The following figure depends on the following:
  - Selected approach: ASCE

- New activities are the contractor responsibility

Analyze Concurrency | Clear All | Next

Owner Responsibility

activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay	Concurrent Activities	
E	EEE	12-Jan-2020	15-Jan-2020	10-Jan-2020	12-Jan-2020	12-Jan-2020	15-Jan-2020	F	
G	GGG	16-Jan-2020	20-Jan-2020	13-Jan-2020	17-Jan-2020	17-Jan-2020	20-Jan-2020	F	G
H	HHH	21-Jan-2020	26-Jan-2020	18-Jan-2020	23-Jan-2020	23-Jan-2020	26-Jan-2020	H	
I	III	30-Jan-2020	01-Feb-2020	27-Jan-2020	29-Jan-2020	29-Jan-2020	01-Feb-2020	I	L
L	End	02-Feb-2020	02-Feb-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	02-Feb-2020	I	L

Contractor Responsibility

activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay	Concurrent Activities	
F	FFF	18-Jan-2020	21-Jan-2020	07-Jan-2020	10-Jan-2020	10-Jan-2020	21-Jan-2020	E	G
G	GGG	18-Jan-2020	22-Jan-2020	13-Jan-2020	17-Jan-2020	17-Jan-2020	22-Jan-2020	G	
H	HHH	23-Jan-2020	28-Jan-2020	18-Jan-2020	23-Jan-2020	23-Jan-2020	28-Jan-2020	H	
I	III	01-Feb-2020	03-Feb-2020	27-Jan-2020	29-Jan-2020	29-Jan-2020	03-Feb-2020	I	L
M	MMM	15-Jan-2020	17-Jan-2020						
L	End	04-Feb-2020	04-Feb-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	04-Feb-2020	I	L

There is Concurrency

Figure 58: Analysis Sheet Verification, ASCE, Contractor is responsible for the new activities Case 2&A

The outputs were compared to the expected results and they proved valid.

Therefore, the model proved that it could run in both cases whether the owner is the responsible party for the new activities or the contractor under the ASCE Standard.

- The following figure depends on the following:
  - Selected approach: AACE
  - New activities are the owner responsibility
  - Analysis time period from 1-Jan-2020 till 15-Jan- 2020

Owner Responsibility

activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay
F	FFF	18-Jan-2020	21-Jan-2020	07-Jan-2020	10-Jan-2020	10-Jan-2020	21-Jan-2020
G	GGG	18-Jan-2020	22-Jan-2020	13-Jan-2020	17-Jan-2020	17-Jan-2020	22-Jan-2020
H	HHH	23-Jan-2020	28-Jan-2020	18-Jan-2020	23-Jan-2020	23-Jan-2020	28-Jan-2020
I	III	01-Feb-2020	03-Feb-2020	27-Jan-2020	29-Jan-2020	29-Jan-2020	03-Feb-2020
M	MMM	15-Jan-2020	17-Jan-2020				
L	End	04-Feb-2020	04-Feb-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	04-Feb-2020

Contractor Responsibility

activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay
G	GGG	15-Jan-2020	19-Jan-2020	13-Jan-2020	17-Jan-2020	17-Jan-2020	19-Jan-2020
H	HHH	20-Jan-2020	25-Jan-2020	18-Jan-2020	23-Jan-2020	23-Jan-2020	25-Jan-2020
I	III	29-Jan-2020	31-Jan-2020	27-Jan-2020	29-Jan-2020	29-Jan-2020	31-Jan-2020
L	End	01-Feb-2020	01-Feb-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	01-Feb-2020

There is No Concurrency

Figure 59: Analysis Sheet Verification, AACE, Owner is responsible for the new activities Case 1&B, 1st assumption for analysis period

The outputs were compared to the expected results and they proved valid.

However, when we changed the analysis time to be from 1-Jan-2020 till 4-Feb-2020, the result becomes that there is concurrency as shown in the coming figure.

