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PROACTIVE CONSTRUCTION CLAIMS ANALYSIS USING BIM

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Abstract: Construction industry is permeated with claims that result from changes in quantities, quality, specifications and many other issues. One of the ways to minimize the effect of these claims is handling them in a proactive manner; this allows the project parties to foresee the potential claims and take necessary measures to avoid them. Thus, project parties will share common goals and achieve project success. This research introduces a BIM-based claims analysis and evaluation model. Firstly, different BIM protocols are demonstrated and analyzed, highlighting BIM protocol critical success factors. Secondly, different claim causes and claim analysis techniques are introduced. Thirdly, a 5D BIM model is developed to forecast potential claims and these claims are assigned to their responsible parties. Afterward, relevant claim evaluation techniques are utilized to evaluate and quantify such claims. Finally, a claim report is generated showing actual and potential claims, their causes, evaluation, and recommendations to derogate their consequences.

1 Introduction

Construction projects are getting more complex nowadays. Thus, the use Building Information Modelling (BIM) is considered crucial to minimize risks and ensuring successful project delivery. BIM simulates construction projects in a virtual environment. BIM comprises all data needed regarding design, procurement, fabrication and construction activities (Azhar, 2011). Plenty of BIM tools are available to be used for different purposes. BIM tools are classified as follow: 1) Preliminary design and feasibility tools, 2) BIM authoring tools, 3) BIM analysis tools, 4) Shop drawing and fabrication tools, 5- Construction management tools, 6) Quantity takeoff and estimating tools, 7) Scheduling tools, and 8) File sharing and collaboration tools (AGC, 2009).

BIM changes the way the project parties interact with each other, due to the concept of collaboration and knowledge sharing between project parties. Therefore, BIM changes the nature of the construction industry from a linear fractured nature to a nature of sharing common goals between project stakeholders (Greenwald, 2012). One of the barriers to adopting BIM is the legal and contractual issues associated with the model. For instance, 1) the ownership of the model, 2) creating and updating the BIM model, 3) the way of delivering information and 4) the priority of documents are contractual uncertainties associated with the BIM model (Gibbs, et al., 2013). (Kujala, et al., 2015) focused on the importance of considering the construction contract as a way that promotes integration and collaboration at the same time ensuring parties' profitability. In other words, changing the current perspective of the contracts; which are documents written for potential disputes in court. BIM dramatically decreases the probability of disputes occurrence.

Despite the exerted efforts in the standard forms of contracts to define liabilities and obligations for each contracting party, due to the complex and dynamic nature of the construction industry, many projects end up with disagreement between the parties (Abdul-Malak, et al., 2002). BIM reduces conflicts between project parties, as it provides clash detection and early identification of errors (Greenwald, 2012). However, there are many factors that may cause a delay in the construction projects such as; unforeseen events, repairs, contractors financial or managerial problems, insufficient technical skills of consultant or contractors…etc. (Birgonul, et al., 2015). A lot of research efforts have been conducted to study different causes of claims in the construction industry as summarized in Table 1. Thus, the question arises regarding the importance of BIM in supporting construction claims. It is vital to solve any conflict or claim in a proactive mode to avoid disputes (Gibbs, et al., 2013). The authors argued that no research efforts investigate how BIM can assist in construction delay claims. Therefore, the aim of this paper is to develop BIM-Proactive Claim Analysis model.

2 Literature Review

Delay can be defined as an unexpected extension to the overall project duration. Delays can be classified into excusable or non-excusable delays. Excusable delays are the delays beyond the control of the contractor. These delays are also known as employer delays. Under excusable delays, the contractors can claim for an extension of time of the contract completion date. On the other hand, non-excusable delays are the delays within the contractor's control. Under non-excusable delays, the employer can claim for liquated damages (Gibbs, et al., 2013). Currently, there are a lot of delay analysis techniques that can be adopted to accurately calculate schedule delay. The following sections discuss the most utilized delay analysis methods.

