

Interactive Exhibit to Assist with Understanding Project Delays

David-John Gibbs¹; Wayne Lord²; Stephen Emmitt³; and Kirti Ruikar⁴

Abstract: Time, a dynamic concept, can be difficult to understand in static form. As a consequence, the proactive management and retrospective analysis of delays on construction projects can prove challenging using conventional methods. This can result in time overruns and the rejection of valid delay claims that can develop into dispute if they are not resolved. Disputes have a negative effect on the construction industry, but their occurrence, value, and duration are rising. This research aims to reduce the likelihood and severity of common delay disputes by providing a solution that aims to (1) assist with the proactive management of delays; and (2) improve the presentation of delay claim information. A detailed background study was undertaken that identified technological opportunities and modes of presentation as potential ways of overcoming the challenges associated with managing and analyzing delays. Two stages of assessment were then undertaken to determine the suitability and application of these findings. The first stage used a workshop with 50 construction adjudicators to determine the appropriateness of modes of presentation in assisting construction claims. The second stage developed the workshop findings with previous research and integrated modes of presentation with delay analysis. The output was an interactive exhibit that was assessed through a simulation based on case study data. The interactive exhibit is intended to support, not replace, traditional methods of delay analysis; however, the solution has difficulties with technology as well as the challenge of creating a holistic tool for both proactive management and retrospective analysis. It is perceived that the interactive exhibit will add most value to the resolution of construction delay claims, but that further investigation is required to validate the proposed concept before it is used in practice. DOI: 10.1061/(ASCE)LA.1943-4170.0000198. This work is made available under the terms of the Creative Commons Attribution 4.0 International license, <http://creativecommons.org/licenses/by/4.0/>.

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Introduction

More than 60% of complex construction projects are not delivered by their due date (CIOB 2008), and this can lead to cost overruns, benefit shortfalls (Flyvberg 2014), and disputes. Disputes occur after a claim is rejected and generate direct and indirect costs for the parties involved (Love et al. 2010). Despite the negative consequences, the number of disputes in the construction industry is expected to rise (NBS 2015), and two of the common causes include (Arcadis 2015)

- Failure to make interim awards on extensions of time and compensation; and

- Poorly drafted or incomplete and unsubstantiated claims.

This research aims to reduce the likelihood and severity of disputes by providing a holistic solution to their common causes. This includes

- Assisting with the proactive management of delays so appropriate control action can be taken and interim awards of time extensions of can be granted; and
- Improving the presentation of delay claims so they are better understood and can be settled before external support is required.

To provide context for the research, a detailed study into delays was undertaken. The study identified the challenges of understanding delays and how technological opportunities and modes of presentation can assist the current legal environment. Because a link between modes of presentation and delay analysis is not present in the literature, two stages of assessment were undertaken to determine the suitability and application of the proposed concept. The first stage determined the appropriateness of using different modes of presentation on construction claims by collecting data from a workshop with 50 industry experts. The second stage developed the findings of the workshop and previous research (Gibbs et al. 2014) to produce a concept that integrates modes of presentation with delay analysis. The output is an interactive exhibit that is assessed through a simulation using case study data. The research findings show that modes of presentation can be integrated with delay analysis and that an interactive exhibit can assist with understanding delay. The proposed concept is intended to support, not replace, traditional methods of delay analysis, and it is recommended that additional stages of assessment be undertaken before the concept is used in practice.

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Background

Managing Time and Analyzing Delay

The term *delay* can be defined as the noncompletion of works by a date agreed in the construction contract (Fenwick Elliott 2012). A delay event can occur for a wide range of reasons (Ramanathan et al. 2012) and can affect project progress or project completion (SCL 2002). A construction program, also referred to as a construction schedule, can be used to manage time on a project and should consider contractual compliance, logic, duration, development, and components (Moosavi and Moselhi 2014). It is recommended that the construction program be produced according to the critical path method (CIOB 2011), which uses activity durations and logical relationships to mathematically calculate the shortest possible time to complete a project (Kelley 1961). Activities that are delayed on the critical path extend project duration, and there may be parallel, or near critical, paths on a project. Therefore, because of the amount of change a project will encounter, it is likely that the critical activities will alter as the project progresses (Whatley 2014).