Owner Responsibility

activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay	Concurrent Activities			
F	FFF	18-Jan-2020	21-Jan-2020	07-Jan-2020	10-Jan-2020	10-Jan-2020	21-Jan-2020	G	H	I	L
G	GGG	18-Jan-2020	22-Jan-2020	13-Jan-2020	17-Jan-2020	17-Jan-2020	22-Jan-2020	G	H	I	L
H	HHH	23-Jan-2020	28-Jan-2020	18-Jan-2020	23-Jan-2020	23-Jan-2020	28-Jan-2020	G	H	I	L
I	III	01-Feb-2020	03-Feb-2020	27-Jan-2020	29-Jan-2020	29-Jan-2020	03-Feb-2020	G	H	I	L
M	MMM	15-Jan-2020	17-Jan-2020								
L	End	04-Feb-2020	04-Feb-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	04-Feb-2020	G	H	I	L

Contractor Responsibility

activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay	Concurrent Activities				
G	GGG	15-Jan-2020	19-Jan-2020	13-Jan-2020	17-Jan-2020	17-Jan-2020	19-Jan-2020	F	G	H	I	L
H	HHH	20-Jan-2020	25-Jan-2020	18-Jan-2020	23-Jan-2020	23-Jan-2020	25-Jan-2020	F	G	H	I	L
I	III	29-Jan-2020	31-Jan-2020	27-Jan-2020	29-Jan-2020	29-Jan-2020	31-Jan-2020	F	G	H	I	L
L	End	01-Feb-2020	01-Feb-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	01-Feb-2020	F	G	H	I	L

There is Concurrency

Figure 60: Analysis Sheet Verification, AACE, Owner is responsible for the new activities Case 1&B, 2nd assumption for analysis period

The outputs were compared to the expected results and they proved valid.

It is clear how changing the analysis period will affect the decision of concurrency existence. Therefore, the model proved that it runs valid results according to the selected analysis period.

- The following figure depends on the following:
  - Selected approach: AACE
  - New activities are the contractor responsibility
  - Analysis period from 1-Jan-2020 to 15-Jan-2020

Owner Responsibility

activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay	Concurrent Activities
E	EEE	12-Jan-2020	15-Jan-2020	10-Jan-2020	12-Jan-2020	12-Jan-2020	15-Jan-2020	F
G	GGG	16-Jan-2020	20-Jan-2020	13-Jan-2020	17-Jan-2020	17-Jan-2020	20-Jan-2020	
H	HHH	21-Jan-2020	26-Jan-2020	18-Jan-2020	23-Jan-2020	23-Jan-2020	26-Jan-2020	
I	III	30-Jan-2020	01-Feb-2020	27-Jan-2020	29-Jan-2020	29-Jan-2020	01-Feb-2020	
L	End	02-Feb-2020	02-Feb-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	02-Feb-2020	

Contractor Responsibility

activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay	Concurrent Activities
F	FFF	18-Jan-2020	21-Jan-2020	07-Jan-2020	10-Jan-2020	10-Jan-2020	21-Jan-2020	E
G	GGG	18-Jan-2020	22-Jan-2020	13-Jan-2020	17-Jan-2020	17-Jan-2020	22-Jan-2020	
H	HHH	23-Jan-2020	28-Jan-2020	18-Jan-2020	23-Jan-2020	23-Jan-2020	28-Jan-2020	
I	III	01-Feb-2020	03-Feb-2020	27-Jan-2020	29-Jan-2020	29-Jan-2020	03-Feb-2020	
M	MMM	15-Jan-2020	17-Jan-2020					
L	End	04-Feb-2020	04-Feb-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	04-Feb-2020	

There is Concurrency

Figure 61: Analysis Sheet Verification, AACE, Contractor is responsible for the new activities Case 2&A, 1st assumption for analysis period

The outputs were compared to the expected results and they proved valid.

However, if the analysis period becomes from 1-Jan-2020 till 4-Feb-2020, the concurrent activities will increase and becomes as the following figure.

Owner Responsibility

activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay	Concurrent Activities				
E	EEE	12-Jan-2020	15-Jan-2020	10-Jan-2020	12-Jan-2020	12-Jan-2020	15-Jan-2020	F	G	H	I	L
G	GGG	16-Jan-2020	20-Jan-2020	13-Jan-2020	17-Jan-2020	17-Jan-2020	20-Jan-2020	F	G	H	I	L
H	HHH	21-Jan-2020	26-Jan-2020	18-Jan-2020	23-Jan-2020	23-Jan-2020	26-Jan-2020	F	G	H	I	L
I	III	30-Jan-2020	01-Feb-2020	27-Jan-2020	29-Jan-2020	29-Jan-2020	01-Feb-2020	F	G	H	I	L
L	End	02-Feb-2020	02-Feb-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	02-Feb-2020	F	G	H	I	L

