Recommendations on the Creation of Computer Generated Exhibits for Construction Delay Claims

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Abstract

Representing the cause and effect of construction delays is a challenging task. The use of demonstrative evidence to assist the representation of construction delay claims is likely to increase given the growth of Computer Generated Imagery (CGI) in the courts and the construction industry'sies drive towards using Building Information Modelling (BIM). This paper identifies how Computer Generated Exhibits (CGE) are currently being used as a form of demonstrative evidence to support construction delay claims through the analysis of two simulations which were created to assist the same claim. The benefits and limitations of the 2D and 4D simulations are discussed and recommendations on the creation of demonstrative evidence for construction delay claim purposes are put forward. The paper recognises the need to test the recommendations and to further investigate how BIM could be used to support delay claims. This forms part of on-going research towards an engineering doctorate.

Key words: animation, BIM, claim, computer generated exhibit, delay, demonstrative evidence, dispute, extension of time, simulation, visualisation.

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1. Introduction

Over 60% of complex construction projects encounter delay (CIOB 2008 and NAO 2001). If the cause of the delay is not an affected project team member's contractual risk, they are entitled to additional time to complete the work and/or financial compensation. In order to obtain this a claim must be submitted. Some claims are inevitable and necessary but if they cannot be resolved they can develop into a dispute (Kumaraswamy 1997).

The global average construction dispute costs US$31.7million, lasts 12.8months (EC Harris 2013) and generates indirect costs of lost productivity, stress and fatigue, loss of future work, reduced profit, and tarnished reputation (Love et al. 2010). Furthermore, skillsets outside of the construction industry are employed to resolve the dispute resulting in money migrating to other sectors which, in turn, has an overall negative effect on the whole of the construction industry.

In order to minimise the likelihood and severity of disputes, demonstrative evidence can be used to make construction delay claims clearer (Keane and Caletka 2008; ~~and~~ Conlin and Retik 1997). Computer Generated Exhibit's (CGE) are a form of demonstrative evidence and guidance on their preparation for the courtroom is discussed in the literature (Cooper 1999 and Schofield 2011). However, no research analyses how CGE are being used to support delay claims at any stage of a construction claim or dispute. To fill the knowledge gap, this paper analyses two different simulations which were developed to support the same delay claim. Identifying the benefits and limitations of each simulation, recommendations on the creation of CGE for construction delay claims are made.

2. Background

2.1. Delays

The term delay is exhaustively used in the construction industry; however, no standard form of construction contract defines the term due to the comparative nature in which it is used (Pickavance 2010). In this paper, the term delay refers to the non-completion of works by a date agreed in the construction contract (Fenwick Elliott 2012). Therefore, the process of analysing delays can be viewed as the forensic investigation into an issue which has caused a project to overrun on time (Farrow 2001). This is distinctly different from disruption, a term generally conjoined with delay, which investigates loss of efficiency due to a disturbance, hindrance or interruption to a contractors working method (SCL 2002). The topic of disruption is not covered in this paper but both can become intertwined and result in construction claims.

Subject to the claiming party, different forms of compensation are available depending on how the delay is categorised (Trauner et al. 2009). On the one hand, the client can claim unliquidated or liquidated damages which protect their investment if the project is not completed by the contract completion date. On the other hand, the contractor can claim an extension of time and/or loss and expense if the project is delayed for reasons beyond their control. In order for the affected party to receive compensation, a claim must be submitted which demonstrates causation, liability and quantum (Williams et al. 2003). The burden of proof is placed with the claimant to prove each of these by showing on the balance of probabilities (Haidar and Barnes 2011) but this can prove challenging.

Construction programmes are the most common way to represent the cause and effect of delays and there are a variety of methodologies available to do this. The choice of methodology will be influenced by a variety of factors (Braimah and Ndekugri 2008) but its selection should be the one which best represents the claim given the resources available (Bubshait and Cunningham 1998).