2.1 Delay Analysis Methods

2.1.1 As-Planned vs. As-Built

As planned vs. as built delay analysis method is considered the simplest method for delay analysis. The method starts with comparing activities, planned start, and actual start, from project baseline. Afterward, the delay is calculated accordingly. Advantages of this method are; simplicity, ease and low cost. However, the main limitations are the in consideration of any change in the critical path and failure to consider concurrent delay (Braimah & Ndekugri, 2008). Society of Construction Law (SCL) suggests that as planned vs. as built is a good start to evaluate a claim. However, this method is not reliable. It can be concluded that as planned vs. as built relies on common sense where the schedule updates are not required and it can be calculated only from bar chart diagram (Arditi & Pattanakitchamroon, 2006).

2.1.2 Impacted As-Planned

In this method, the delayed event is added as an activity in the baseline schedule. Then, the amount of delay is calculated as the difference between baseline completion before and after adding delaying event(s). The main advantage is that this method does not require the as-built schedule. However, it doesn't consider critical path and that's its main limitation. Moreover, it assumes that the schedule remains logic after adding delay event(s) activity (Pickavance, 2010). The main drawback of this method is considering only planned schedule to determine the delay regardless any actual duration (Arditi & Pattanakitchamroon, 2006). Impact as-planned method is the least favored delay analysis method. Moreover, many courts do not accept impacted as-planned as a delay analysis method.

2.1.3 Collapsed As-built:

Collapsed as built method starts by developing the as-built schedule including all delay event(s) activity, then the delay event activity is removed. Finally, the collapsed duration is calculating before and after removing delay activity (Zack, 2001). Collapsed as-built method is based on "what if analysis". Many courts accept this delay analysis method as it takes into consideration actual duration (Arditi & Pattanakitchamroon, 2006). Collapsed as-built can be used when there is no schedule information and the schedule updates cannot be obtained from progress reports. This method can calculate delay in limited time and money situations (Arditi & Pattanakitchamroon, 2006). The main advantage of collapsed as-built method is accuracy. On the other hand, the main limitations are ignoring changes in the critical path and exerting a lot of effort to develop an as-built schedule (Zack, 2001).

2.1.4 Window analysis:

In this method, the as-built schedule is divided into time periods, windows, and then the periods are updated regularly. The delay is calculated for each time period. Considering the critical path is the main advantage of window analysis. On the other hand, window analysis is costly, complex and needs a lot of effort (Zack, 2001).

2.1.5 Time impact analysis method

Time impact analysis method is the most reliable delay analysis method. In this method, the relation between delay event(s) and project logic in considered. The analysis starts by dividing project schedule into periods. Then, the delay events are integrated into the project schedule. This method reduces dispute between parties. This method motivates the idea of following up on the project day-by-day, besides keeping the record for the concurrent delay(s), float ownership, recovery time and acceleration. The main advantage of this method is taking both parties delay(s) into consideration (Arditi & Pattanakitchamroon, 2006). Time Impact Analysis overcomes the shortcoming of the impacted as-planned method. It is applicable where project data and schedule updates are available and well documented (Perera, et al., 2016).

2.2 Choosing Delay Analysis Method (DAM)

A lot of authors studied factors to choose a delay analysis methodology. Figure 1 depicts the different factors that are adopted for choosing delay analysis methods based on (Braimah & Ndekugri, 2008), (Arditi & Pattanakitchamroon, 2006), and (Perera, et al., 2016). The factors are divided into three groups, project documents, delay nature and project criteria. As mentioned earlier in the literature, the project conditions play a central role in choosing its delay analysis method. These factors are further utilized in the research methodology.