Contractor Responsibility

activity ID	Activity Name	Start	Finish	BL Start	BL Finish	Start of Delay	End of Delay	Concurrent Activities				
F	FFF	18-Jan-2020	21-Jan-2020	07-Jan-2020	10-Jan-2020	10-Jan-2020	21-Jan-2020	E	G	H	I	L
G	GGG	18-Jan-2020	22-Jan-2020	13-Jan-2020	17-Jan-2020	17-Jan-2020	22-Jan-2020	E	G	H	I	L
H	HHH	23-Jan-2020	28-Jan-2020	18-Jan-2020	23-Jan-2020	23-Jan-2020	28-Jan-2020	E	G	H	I	L
I	III	01-Feb-2020	03-Feb-2020	27-Jan-2020	29-Jan-2020	29-Jan-2020	03-Feb-2020	E	G	H	I	L
M	MMM	15-Jan-2020	17-Jan-2020									
L	End	04-Feb-2020	04-Feb-2020	30-Jan-2020	30-Jan-2020	30-Jan-2020	04-Feb-2020	E	G	H	I	L

There is Concurrency

Figure 62: Analysis Sheet Verification, AACE, Contractor is responsible for the new activities. Case 2&A, 2nd assumption for analysis period

The outputs were compared to the expected results and they proved valid.

Therefore, the model proved that it could run in both cases whether the owner is the responsible party for the new activities or the contractor under the AACE Standard.

Final Result Sheet:

SCL Protocol:

Based on the previous sheets outputs, the model proved that there is no concurrency based on SCL protocol in both cases if the new activities were the owner responsibility or the contractor responsibility.

- The following figure depends on the owner is responsible for the new activities.

Final Result

Your Approach for Concurrency Analysis	SCL Protocol
Baseline Project Finish Date	30-Jan-2020
Update Finish Date	02-Feb-2020
Time Impact Finish Date	04-Feb-2020
Total Delay	5
Concurrent Delay	There is No Concurrency
Contractor is Responsible for a Delay of	2
Owner is Responsible for a Delay of	5
Extension of time Granted to Contractor	5

Figure 63: Final Result Sheet Verification, SCL Protocol, Case 1&B, Owner is responsible for the new activities

The outputs were compared to the expected results and they proved valid.

- The following figure depends on the contractor is responsible for the new activities

Final Result

Your Approach for Concurrency Analysis	SCL Protocol
Baseline Project Finish Date	30-Jan-2020
Update Finish Date	02-Feb-2020
Time Impact Finish Date	04-Feb-2020
Total Delay	5
Concurrent Delay	There is No Concurrency
Contractor is Responsible for a Delay of	5
Owner is Responsible for a Delay of	3
Extension of time Granted to Contractor	No Extension

Figure 64: Final Result Sheet Verification, SCL Protocol, Case 2&A Contractor is responsible for new activities

The outputs were compared to the expected results and they proved valid

Therefore, the extension of time granted to the contractor will depend on the dominant cause of delay in case of SCL protocol. The model proved its validity in both cases whether the contractor is the responsible party or the owner.

ASCE:

Based on the previous sheet output, there is concurrency according to the ASCE in both cases if the contractor is the responsible party for the new activities or the owner in the responsible party.

- The following figure depends on the owner is the responsible party for the new activities

Final Result

Your Approach for Concurrency Analysis	ASCE	
Baseline Project Finish Date	30-Jan-2020	
Update Finish Date	02-Feb-2020	
Time Impact Finish Date	04-Feb-2020	
Total Delay	5	
Concurrent Delay	There is Concurrency	2
Contractor is Responsible for a Delay of	0	
Owner is Responsible for a Delay of	3	
Extension of time Granted to Contractor	5	

Figure 65: Final Result Sheet Verification, ASCE, Case 1&B Owner is responsible for the new activities

The outputs were compared to the expected results and they proved valid.

- The following figure depends on that the contractor is the responsible party for the new activities

Final Result

Your Approach for Concurrency Analysis	ASCE	
Baseline Project Finish Date	30-Jan-2020	
Update Finish Date	02-Feb-2020	
Time Impact Finish Date	04-Feb-2020	
Total Delay	5	
Concurrent Delay	There is Concurrency	3
Contractor is Responsible for a Delay of	2	
Owner is Responsible for a Delay of	0	
Extension of time Granted to Contractor	3	

Figure 66: Final Result Sheet Verification, ASCE, Case 2 &A Contractor is responsible for the new activities

The outputs were compared to the expected results and they proved valid.

Therefore, the contractor is granted extension of time for the concurrent delay plus the delays that are owner responsibility. The model proves that and gives valid results in both cases whether the owner is the responsible for the new activities or the contractor.

AACE:

Based on the previous sheet output, concurrency depends on the selected analysis period in case of AACE standard.