Good project management recommends that the construction program be continually updated and revised as more accurate and detailed information becomes available, which includes impacting change events into the program (CIOB 2011). Delay can still occur if this good practice is followed, but the proactive approach should allow the effect of change to be realized close to when the event arose. Therefore, appropriate control action can be taken or prospective claims can be submitted based on the findings of the analysis. However, many projects do not follow this good practice, and the processes and tools they adopt for proactive management may not produce the information required for retrospective analysis (Scott 1990). As a consequence, if the effect of a change event is not analyzed contemporaneously, a retrospective delay analysis may be required.

A delay analysis forensically investigates the issues that have caused a project to run late (Farrow 2001). There is no single way to prove delays, so there is no standard way of undertaking a delay analysis (Tieder 2009). This has led to the development of numerous methodologies that can yield different results, even if the same methodology is used (Brimmah 2013).

The legal system leans toward the use of construction programs, particularly the use of the critical path method, for delay analysis (Bayraktar et al. 2012). A plethora of titles exist for types of delay analysis (AACE 2011), and there is no preferred type; however, some recognized analysis methods can be categorized (SCL 2015):

- As-planned versus as-built;
- Impacted as-planned;
- Collapsed as-built;
- Longest path analysis; and
- Time impact analysis.

The benefits and limitations of these methodologies are discussed in the literature (Arditi and Pattanakitchamroon 2006), but the chosen methodology will be influenced by a variety of factors, most notably the factual material available (Brimmah and Ndekugri 2008). Not all of the methods are recognized as appropriate for both proactive management and retrospective analysis, so adjustments for delay type scrutiny, excusable delays, and treatment of concurrent delays may need to be made depending on whether the method is classified as rough, simple, or sophisticated (Ng et al. 2004). This classification can influence how delay is communicated.

The time impact analysis is identified as a sophisticated methodology that can be used for both proactive management and

retrospective analysis of delay (CIOB 2011). This methodology involves the following activities (SCL 2002):

- Bringing the program up to date before the delay event occurs and correcting incorrect logic and durations;
- Modifying the program to reflect achievable plans and any recovery action to be taken;
- Impacting the delay event into the program; and
- Reviewing the impact of the delay event on the project completion date.

The time impact analysis is best applied prospectively, but it can also be used for retrospective analysis. However, this methodology is not without its shortcomings, and it is recommended that the findings be compared with as-built information to ensure the integrity of the analysis (Whatley 2014).

To make complex analyses easier to understand, *windows* (sometimes called *time slices*) can be applied to any delay analysis method. This involves dividing the program into logical segments and analyzing the impact of delay in each segment (Pickavance 2010). However, even if this approach is used, the claim may still not be understood or agreed on; thus, it can be rejected and potentially develop into a dispute.

Claims and Disputes

The number of disputes in the construction industry are expected to rise (NBS 2015), and the global average construction dispute costs US\$51.1 million, lasts 13.2 months (Arcadis 2015), and generates indirect costs of lost productivity, stress and fatigue, loss of future work, reduced profit, and tarnished reputation (Love et al. 2010). A dispute occurs when a claim cannot be resolved; however, because change is inevitable on any project, some claims are an inherent and necessary part of construction (Kumaraswamy 1997). Therefore, claims should not be judged emotively or as an indication of project failure (CRC 2007). Instead, they should be addressed appropriately to avoid the potential of dispute.

Claim Requirements

A claim is intended to return the party affected by a change to the position they would have been in if the change had not occurred (*Robinson v. Harman*). Unless designated in the contract, a claim is required to be proven to receive damages, and the burden of proof lies with the party making the assertion. A claim should prove breach, causality, responsibility, and quantum (Williams et al. 2003) that is not too remote (*Hadley v. Baxendale*), and be presented in its clearest form (*National Museums and Galleries on Merseyside Board of Trustees v. AEW Architects and Designers Ltd.*). It will be judged on the balance of probabilities, which is that an event is more likely than not to have occurred, and can be swayed by the standard of evidence provided (Haidar and Barnes 2011). This will depend on the available facts and how they are presented (Gibbs et al. 2013), with preference given to neutral, contemporaneous records (Kangari 1995). The recoverable damages will be subject to remoteness and how the delay is categorized, which is dependent on the contract and the claiming party (Fig. 1).