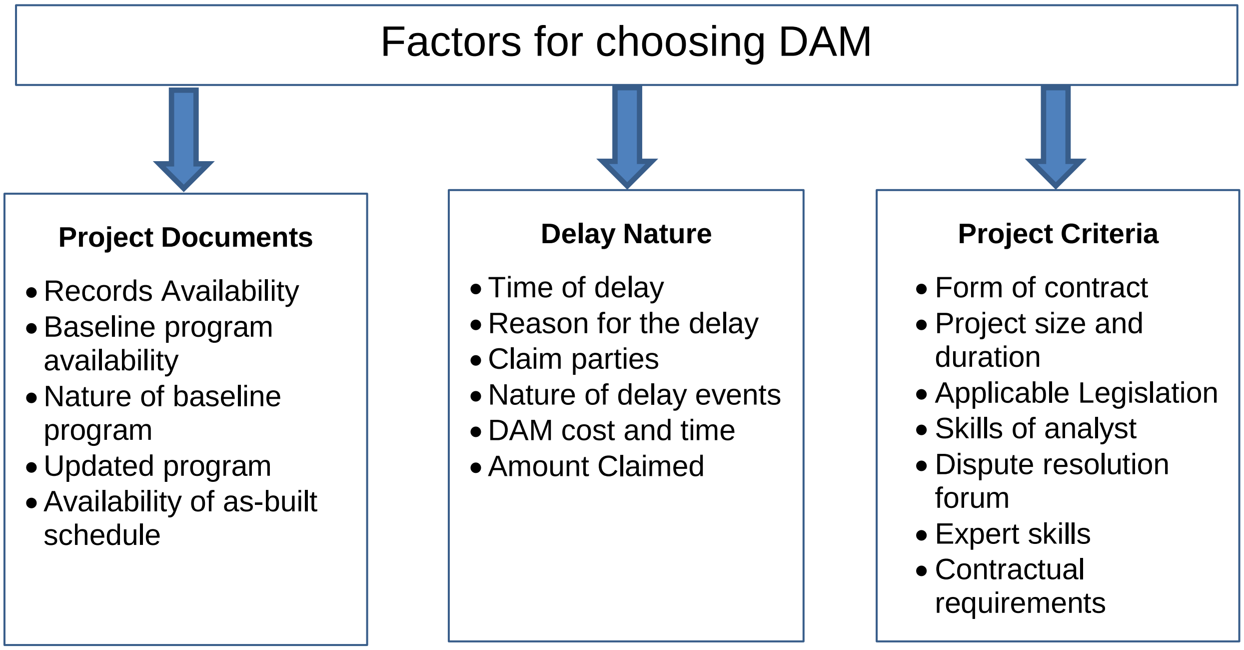

Figure 1: Factors for choosing Delay Analysis Methods

Table 1: Summary of Claims Causes

Groups	Sub-Group	Assaf et al. (1995)	Ogunlana et al. (1996)	Chan and Kumaraswamy (1997)	Odeyinka and Yusif (1997)	Noulmanee et al. (1999)	Al-Momani (2000)	Frimpong et al. (2003)	Gunduz et al., (2004)	Assaf and Hejji (2006)	Scott and Harris (2004)	Wiguna and Scott (2005)	El Razek et al. (2008)	Mahamid et al. (2012)	Kadry et al., (2016)
Cash related Problems	Financial problems	•	•	•	•			•	•	•		•	•	•	•
	Owners' lack of experience in the construction business							•		•					
	Cash flow problems	•		•	•			•	•					•	
	Delayed payments	•	•	•					•	•		•	•		•
	Wrong cost estimate							•							•
Resources problems	Insufficient resources of organizations	•				•			•	•				•	
	Equipment management problems, Shortage of equipment	•	•		•				•	•				•	•
	Shortage of manpower, labor productivity	•		•	•			•	•	•					•
	Material management problems and material procurement, Late deliveries	•	•	•	•		•	•	•	•					•
	Subcontractors	•	•						•	•					
Party incompetency	Poor technical performances Interference, inadequate contractor experience or The inadequacy of subcontractors	•	•	•		•		•	•	•					•
	Defective construction work or a defective design or		•						•	•		•			
	The problems caused by clients and consultants	•		•			•		•	•					•
	The problem of shortages or inadequacies in industry infrastructure		•						•						
	Inadequate site inspection,		•		•										
	Incomplete and unclear drawings			•		•	•			•					
Changes	Necessary variation of works, Variation in orders, Design and material changes, Design change by the client, Design changes by the owner or his agent client-initiated variations, Changes in the design and scope, an instruction is given to change the work	•	•	•	•				•	•	•	•	•		•
	An increase in quantities						•								
External factors	Unforeseen ground condition	•	•	•				•	•	•					
	Acts of nature, labor disputes and strikes	•			•				•						
	Weather conditions,	•	•	•				•	•	•		•			
	significant probability.	•							•		•				
	Site conditions						•			•					
Project Management	Low speed of decision making involving all projects team,	•	•	•	•			•	•	•					•
	Poor contractor management	•						•	•						•
	Coordination and communication problems		•	•		•		•	•	•					•
	Contract management	•							•				•		
	Award project to lowest bid price		•						•					•	
	Planning and scheduling problems	•		•	•			•	•	•					
	Poor site management and supervision	•		•					•	•				•	
	Failure to posses site										•				
	Original contract duration is too short									•					•
Social conditions	Political situation			•					•					•	
	Economic conditions						•		•						
	An increase in the prices of the material used in construction							•	•			•			
	Social and cultural factors	•	•							•					