This has led to the development of numerous methodologies which can yield different results, even if the same methodology is used (Keane, 2008). To add further complexity to the issue, there is inconsistency in the naming of the methodologies (AACE, 2011) but it is argued that Tthe most reliable thorough of these methodologies is titled the time impact analysis. The time impact analysis which can be used for prospective or retrospective analysis by analysing the effect of the delay on successive tasks based on the work achieved up to the point of the delay; however, (SCL 2002). this method of analysis is time consuming, costly and requires a certain standard of project records (SCL 2002). A variation of the time impact Under this analysis is the window analysis which uses a system of 'windows', usually weeks or months, can be used whichto breaks the construction period into sections , usually weeks or months(Arditi and Pattanakitchamroon 2006), and delay events are successively inserted and analysed for each window. Under this method, the delay analysis is undertaken in the window and the revised schedule is used as the baseline for the subsequent window (Hegazy and Zhang 2005). The reasons for the deviations from the dates in each window are then established (Whatley 2014).

(Arditi and Pattanakitchamroon 2006). The baseline for the next window is the impacted programme which has been generated from the previous window (Hegazy and Zhang 2005). However, despite its merits, this method of analysis is time consuming, costly and requires a certain standard of project records (SCL 2002).

2.2. Challenge for delay analysts - representation

Case-law stresses the need to *"show that the claiming party was actually delayed by the factors of which it complains"*[i] and leans towards the use of construction programmes, particularly the use of the critical path method[ii], to demonstrate this.At present, delay claims are paper intense, comprising of complex construction programmes and supporting to understand (Kumaraswamy and Yogeswaran 2003). This is emphasised in the UK legal system by Judge Humphrey Lloyd QC in Balfour Beatty Construction v. Lambeth London information to answer the questions he sought regarding a delay claim:.

"This letter shows that the adjudicator was unable to make use (and, possibly, sense) of the material submitted on behalf of BB which included BB's "as-built" programme and analysis." [iii]

Furthermore, case-law states that delay analysts must follow an objective approach and support their findings with factual evidence[iv]. This can result in a claim becoming document intense which can prove challenging to understand in a limited time period. This is particularly true for individuals who were not involved in the project or who have limited practical construction experience, especially when it comes to Furthermore, deciphering supporting information to allow for an informed judgement to be made can prove a challenging task, especially interpreting technical construction drawings (Dziurawiec and Deregowski 1986). This is apparent in Hunte v. E Bottomley & Sons where Lady Justice Arden states:

"Those who prepare bundles or skeleton arguments would do well to remember that a plan, map, diagram or photograph which is clear to people who are fully familiar with the case may well not be wholly clear to a judge coming to the case for the first time." [v]

In an attempt to combat these problems, the legal system is moving towards the use of technology to assist with the presentation of evidence.

2.3. Visual aids

Since the 1980s the entertainment industry has developed Computer Generated Imagery (CGI) for the internet, television, computer/video games and film. Its continual application has led to higher quality outputs and the availability of 'off-the-shelf' software (Parent 2012).

Within the construction industry CGI is predominantly used in architectural design but it can be used to assist understanding and communication between interdisciplinary groups (Bouchlaghem et al. 2005). This benefit has been realised in legal proceedings and the use of CGE is rising as courts are becoming increasingly technologically sophisticated (Narayanan and Hibbin 2001).

CGI produces visualisations which represent information at a point in time and are used to enhance understanding (Card 1999). Advancing visualisations through time generates a simulation which is classified as an animation if the user is unable to interact with it (Macal 2001). These forms of CGI can be used as CGE under the rubric of demonstrative evidence which has the overall aim of aiding understanding and clarifying facts for the judge and jury (Norris and Reeves 2012). CGE can be used for a variety of purposes and its value as evidence will vary depending on the supporting documentation and how it is employed (Schofield et al. 2005). This ~~and c~~can be classified with increasing probative value as introductory, illustrative or evidential evidence (Burr and Pickavance 2010).