- The following figures are based on that the owner is the responsible party for the new activities.
  - Analysis period is 1-Jan-2020 to 15-Jan-2020

Final Result	
Your Approach for Concurrency Analysis	AACE
Baseline Project Finish Date	30-Jan-2020
Update Finish Date	02-Feb-2020
Time Impact Finish Date	04-Feb-2020
Total Delay	5
Concurrent Delay	There is No Concurrency
Contractor is Responsible for a Delay of	2
Owner is Responsible for a Delay of	5
Extension of time Granted to Contractor	5

Figure 67: Final Result Sheet Verification, AACE, Case 1&B Owner is responsible for the new activities, 1st assumption for analysis period

The outputs were compared to the expected results and they proved valid

- Analysis period is 1-Jan-2020 to 4-Feb-2020

Final Result		
Your Approach for Concurrency Analysis	AACE	
Baseline Project Finish Date	30-Jan-2020	
Update Finish Date	02-Feb-2020	
Time Impact Finish Date	04-Feb-2020	
Total Delay	5	
Concurrent Delay	There is Concurrency	2
Contractor is Responsible for a Delay of	0	
Owner is Responsible for a Delay of	3	
Extension of time Granted to Contractor	5	

Figure 68: Final Result Sheet Verification, AACE, Case 1&B Owner is responsible for the new activities, 2nd assumption for analysis period

The outputs were compared to the expected results and they proved valid.

Therefore, the model gives valid outputs depending on the selected analysis period.

- The following figure depends on the contractor is responsible for the new activities
  - Analysis period is 1-Jan-2020 to 15-Jan-2020

Final Result		
Your Approach for Concurrency Analysis	AACE	
Baseline Project Finish Date	30-Jan-2020	
Update Finish Date	02-Feb-2020	
Time Impact Finish Date	04-Feb-2020	
Total Delay	5	
Concurrent Delay	There is Concurrency	3
Contractor is Responsible for a Delay of	2	
Owner is Responsible for a Delay of	0	
Extension of time Granted to Contractor	3	

Figure 69: Final Result Sheet Verification, AACE, Case 2&A, Contractor is responsible for the new activities, 1st assumption for analysis Period

The outputs were compared to the expected results and they proved valid.

- The following figure depends on the contractor is responsible for the new activities
  - Analysis period is 1-Jan-2020 to 4-Feb-2020

Final Result		
Your Approach for Concurrency Analysis	AACE	
Baseline Project Finish Date	30-Jan-2020	
Update Finish Date	02-Feb-2020	
Time Impact Finish Date	04-Feb-2020	
Total Delay	5	
Concurrent Delay	There is Concurrency	3
Contractor is Responsible for a Delay of	2	
Owner is Responsible for a Delay of	0	
Extension of time Granted to Contractor	3	

Figure 70: Final Result Sheet Verification, AACE, Case 2&A, Contractor is responsible for the new activities, 2nd assumption for analysis period

The outputs were compared to the expected results and they proved valid. Therefore, the model runs according to the selected analysis period and gives valid outputs. The model proved that it gives valid results whether the contractor or the owner is the responsible party for the new activities under the AACE approach.

5.2 Chapter Summary:

This chapter included different tests to ensure the validity of the model. These tests are summarized in the following table.

Table 3: Summary of Verification Tests Done for the Model Sheets

Sheet Name	Test
Schedule	• Number of predecessors= and/or does not= number of successors • Different relationships with different lags • Different Number of activities
Update Schedule	• Number of activities as Baseline schedule and/or is different • Number of predecessors and successors are as baseline schedule and/or different
Time Impact	• Different number of activities, number of predecessors, number of successors • Different party's responsibility for the new activities

The model proved its validity in the previous tests when compared to the expected results. The main limitations in the model are that activities run based on calendar days not working days. In addition, another limitation is that the first activity has to be the start activity and the last activity has to be the finish activity.

Chapter 6: Model Validation:

In this section, the model is tested using actual project data. The project basic information and reflections on the model outputs are highlighted in details.

6.1 Project Information:

A well-known hospital in Cairo is used for validation. The project is composed of two towers; the first one is the hospital and the second one is a medical tower. The building is composed of three basements, ground floor and eight floors. The building capacity is 158 beds, 5 operating theatres & 220 Medical offices. The contract scope is the Architectural and MEP package. The following table shows the basic project data.