2.3 Claims Quantification

The contractor can claim compensation for 1-loss and/or expense, 2- Immediate cost, 3-overheads and profit and 4- claim preparation fees. This section discusses each case. Firstly, loss and/or expense where the contractor has to prove out of pocket losses and loss of profit (Hughes & Murdoch, 2000). Quantification of the direct cost, material, equipment and labor, is a simple issue, as the contractors can generally prove the accused cost due to the claim event (Scott & Harris, 2004). Secondly, immediate cost where the project duration is prolonged, any extra cost occurred by a contractor shall be compensated. For instance, if material or labor cost increased due to an increase in the project duration, the contractor shall be compensated. Thirdly, overheads and profit cost where the contractor is compensated for the indirect cost for the extension of time. Indirect cost including site and office overheads is complex to quantify because overheads are not linear during the construction stage (Scott & Harris, 2004). Site overheads can be calculated based on preliminary amount break down. There is no clear method to calculate general overheads. Fourth, claim preparation fees, as there is no obligation in the contract for the contractor to prepare a claim. The claim preparation process is carried out by the contractor. However, if the engineer requested evidence which requires a lot of time and money, the contractor shall be compensated (Hughes & Murdoch, 2000).

2.4 Claiming Evaluation Procedure

Traditionally, in order to evaluate a claim, the burden of proof is the claimant duty. Although there are several delay analysis methods, there is not a universally accepted option. Choosing the delay analysis method depends on the many project factors as illustrated above. (Abdul-Malak, et al., 2002) concluded that effective claim documents should include: detailed and accurate description of the event(s), analysis of the facts and contractual grounds, detailed breakdown of EOT claimed, methods adopted to calculate EOT and detailed breakdown of extra cost including direct and indirect cost and method of calculation. Finally, supporting documents i.e. Minutes of Meetings, correspondence, drawing register, BOQ, Inspection Requests, Request for Information…etc. should be added to all the previous. (Kartam, 1999) developed a general framework for analyzing construction claims which are: 1) Gather Information i-Schedule ii- Project Documents including correspondence, 2) Data preparation; information retrieval, 3) Identify delayed activities, 4) Choose delay analysis method, and 5) Generate delay analysis Report

2.5 Shortcomings of delay analysis methods

(Birgonul, et al., 2015) identified shortcomings of current delay analysis methods. Mainly the shortcomings are float ownership, concurrent delay, resource allocation, rework, change in quantity, acceleration, productivity estimation and an introduction of new items. Total float is a critical asset, therefore, float ownership is a major dispute source, if the project suffers delay. There are a lot of opinions regarding float ownership; some scholars argue that contractor owns the float, others stated that float should be shared between parties with different percentages. Concurrent delay can be defined as "The situation in which two or more delays occur at the same time, either of which it had occurred alone, would have affected the ultimate completion date" (Birgonul, et al., 2015). Therefore, it can be concluded Time impact Analysis overcome float ownership problem and concurrent delay. However, resource allocation, rework and change in design, acceleration, productivity estimation and an introduction of new items are still an issue. Therefore, this research argues that BIM and Integrated Project Delivery (IPD) approach hugely help to overcome current delay analysis evaluation.