Cases such as the State of Connecticut v. Alfred Swinton have used CGE and established the following authenticity requirements:

1. *The computer equipment is accepted ~~and~~ in the field as standard and competent and was in good working order,*
2. *Qualified computer operators were employed,*
3. *Proper procedures were followed in connection with the input and output of information,*
4. *A reliable software program was utilized,*
5. *The equipment was programmed and operated correctly, and*
6. *The exhibit is properly identified as the output in question.*[vi]

The value of visualisations and animations have been investigated to assist the representation of disruption claims in the construction industry and found the use of a side by side comparison of as-planned v. as-built progress beneficial (Pickavance 2007). However, little research has been published on the use of CGE for delay claims. Acknowledgement has been given to the associated benefits of CGE in assisting the mitigation, representation and understanding of delay claims (Conlin and Retik 1997; Keane and Caletka 2008), but this does not identify how CGE has been practically used and how it could be applied for delay claim purposes. This could be attributed to the limitedUnfortunately, CGE is rarely used in construction delay claims as the technology associated with delay claims them lags behind that of other stages of the construction lifecycle (Vidogah and Ndekugri 1998), or because organisations do not want to publicise their competitive advantage. Furthermore, the dissemination of information is limited from a legal standpoint because CGE might only be used in some adjudications and arbitrations (Pickavance 2010) where the decision or award is rarely/if ever reported.

. However, visualisations and animations have been investigated to represent the cause and construction project. This can be attributed to the growth of Building Information Modelling (BIM);, a process of working which the UK government has mandated a minimum level of use on all public sector construction projects by 2016. BIM is seen as a way of tackling the inefficiencies present in the industry through the process of recording and sharing all of a project's information throughout its lifecycle in electronic formatone, central, electronic, location (Cabinet Office 2011). This information is generated from, or is linked to, a 3D virtual representation of the project which is produced using object based parametric modelling software. This software advances from 'traditional' CAD based lines and places objects with rules and parameters which determine both geometric and non-geometric properties and features (Eastman et al. 2011). The relationships and constraints between objects ensure realistic connections between elements and when designed in a single source modelthrough synchronisation, a change to an object in one view will automatically update all other views and linked information. The benefits of synchronised information can be expanded to multiple dimensions which ~~Through the synchronised information, multiple dimensions become available. These~~ include 4D (time), 5D (cost) and 6D (FM) (RIBA 2012). ~~where a~~If synchronised correctly, a change in any one of these views or dimension will instantly change all of the linked information ~~dimensions, views~~ for all other dimensions and will, therefore, report the most up-to-date information on the project. This ~~could~~ could also be used retrospectively to assist the representation of delay claims (Gibbs et al. 2013) ~~and the potential addition of new legal documents on BIM projects~~ and could advance the construction dispute resolution system through the addition of new legal documents (Greenwald 2013).

3. Method

This research collects primary data through a case study. Case studies are a recognised research methodology which explore complex problems in the context of their real-world environment (Yin 2013). Previous research has utilised case studies to demonstrate the application of CGE as supporting evidence (Schofield 2011; Pickavance 2007) and this paper maintains that case studies are a suitable research methodology for the subject area.

Although ~~In order to analyse the use of CGE in construction delay claims, primary data was collected through a case study. The use of a case study as a viable research methodology for construction claims is enhanced through Pickavance's (2007) research. Although~~ the level of detail included in this paper has been limited to preserve the claims anonymity, the lessons learnt can offer a "force of example" and may be transferable~~able~~ to other construction ~~delay~~ claims (Flyvberg 2006).

3.1. Background to the case

Claim consultants were approached in 2010 by a sub-contractor (from here on known as the client) requesting expert delay analysis support on a construction project in the United Kingdom. The works, valued at several million pounds, included the design and construction of a reinforced concrete frame, internal stair cases and the provision for tower cranes including the construction of the tower crane bases.

After investigation by delay analysts, critical delays were found in areas 'A' and 'B' for periods EOT1 and EOT2. The chosen delay analysis methodology was time impact analysis, which broke the total project duration into one month windows. This identified protective scaffolding and edge protection restrictions, which were the responsibility of others, as prominent delaying activities through stop-start relationships restricting the continuity of successive activities. Although not a complex site, the numerous on-going parallel tasks made it difficult to understand the cause and effect of these delay events. In an attempt to provide clarity on ~~this~~the claim, CGE was explored as a method of enhancing understanding.