Table 4: Validation Project Basic Information

Contract	FIDIC 1987
Contract Type	Unit Price
Contract Price	371,273,986 EGP
Commencement date	3rd of November 2013
Contract Finish Date	3rd of September 2015
Contract Duration	670 days

The owner imposed different design modifications in different zones of the building. Then, the work on the building was delayed. Therefore, the Contractor sent a claim requesting extension of time and cost reimbursement. The claim included mainly three events about design modifications in different zones in the building. The main three events under consideration are:

- 26th Feb 2014: Major imposed Architectural and MEP design modifications
- 15th May 2014: Major imposed Electrical design modifications
- 19th May 2014: Major imposed Arch design modifications

The Contractor claimed extension of time of 109 days due to the owner imposed design modifications that affected most of the work in the hospital shifting the project completion date from 3rd of September 2015 to 21st December 2015. In addition, the Contractor claimed cost reimbursement for that period equal to 19,451,341 EGP. On the other hand, the Consultant replied with a counter claim in which he rejected the time extension claimed by the contractor in the first two events. The consultant justified his rejection by claiming that the imposed design modifications in the first two events were minor and not affecting the work that much. In addition, the Consultant claimed that the Contractor was already behind schedule because of his own delays regardless the Owner delays. The Consultant has accepted only the third event and accepted to grant the Contractor an extension of time of only 63 days due to that event. However, the Consultant claimed that there were concurrent delays, so the Contractor will not be cost compensated. In response to that, the Contractor rejected that counter claim and insisted on claiming both time and cost compensation. In addition, he rejected the Consultant's concurrency claim stating that according to the SCL protocol, there is no proved concurrency in the project and the Contractor's delays was due to Owner continuous design modifications.

It is worth to highlight that there were no clauses in the contract specifying the accepted definition of concurrency and its remedy or the accepted technic to be adopted in case of its occurrence. In addition, the Consultant didn't specify the theory he used to derive his conclusions. He just claimed that the Contractor was concurrently delayed in his work with the Owner imposed design modifications. In addition, he mentioned that "as practice" in presence of concurrency, time is granted but no cost compensation. Therefore, this section aim is to input the project data into the model and compare the results suggested by the model to both the Contractor's claim, and Consultant's counter claim. After that, the researcher reflections on both are highlighted.

6.2 Validating the Model:

The following are the steps taken to input the data into the model:

- The second and third sheets outputs namely "Schedule" & "Update Schedule" will be compared to the project primavera schedule to prove that the model is running accurately and is giving the same results. Because the model is based on calendar days, the primavera schedule was first run as calendar days as well, so the project baseline finish date becomes 10 May 2015.
- **Start Sheet**: General information about the project was inputted. The model is run using the three protocols to compare the output to both claims.
- **Schedule Sheet**:
    - All activities IDs, names, durations and responsibility for each activity as contract agreements were inputted.

- Number of activities= 2850
- Max number of predecessors=60
- Max number of successors=102
- Relationships & lags between each activity and its predecessors were inputted.
- Then, the model was run identifying the successors and the early & late dates.
- These dates were compared to the actual data from primavera to ensure its accuracy.
- The model gives an accurate result in all activities with a small difference in project finish date of 6 days.
- Primavera finish date based on calendar days = 10 May 2015 while the model finish date= 16 May 2015.
- That difference can be justified as follows:
  - The finish to start relationship in the model was based on the following. The activity will start on the following day after the preceding activity finishes. However, in primavera, some activities follow the same logic, while others start on the same day. That is because in primavera the time unit is hour, so once the activity finishes in terms of hours, the succeeding one will start.
  - Therefore, that small difference is neglected.

- **Update Sheet**: As we have three events, we did the update just before the event arise. So, we had three updates as follows:
  - Update of 26 Feb 2014, Update of 15 May 2014, Update of 19 May 2014.
  - The following aspects were adopted in the three updates:
    - Actual dates and percent complete were inputted.
    - The updated finish date in each of the updates was compared to the actual data from primavera and it was proved accurate.
    - The following were the results from the model for each update compared to that of primavera:
  - **Update of 26 Feb 2014**: Primavera New date: 1-July-2015 while the model new date: 6-July-2015, with a difference of 5 days, which could be justified just like the baseline schedule due to the finish to start relationship. The finish to start relationship in the model was based on that the activity will start on the following day after the preceding activity finishes. However, in primavera, some activities

follow the same logic, while others start on the same day. That is because in primavera the time unit is hour, so once the activity finishes in terms of hours, the succeeding one will start.Therefore, that small difference is neglected.