2.6 Claim Automation

(Yang & Kao, 2009) classified delay analysis into three main categories; 1) Process-based schedule delay analysis method (i.e. Net impact, collapsed but for, Window analysis and As-planned), 2) Mathematical delay analysis methods and 3-computer based delay analysis method (Yang & Kao, 2009). (Tsai, et al., 2013) concluded that computer delay analysis methods are the most effective due to its ability to reduce manually time-consuming tasks. Moreover, delay analysis mathematical model hugely varies depending on the assumptions. There are three main pillars to achieve effective computer delay analysis which are; automated process, rich analysis results, and simple operation procedure.

3 Research Methodology

The utilization of BIM in the research is based on two core pillars, the visualization and the availability of all required data and information on the developed model. The visualization is used to demonstrate both the project plan at the start and the updates and the classification of delayed activities as illustrated later. On the other hand, the model is acquainted with all the activities data and information, including, but not limited to, dates, durations, quantities and notices. The research framework is divided into four main stages, Pre-contract agreement stage, 5D BIM Model development stage, Progress update stage and proactive claim analysis stage. The research aims at implementing the framework starting from the pre-contract agreement stage through establishing two processes, the claims causes' responsibility matrix and the delay analysis method selection criteria. Firstly, the claims causes' responsibility matrix is based upon the literature review presented in Table 1. The causes are segmented into seven segments, clash related problems, resources problems, party incompetency, changes, external factors, project management problems and social conditions. Each group is further broken down into more sub-groups. Each sub-group is assigned a code which will be used afterwards to relate the relevant delays or events. Afterward, the project parties are listed on a horizontal upper axis, and the responsibility of each project party on the relevant claim cause is assigned. This document should be agreed upon between project parties before the contract is signed and then attached to the contract agreement. Secondly, the delay analysis method selection criteria are developed. According to the literature review in section 2.1, the factors for choosing the relevant delay analysis method can be divided into three main factors, project documents, delay nature and project criteria. Based on the breakdown of these three factors, a suitable delay analysis method is chosen for the project. Like the claims causes responsibility matrix, the delay analysis method should be settled and agreed upon before the contract is signed.

The second stage is the 5D BIM Model development stage. It consists of two processes, the 3D BIM model development and the schedule and cost integration with the 3D model. A LOD 300 BIM model is developed and integrated with the project's schedule and cost. The level of detail of both the schedule and the model should be coordinated in order to leverage the benefits of both tools. Once the model is loaded with the project schedule and cost, the developed 5D model is utilized for the next step which is the progress update stage.

The progress update stage comprises for updating both the project schedule and model according to the actual project progress. Comparing the project baseline and actual progress, the variance between the planned and actual activities dates can be concluded. Once the schedule is updated, the delayed activities are filtered and funneled to the next stage. If there are no delayed activities, then another filter is performed. The definition of delayed activities in this research is the activities which have negative variance between their baseline and updated finish dates. The next filter is for the activities with assigned claim notices or change of scope. The activities with either claim notices or change of scope are also moved to the next stage. If neither is applicable after the update, the cycle moves to the next update. The later update cycles show all the delayed activities even if they were considered earlier in order to verify the effectiveness of the implemented corrective action(s).

The last stage is the Proactive claim analysis stage, which is pivotal to the methodology of the research. Both the delayed activities and the activities with claim notices or scope change are directed to that stage but at different junctions. The delayed activities are posited in the claims causes' responsibility matrix to allocate the project party responsible for each one. Also, the delay cost impact of each activity is calculated by the project team in order to quantify the effect of such delays on the overall project. This quantification is based on the pre-contract agreement stage outputs and the contract agreement conditions. Afterward, a duration index is calculated for each of the delayed activities. The duration index is the ratio of the actual durations of the activities to their original durations. A threshold value is assigned for this index. The delayed activities are categorized according to two criteria, the duration index and the total float. Activities with duration index greater than or equal to the threshold and total float less than or equal to zero are categorized as first degree severity activities. Activities with duration index less than the threshold and total float less than or equal to zero are considered second degree severity activities. While activities with duration index greater than or equal to the threshold and total float greater than zero are assigned third degree severity. Finally, activities with duration index less than the threshold and total float greater than zero are classified as activities with a fourth degree of severity. Activities with first degree severity are considered the most critical to consider in the analysis, whereas activities with a fourth degree of severity are considered the least critical ones on the project.