3.2. 2D simulation

A prototype 2D simulation of area 'A' was created by a delay analyst using Microsoft Excel to determine whether simulations could offer additional clarity to the claim (Figure 1). The Excel simulation compares as-planned v. as-built progress side by side for the North, South, East and West faces of the building. Each floor comprises of the key sequencing activities which include: deck installed, scaffolding, edge protection, freedom to complete floor and floor complete. Individual colours were applied to each activity for each level of the building but, this has been adjusted to hatching for clarity in this publication. The progress of the works was automated by linking the visualisation to a bespoke Microsoft Excel construction programme.

The client saw a benefit~~s associated of~~with the simulation ~~were clear to the client who~~and subsequently halted the development of the 2D simulation. As the claim consultants did not have expert skills in virtual modelling, an external organisation was employed to create a simulation to support the claim. Under the client's request, communication was not allowed between the claim consultants and the virtual modelling organisation.

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3.3. 4D simulation

A 4D simulation of the client's work was created by a virtual modelling organisation using Synchro software. An open viewer of the software was made available which allowed the simulation to be viewed and analysed but no alterations could be made.

The simulation incorporated all of the client's work and colour coded the concrete superstructure levels (Figure 2). The visualisation was linked to an as-planned programme within the software to create the~~a~~ fourth dimension, time. Under the 4D simulation, ~~the~~

delayed elements were highlighted in red, returning to the floor level colour once the ~~delay~~ was installed. Due to the client's budget, the 4D simulation was not developed any further than the first revision.

~~5.1.~~4.1. 2D simulation

~~5.1.1.~~4.1.1. Benefits

The 2D simulation provides an easy to understand representation of delays. The simulation colour codes five elements of sequencing works which make it clear to understand what is in delay and ~~its~~ the ~~e~~effect on the rest of the project. The simulation shows as-planned v. as-built progress side by side, as recommended by Pickavance (2007), for all faces of the project which ~~. Seeing all faces of the project~~ simplifies the understanding of how the works progressed in an area and the impact of delay. In order to assist the understanding of the as-planned and as-built progress, the simulation can be paused, or a specific date selected, to represent provide a visual image comparison of planned and actualof progress at a point in

5.1.2.4.1.2. Limitations

Some of the limitations associated with the 2D simulation could have been tackled if the simulation had been continually developed; others are inherent in the software.

If additional time and resources were available to develop the 2D simulation, it could have included additional activities involved in constructing the project. In its current state, the 2D simulation demonstrates the sequencing of works to complete each horizontal level, it does not take into account the erection of columns or striking of formwork. Although simple to demonstrate in the software, the records available from the client did not allow for its incorporation at the time it was produced.

Limitations in the software exist as it could not be linked to a construction programme with recognises logic, a recognised tool for successful delay claim resolution. D. A duplication of effort was, therefore, is required to ensure the creation of an accurate construction which coordinated with Microsoft Excel the software recognises.

A further limitation is that the simulation is not eye-catching or to scale. The simulation does not represent the site layout or space available between areas, which may give a misconception of the amount of work undertaken and incomplete. If the site has not been visited by the viewer, it would not assist with understanding the size and layout of the works which is identified as a challenge for some individuals.. Furthermore, the simulation only shows four sides of one building and not the whole project. Although this may be suitable for a single tower block, if all buildings on the particular projectmultiple buildings were included in one view, it would may become difficult to understand.

~~5.1.3.~~4.1.3. **Possible improvements**

~~As t~~The 2D simulation was developed in a Microsoft Office software ~~packag~~package which makes ~~e,~~ it ~~is~~ extremely interoperable. The simulation does not utilise this and the possibility exists to add annotations and link documents, such as the narrative, delay programme or photographs, to the ~~visualisation~~ simulation to provide ~~clarity and supportive~~ evidence and clarity on the key requirements of causation, liability and quantum.