- **Update of 15 May 2014**: Primavera New date: 7-Sep-2015 while the model new date: 12- Sep-2015, with the same difference of 5 days that could be justified as done before in the baseline and the update of 26 Feb 2014.
- **Update of 19 May 2014**: Primavera New date:11-Sep-2015 while the model new date: 16- Sep- 2015, with the same difference of 5 days that could be justified as done before in the baseline and the update of 26 Feb 2014 and update of 15 May 2014.
- Therefore, the model proved its accuracy in all the previous updates with a small-justified difference of 5 days that could be neglected.
- After proving that the model could run the sequence of the activities accurately and give valid results, the rest of the sheets are run based on the same logic as will be discussed. Then, the final result is compared to the Contractor's claim and Owner's counter claim.

- **Time Impact Sheet:**
  - The researcher impacted the three updates with the event activities related to that update and the relationships are adjusted accordingly.
  - Update of 26 Feb 2014 impacted schedule: has 31 new activities
  - Update of 15 May 2014 impacted schedule: has 4 new activities
  - Update of 19 May 2014 impacted schedule: has 4 new activities
- **Owner Responsible Sheet:**
  - The following was done for the three updates:
    - No new inputs were put in this sheet except the data date, the model runs the Owner responsible delays based on the given information in the previous sheets.
    - The finish date is the date based on the owner delays only assuming the Contractor activities will run as sequence.
- **Contractor Responsible Sheet:**
  - The following was done for the three updates:

- No new inputs were put in this sheet except the data date, the model run the Contractor responsible delays based on the given information in the previous sheets.
- The finish date is the date based on the Contractor delays only assuming the Owner activities will run as sequence.

- **Analysis Sheet:**
  - Concurrent analysis is done for the 3 updates three times based on SCL protocol, ASCE, and AACE approaches
- **Final Sheet**:

The following are the final result obtained from the model for the 3 events based on the 3 approaches:

Event 1: 26 Feb 2014, Major imposed Architectural and MEP design modifications

Final Result

Your Approach for Concurrency Analysis	SCL Protocol
Baseline Project Finish Date	16-May-2015
Update Finish Date	06-Jul-2015
Time Impact Finish Date	15-Aug-2015
Total Delay	91
Concurrent Delay	There is No Concurrency
Contractor is Responsible for a Delay of	51
Owner is Responsible for a Delay of	91
Extension of time Granted to Contractor	91

Figure 71: Validation, Event 1, SCL Protocol Final Result

Final Result

Your Approach for Concurrency Analysis	ASCE	
Baseline Project Finish Date	16-May-2015	
Update Finish Date	06-Jul-2015	
Time Impact Finish Date	15-Aug-2015	
Total Delay	91	
Concurrent Delay	There is Concurrency	51
Contractor is Responsible for a Delay of	0	
Owner is Responsible for a Delay of	40	
Extension of time Granted to Contractor	91	

Figure 72: Validation, Event 1, ASCE Final Result

Final Result

Your Approach for Concurrency Analysis	AACE	
Baseline Project Finish Date	16-May-2015	
Update Finish Date	06-Jul-2015	
Time Impact Finish Date	15-Aug-2015	
Total Delay	91	
Concurrent Delay	There is Concurrency	51
Contractor is Responsible for a Delay of	0	
Owner is Responsible for a Delay of	40	
Extension of time Granted to Contractor	91	

Figure 73: Validation, Event 1, AACE Final Result

- From the previous results, it is clear that the three approaches give the same extension of time; however, the difference would be in the cost compensation and if there is proved concurrency or not.
- SCL protocol: According to the given project information, there is no proved concurrency. In addition, because the Owner responsible delays lead to a project finish date later than that due to Contractor responsible delays, the Contractor will be granted a full extension of time for the Owner delays. However, he will be compensated for the cost incurred due to owner delays only which in this case 40 days.
- It is obvious that the AACE & ASCE give the same result in terms of extension of time; however, they differ in analyzing concurrency and cost compensation as previously illustrated in literature and model development sections.
- AACE & ASCE: in this project, concurrency was proved according to the two approaches. Therefore, the Contractor will be granted extension of time due to concurrent delays and Owner responsible delays.
- According to the AACE, the Contractor will not be compensated for the concurrent delays.
- In case of the ASCE, the Contractor will be granted extension of time only except if he could separate his responsibility from the Owner's responsibility in the concurrent delays with supported evidence. In this case, apportionment could be applied.