Delayed activities with a duration index greater than the predefined threshold value are activities which have an unrealistic duration estimate from the project planning stage. The actual duration of these activities should be considered in the remainder of the project. On the other hand, the delayed activities with a duration index less than the threshold value are activities which exceeded the planned duration estimate due to productivity drawbacks, site conditions or any recoverable reason. These activities are dealt with during the construction stage in order to match the actual activity duration with the planned. As a result, for all the delayed activities with a duration index greater than the threshold value (i.e., activities with first and third degree of severity), a delay projection is performed. The delay projection implies that the activities' actual durations is used to replace their planned durations in the similar remaining activities of the project. This projection aids project team to foresee the impact of the activities' realistic duration on the project's overall finish date. All the delayed activities are then loaded on the 5D BIM model in order to visualize the pattern of their status' development. A unique color is used to represent each category of the delayed activities on the 5D BIM model. First degree severity activities are colored red, second degree are orange, third degree are yellow while fourth degree activities are green. The BIM visualization and analysis capabilities enable project team to interpret the delayed project areas and the areas with a potential for a delay or a claim.

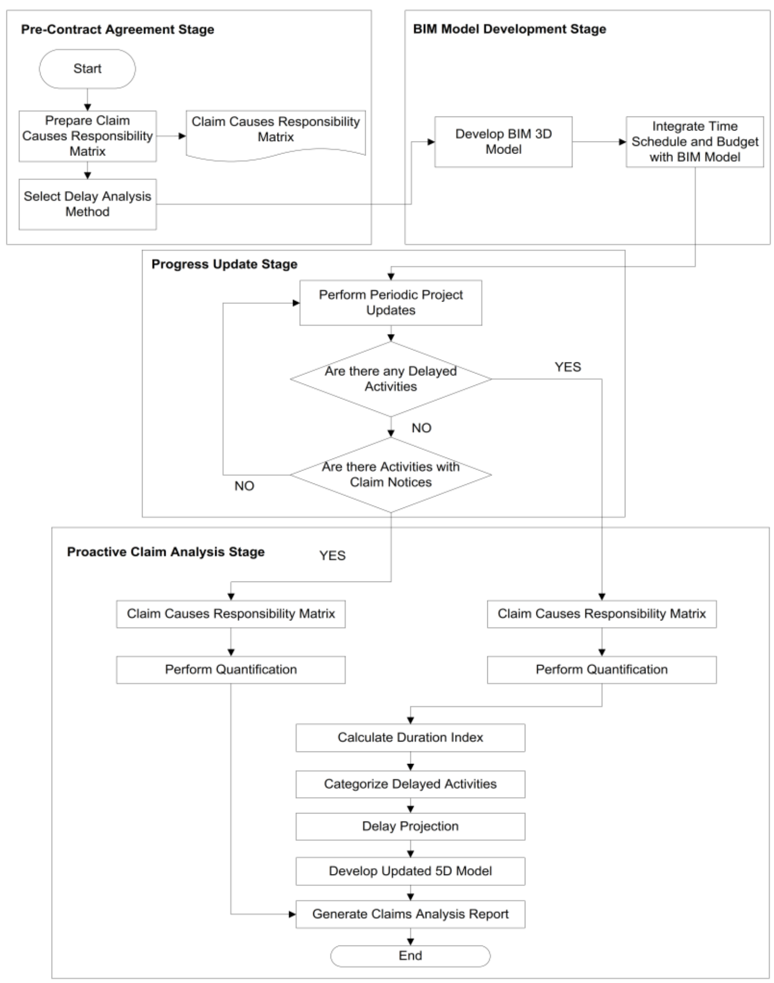

Figure 2: Flowchart of claim analysis using BIM

As for the activities with notices of claims, they are fed to the same stage but at a different point. They are allocated to the claim causes responsibility matrix and a code is assigned to each one. They are further quantified by the project team in order to forecast the impact of the applicable ones on the project's time and cost. A final report is produced after each cycle to sum up the results of the whole process. Figure 2 depicts a flowchart for the proposed methodology.