While the 2D simulation ~~simply represents~~provides clarity on the construction delays, its visual impact is limited through the software capabilities. Therefore~~, another piece of~~ additional software could be used to make it more visually appealing.

~~5.2.~~4.2. 4D simulation

~~5.2.1.~~4.2.1. **Benefits**

The 4D simulation provides an accurate, detailed, virtual representation of the construction works which were undertaken by the client. This allows the viewer to clearly understand the construction site without ever having to visit. With the ability to pan around the simulation it is possible to assess a specific building or element from any desired angle. When linked to the construction programme, it allows the viewer to see the construction of the building virtually, without having to understand the construction programme in detail. Thus, it helps overcome some of the challenges delay analysts face.

~~5.2.2.~~4.2.2. **Limitations**

Despite the benefits realised in the 4D simulation, it was not useful in ‘showing’ the cause and effect relationship of the delay event, a key requirement identified in the case-law.

~~conveying the cause and effect relationship of the delay event.~~

Given the ~~software~~ restrictions of the software, annotations, links and photographs ~~could~~ included to assist with understanding. Despite the ability to pan around the simulation, the single view of the project did not show the effect of scaffolding restrictions ~~to be seen at one~~ building. Furthermore, the simulation only represented the finished floor and column elements, it did not break down the sequencing of delay events or include any resources, such as scaffolding. These are features supported by the software which would ha~~d~~ve ~~these these capabilities and it would have~~ assisted understanding the cause and effect of delays.

~~5.2.3.~~4.2.3. Possible improvements

The limitations of the 4D simulation could have been mitigated if direct contact was allowed between the claim consultants and the virtual modelling organisation. The reason why communication was ~~not allowed~~restricted is unknown but it is ~~expected~~ assumed to be due to confidentiality reasons given the sensitive nature of the case. It is thought that the individuals creating the simulation had no experience of delay analysis. If direct communication was allowed, the two teams would have been able to assist each other and this may have solved the ~~main~~ problem of not having as-planned v. as-built progress side by side. This function is not ~~included~~ available in all software packages; however, the software used in this particular case ~~is~~ does have this function~~capable~~. Additionally, the software could have been used to generate multiple angles or snapshots of the project for an exact moment in time. This would allow the impact of the delay to be represented for the whole project at ~~one~~ a point in time.

The 4D simulation could be further enhanced ~~through~~ by attaching or linking information ~~which relate to the delay report~~as the required supporting evidence for the claim. If this is not an available feature in the software, additional software could be employed, such as a voice recorded description of the analysis which plays over the simulation ~~would have been of benefit~~.

~~6.~~5. Recommendations

~~6.1.~~5.1. Cost benefit analysis

~~Firstly, a~~A cost benefit analysis should be undertaken to determine whether CGE will add value to the claim, if not, it should not be created. If CGE is deemed beneficial, the added value should be determined and an appropriate budget set to avoid excessive and disproportionate legal costs which are common in civil litigation (Jackson 2010). The budget should take into account the level of detail required for the CGE to support the claim and should allow for the exhibit to be refined through multiple revisions.

Ideally, ~~the~~ a claim should be resolved at the earliest opportunity to stop it escalating (Keane and Caletka 2008). Therefore, CGE could be employed at the initial claim in an attempt to reduce the likelihood of it developing. This may, therefore, require a CGE of lower probative value.

With more projects likely to have virtual models created due to the increasing uptake of BIM, it should become cheaper and easier to refine the models which were developed to manage the project to support a construction claim.

~~6.2.~~5.2. Determine what's necessary

The purpose of CGE is to assist the understanding of complex material; therefore, the exhibit should reflect what is being discussed in its simplest and clearest form.

~~6.2.1.~~5.2.1. Software and expertise

It is easy to buy into specialist software to produce CGE; however, this will create additional costs, require training and could add little, or no, value to the claim. ~~Therefore, k~~Knowing the ~~strengths and limitations~~capabilities of readily available software, such a Microsoft Excel, and the skills of the in-house team can be beneficial when creating a CGE for a construction claim.