Event 2: 15 May 2014, Major imposed Electrical design modifications

Final Result

Your Approach for Concurrency Analysis	SCL Protocol
Baseline Project Finish Date	16-May-2015
Update Finish Date	12-Sep-2015
Time Impact Finish Date	19-Sep-2015
Total Delay	126
Concurrent Delay	There is No Concurrency
Contractor is Responsible for a Delay of	79
Owner is Responsible for a Delay of	126
Extension of time Granted to Contractor	126

Figure 74: Validation, Event 2, SCL Protocol Final Result

Final Result

Your Approach for Concurrency Analysis	ASCE	
Baseline Project Finish Date	16-May-2015	
Update Finish Date	12-Sep-2015	
Time Impact Finish Date	19-Sep-2015	
Total Delay	126	
Concurrent Delay	There is Concurrency	79
Contractor is Responsible for a Delay of	0	
Owner is Responsible for a Delay of	47	
Extension of time Granted to Contractor	126	

Figure 75: Validation, Event 2, ASCE Final Result

Final Result

Your Approach for Concurrency Analysis	AACE	
Baseline Project Finish Date	16-May-2015	
Update Finish Date	12-Sep-2015	
Time Impact Finish Date	19-Sep-2015	
Total Delay	126	
Concurrent Delay	There is Concurrency	79
Contractor is Responsible for a Delay of	0	
Owner is Responsible for a Delay of	47	
Extension of time Granted to Contractor	126	

Figure 76: Validation, Event 2, AACE Final Result

- The previous results are cumulative results including Event 1 & 2 together.
- From the previous results, the SCL protocol continues to prove that there is no concurrency; however, owner delays lead to a later project finish date than the contractor delays. Therefore, the contractor will be granted a full extension of time.

- AACE & ASCE: as concurrency is proved, the Contractor will be granted extesnion of time due to concurrency and Owner delays.
- However, for cost compensation, AACE wouldn't grant the Contractor any cost compensation due to concurrent delays.
- According to ASCE, the Contractor wouldn't be compensated for the concurrent delays except if he could segregate with evidence his responsibility from the Owner's responsibility in the concurrency, then apportionment could be applied.

Event 3: 19 May 2014, Major imposed Arch design modifications

Final Result

Your Approach for Concurrency Analysis	SCL Protocol
Baseline Project Finish Date	16-May-2015
Update Finish Date	16-Sep-2015
Time Impact Finish Date	06-Oct-2015
Total Delay	143
Concurrent Delay	There is No Concurrency
Contractor is Responsible for a Delay of	79
Owner is Responsible for a Delay of	143
Extension of time Granted to Contractor	143

Figure 77: Validation, Event 3, SCL Protocol Final Result

Final Result

Your Approach for Concurrency Analysis	ASCE	
Baseline Project Finish Date	16-May-2015	
Update Finish Date	16-Sep-2015	
Time Impact Finish Date	06-Oct-2015	
Total Delay	143	
Concurrent Delay	There is Concurrency	79
Contractor is Responsible for a Delay of	0	
Owner is Responsible for a Delay of	64	
Extension of time Granted to Contractor	143	

Figure 78: Validation, Event 3, ASCE Protocol Final Result

Final Result

Your Approach for Concurrency Analysis	AACE	
Baseline Project Finish Date	16-May-2015	
Update Finish Date	16-Sep-2015	
Time Impact Finish Date	06-Oct-2015	
Total Delay	143	
Concurrent Delay	There is Concurrency	79
Contractor is Responsible for a Delay of	0	
Owner is Responsible for a Delay of	64	
Extension of time Granted to Contractor	143	

Figure 79: Validation, Event 3, AACE Protocol Final Result

- The previous results are cumulative results including Event 1, 2 & 3.
- From the previous results, the SCL protocol continues to prove that there is no concurrency; however, Owner delays lead to a later project finish date than the contractor delays. Therefore, the Contractor will be granted a full extension of time.
- AACE & ASCE: as concurrency is proved, the contractor will be granted extension of time due to concurrency and owner delays.
- However, for cost compensation, AACE wouldn't grant the Contractor any cost compensation due to concurrent delays.
- According to ASCE, the Contractor wouldn't be compensated for the concurrent delays except if he could segregate with evidence his responsibility from the Owner's responsibility in the concurrency, then apportionment could be applied.

From the previous results, the model matched the Contractor Claim that there is no proved concurrency based on the SCL protocol.

The model recommends an extension of time of 143 days, which is closer to the Contractor claim of 109 days. The model gives a larger extension of time because of the following:

- Lack of information: the exact impact of the design modifications was not available. For example, one of the modifications was related to modification of screed in 1st floor. It was not obvious if that modification will need complete removal of what is already done or partial removal. In addition, it wasn't clear to which zone that modification applied. Therefore, that modification was linked to the 1st floor general screed activity as if they will 100% affect them, which may be different from the Contractor's assumption.