4 Case Study

To demonstrate the proposed methodology, a case study is presented. A residential compound located in Egypt is considered for this purpose. The project has a total land area of 238,000 square metres and includes 130 buildings as depicted in Figure 3. A claim causes responsibility matrix is developed for the project. Also, due to the availability of reliable project documents and periodic updates, time impact analysis method is chosen to analyze the project's delays. A BIM model of LOD 300 is then developed for the whole project with its different disciplines. The BIM model is equipped with shared parameters in order to facilitate the linkage between the BIM model and the project schedule. Afterwards, a level 3 schedule was built for the same disciplines. The construction planned start of the project was June 09, 2016 with 4 zones and last zone finish date is March 21, 2019. The schedule comprises a total of 3,210 activities. As such, the model is synchronized with the schedule accordingly through rules to map between the time schedule and the selection sets to complete the 5D model.

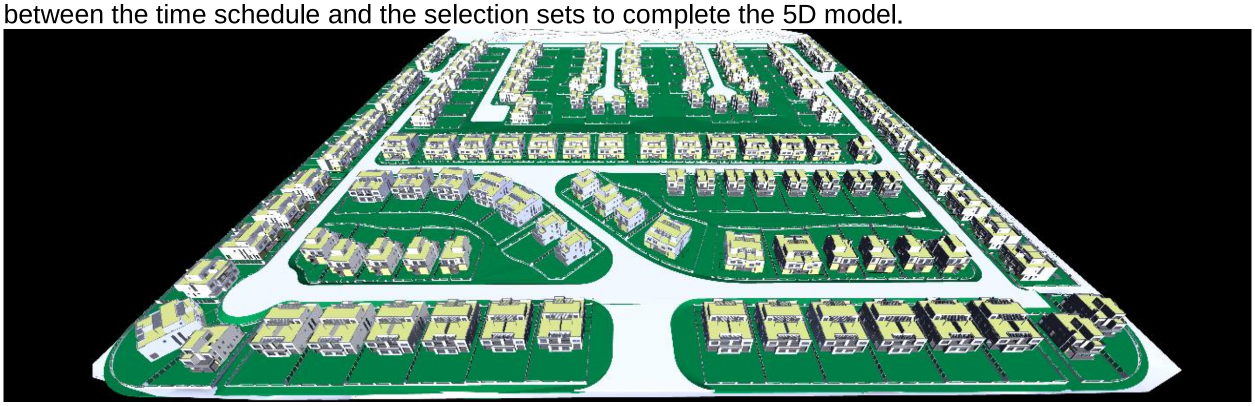

Figure 3: The Developed BIM Model

A project update is performed on the 27th of December, 2016. Delayed activities and activities with claim notices are filtered. A code of the claim cause is then assigned to them indicating their position in the matrix and their respective responsible project party(s). Afterwards, the activities go through the quantification process in order to calculate their time and cost impact on the project. For the delayed activities, an analysis is performed for the updated time schedule to deduce the severity of each delayed activity based on the criteria presented earlier. The threshold value is set to 1.5. Table 2 summarizes the results of the update. A total of 1,097 activities have negative BL Project Finish Date - Variance but 123 activities only the duration index is greater than 1. The 123 activities imply both the completed and in progress activities. Only the in-progress activities are considered in the periodic analysis, while both he completed and in progress activities are fed to the final report in order to assess the effectiveness of the previously implemented solutions.

Table 2: Updated Activities Classification

	Duration index≥1.5		1<Duration index<1.5	
	TF≤0	TF>0	TF≤0	TF>0
No. of activities (In Progress Only)	12	15	1	10
Degree of severity	1st degree	3rd degree	2nd degree	4th degree
Total (Completed and In Progress)	82		41	

The activities with the first and third degree of severity are then used to obtain a delay projection. Next, the new duration and quantification results are loaded to the 5D BIM Model to visualize the project current and status (see Fig. 4). Finally, after visualizing these results, a report is prepared to summarize the whole procedure and keep the historical data for the activities. The report includes both the delayed activities and the activities with claim notices with their respective data. Figure 5 depicts a sample of generated report.