~~6.2.2.~~5.2.2. Simple can be effective

Regardless of the software employed, the CGE must have impact and engage the viewer; however, it is important that it does not distract from critical information (Cooper 1999).

To effectively convey the findings of the delay analysis, only the information relevant to the claim should be included in the exhibit and that of significant importance should be emphasised without appearing patronising. If CGE is used, it is advised to not exceed 20minutes in duration and could be broken up by ‘energy shifts’, such as oral discussion to retain the viewer’s attention (Boyle 2008). Specific delay events or each window of analysis could be represented to keep within the duration.

Given the difficulty of representing the whole of the construction site in one view, the cause and effect for specific areas of the site could be simulated. This could be represented as multiple views on one screen or divided into individual simulations with a concluding simulation to show their collective impact. This could also be used break up the duration of the CGE.

What is to be represented and how it is to be used will determine the level of detail to be included in the exhibit. Schematics may be adequate to introduce the construction site; however, detailed technical visualisations may be required as evidential evidence to demonstrate design changes. Key resources used in events which cause delay should be displayed but unnecessary detail should be avoided as it can incur unnecessary costs and may distract the viewer.

Colours are an effective way of conveying meaning if used correctly but overuse can become distracting. The same applies to the incorporation of additional information to a simulation, such as voiceover, photographs, annotations and links. Although these may provide clarity, too much may become distracting, confusing and lose impact.

~~6.3.~~5.3. Side by side comparison with timeline

If CGE is used to support construction delay claims, a side by side comparison of as-planned and as-built progress is highly recommended. This direct visual comparison will generate impact and provide clarity on the effect of delay events.

If a simulation or animation is used, the construction programme driving it should be displayed to relate the construction to a point in time. The construction programme should be factual, visually appealing, easy to follow and readable (Keane and Caletka 2008). The delay analysis programme may be too complex; therefore, a simplified timeline may need to be created.

~~6.4.~~5.4. Communication

To effectively use CGE to represent the delay analysis, communication between the delay analysts and the virtual modelling organisation is recommended. It is unfair to expect a virtual modelling organisation to understand a complex delay claim and accurately demonstrate it in a virtual environment with no support from a delay analyst. Neither is it fair to expect a delay analyst to be able to virtually model a construction site. Ideally, a role would be created for an individual who has an appreciation of both disciplines and can advise on the above points. If this is not feasible, a constant clear line of communication between both teams is essential.

Information which may not traditionally be requested by delay analysts, such as technical drawings, may be required to develop the CGE. It is recommended that this information is requested early on to assist with the development of the CGE; however, it is acknowledged that obtaining relevant information is a separate challenge for delay analysts (Gibbs et al. 2013).

7.6. Conclusion and future work

If used correctly, CGE can assist with the representation of construction delay claims. The use of CGE is likely to rise given the construction industry'sies move towards BIM and the increasing use of technology in the courts. However, it is evident from the case study that whilst some aspects of CGE are used effectively, as a whole it was not successful in assisting with the delay claim.

The recommendations are not exhaustive and whilst some may be apparent, the case study demonstrates that they were not employed and may have not been acknowledged during the creation of the CGE. The limitations identified in the two exhibits may be due to the limited published research in the area and/or the organisations' limited practical experience of applying CGE to a construction delay claim. Therefore, if the recommendations are utilised it is hoped that they will improve the future creation of CGE to support construction delay claims.

Further research is required to test the recommendations and understand how they could be transferred to assist the use of CGE on other types of construction claims. This, along with the potential of utilising BIM to assist with construction delay claims, is being investigated as part of an Engineering Doctorate (EngD).

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[ii] Alstom Ltd v. Yokogawa Australia Pty & another (No.7) [2012] SASC 49

[iii] Balfour Beatty Construction v. Lambeth London Borough Council [2002] EWHC 597.

[iv] Walter Lilly & Company Ltd v. Mackay & Anor [2012] EWHC 1773

[v] Hunte v. E Bottomley & Sons [2007] EWCA Civ 1168.

[vi] State of Connecticut v. Alfred Swinton [2004] (SC 16548).