- The fragnet activities (which are the new activities that are added to the schedule to represent the claim events effect) and their durations were assumed. These assumptions may be different from the Contractor Assumptions. For example, it was assumed that the modification of screed would require the following new activities; submittal of new shop drawings, approval for shop drawings and removal of any abortive work, with durations of 18 days, 15 days & 7 days respectively. The Contractor may have assumed different activities with different durations.

Therefore, in general the Contractor's claim seems to be more valid and is supported with valid proofs especially in the concurrency issue. On the other hand, the Consultant's counter claim needs reconsideration and revisions. That could be justified as follows; the Consultant rejected the first two events without impacting the schedule with them to prove that they are of minor to no effect. The Consultant as well claimed that there are concurrent activities. However, the proofs he used for supporting that claim are lacking accuracy and logic. For example, when he tried to support his claim of concurrent activities, he looked at all activities in the project and highlighted concurrency between Owner delays and Contractor delays without taking into consideration two important concepts. First, concurrency should be studied on the critical path only. Second, for delays to be considered concurrent, they have to be independent of each other. In addition, he didn't mention the standard that he used to derive these conclusions. Therefore, the researcher sees that the Consultant counter claim needs further amendments and consideration. On the other hand, the Contractor impacted the schedule with all design modifications showing that they are all affecting the critical path. In addition, for concurrency, he mentioned that there is no concurrency based on the SCL protocol and highlights that concurrency should be studied for the critical path only.

Accordingly, the proposed model will be beneficial in case of concurrency claims, as it will guide the user into the main steps that he should follow while analyzing concurrency. Moreover, it will give him the opportunity to select the concurrency approach that is best suitable for the project to give valid evidence to support his claims.

6.3 Chapter Summary:

This Chapter validated the proposed model in this research using actual project data and compared the results to the Contractor’s claim and the Consultant’s counter claim. The model output matched the Contractor’s claim that there is no proved concurrency based on the SCL Protocol. On the other hand, it recommends that the Consultant’s counter claim needs further amendments and revisions.

Chapter 7: Conclusions & Recommendations:

7.1 Conclusions

Concurrent delays are the most debatable delay type in the construction industry because there is no agreed upon definition for them. In this research, the definition for concurrent delay and its remedy is discussed in light of different perspectives. First, the different countries' Laws including the Egyptian Law, English Law and the US Law. Second, different internationally accepted protocols including SCL Protocol, AACE & ASCE. Third, different standard type of contracts including FIDIC 2017 & NEC 3. The different protocols are all compatible with the Egyptian Law. Therefore, they are incorporated in an analytical model that could help the user to select one of the them (i.e. SCL Protocol, AACE & ASCE), then the model identifies concurrency and the responsibility for each party.

The model is built using MS visual Basic because it provides wide array of functions, allows for macro recording and it is easy to be used. It also allows for building comprehensive models. The model consists of eight sheets for incremental analysis of concurrent delays. These sheets are Start, Schedule, Update Schedule, Time Impact, Owner Responsibility, Contractor Responsibility, Analysis & Final Result sheets.

The model was initially tested using different what if scenarios and proved its validity. Then, it was validated using actual project data. The model output matched the Contractor claim that there is no proved concurrency based on the SCL protocol.

The proposed model could work as a guidance to the basic steps that the user should follow while analyzing concurrency. In addition, it will identify if there is concurrency or not and will recommend the extension of time that should be granted to the Contractor.

It is recommended that the parties to the contract agree from the beginning of the project on the definition they accept for concurrency and its remuneration to reduce claims arising from differences in perceiving it.

7.2 Limitations:

The main limitations of the model proposed in this research are as follows:

- It is efficient and effective for projects for number of activities up to 500.
- When number of activities is larger than 2000, it becomes time consuming.
- It runs the schedule as calendar days, not working days. Therefore, the user should adjust his data accordingly.
- The first activity has to be the start activity and the last activity has to be the end activity.
- The user should input all activities after each other, without WBS.
- The activities are duration dependent, not resource dependent.

7.3 Recommendations for Future Research:

The proposed model could be further developed and modified by future researches by including the following points:

- Adding the cost compensation to the model and investigating if the concurrent delays could be apportioned or not.
- Allowing for importing the schedule and the updated schedule from Primavera to allocate more time for analyzing the schedule and concurrency.
- Including calendars, so the schedule could run based on the project calendar not working days.
- Highlighting if the delays were pacing delays or not.

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