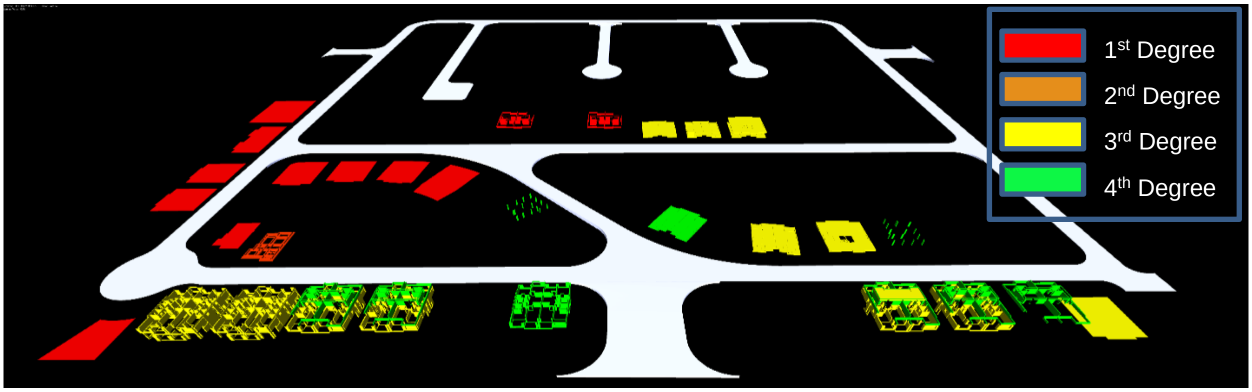

Fig. 4: 5D BIM Model with Delayed Activities Categorization

<table>
<tr><th colspan="6">Project Information</th></tr>
<tr><td>Project Name</td><td>Palm Valley</td><td>Baseline Start Date</td><td>9-Jun-16</td><td>Basline Finish Date</td><td>21-Mar-19</td></tr>
<tr><td>Project Budget</td><td>EGP 342,716,008</td><td>Adapted DAM</td><td>Time Impact Analysis</td><td>Project Percentage of Completion</td><td>23.3%</td></tr>
<tr><th colspan="6">Schedule update Results</th></tr>
<tr><td>Update Cut-off Date</td><td>27-Dec-16</td><td>Project Finish Date</td><td>20-May-19</td><td>Total Float</td><td>-59</td></tr>
<tr><th colspan="6">Report Summary</th></tr>
<tr><td rowspan="5">Number of delayed activates</td><td rowspan="5">1097</td><td>Delayed Activities Type</td><td>Delayed activity number</td><td>Projected finish date</td><td>20-Jun-19</td></tr>
<tr><td>First degree Severity</td><td>12</td><td rowspan="2">Expected delay (days)</td><td rowspan="2">60</td></tr>
<tr><td>Second degree Severity</td><td>1</td></tr>
<tr><td>Third degree Severity</td><td>15</td><td>Cost Impact</td><td>EGP 5,959,157</td></tr>
<tr><td>Fourth degree Severity</td><td>20</td><td>Cost Impact %</td><td>1.7%</td></tr>
</table>

Report Details

Activity Name	Activity Code	Cause of Delay	Delay Type (based on responsibility matrix)	Duration Index	Severity Degree	Corrective Action	Delay (days)	Cost Impact
Earthworks	A30320			8.6	1st		-45	
Earthworks	A44620			6.14	1st		-43	
Block Works of the Penthouse Floor	[illegible]			1.6	1st		-27	

Figure 5: Claim Analysis Summary Report

5 Conclusion

In order to minimize the impact of claims in construction projects, the research proposed a methodology to assist project parties in handling them in a proactive manner. This is achieved through the combination utilizing claims causes responsibility matrix and 5D BIM model in order to visualize and foresee project areas with claims or even a potential of claims. The BIM model is used in order to leverage two main advantages which are the visualization and data storage features it possesses. Finally, a report is generated that provides the analysis of each project update.

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