Delay Claim Challenges

Previous research identified two challenges associated with analyzing delay: the retrieval of information to perform the analysis and the communication of the findings (Gibbs et al. 2013). Attempts to address the retrieval of delay claim information are presented in the literature (Alkass et al. 1995), and developments in electronic document management systems should, in some way, assist with addressing this challenge. However, little research is published that investigates how to improve communication and understanding of

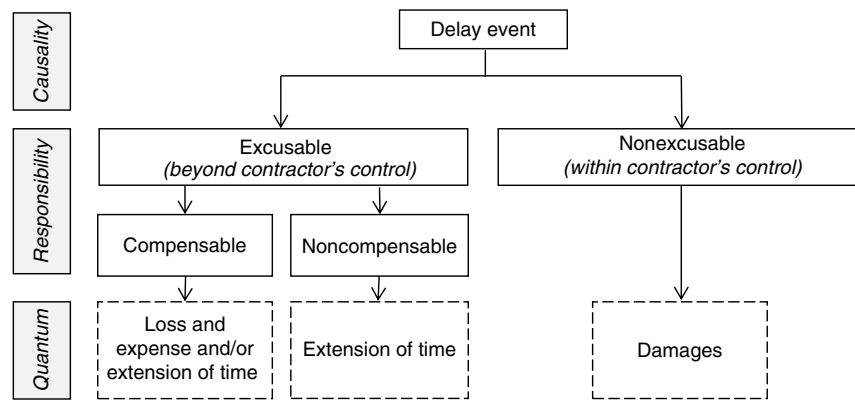


Fig. 1. Generalized interpretation of the categories of delay (adapted from Trauner et al. 2009)

the cause and effect of delay to support proactive decision making and retrospective analysis.

Although it may be simple for a claim to originate, communicating and agreement on the effect of change on a project can be difficult. This is because a change to a single item has a *ripple effect* on other, often complex and interrelated work activities (CIRIA 2001). Therefore, the sum of individual changes does not necessarily equal the overall change to a project (Williams et al. 1995).

Conventionally, construction delay claims are paper-intensive and consist of a claim report narrative, construction programs, and supporting evidence. However, these modes of communication are not always appropriate because time, a dynamic concept, can be difficult to understand in a static format (*Balfour Beatty Construction v. Lambeth London Borough Council*). In the current process, users must conceptually associate two-dimensional (2D) drawings with the related project tasks to form an image of what occurred on the project (Koo and Fischer 2000). Interpreting 2D technical drawings can be challenging (Girbacia 2012), especially for individuals with limited practical experience of the project (*Hunte v. E Bottomley & Sons*), and this can make judging the effect of change events difficult. Therefore, although it may be clear that damage has been suffered as a result of delay, this can be extremely difficult and expensive to prove (*Clydebank Engineering Co. v. Don Jose Yzquierdo y Castaneda*). In an attempt to overcome these challenges, the courts have started to use technology (Narayanan and Hibbin 2001; Feigenson and Spiesel 2011; Schofield 2011).

Use of Technology in the Legal Sector

The legal sector tends to be risk averse, so any technology that is adopted by legal service providers is required to go through rigorous analysis and review to ensure that it is correctly used and fit for purpose. Client demands, competitive pressure, and the recession have prompted law firms to increase information technology (IT) use, but investment in technology by the legal sector still remains lower than it is in other industries (LSN 2015).

In an attempt to improve efficiency, the United Kingdom criminal justice system is going through a process of digitization. The aim is to reduce the heavy reliance on paper, which contributes to fragmentation and wasted time, and replace it with digital case files, digital courtrooms, and a single information management system (MoJ 2013). To support this initiative, screens and equipment are being installed in courts. This will provide the opportunity for in-court digital evidence such as video links with witnesses and the clear display of evidence directly to the court from an advocate's personal laptop or handheld device (MoJ 2014). This opens up numerous opportunities for presenting evidence.

Opportunities

Further investigation was undertaken to determine how the technological capabilities of the courts can be harnessed to improve the communication of delay events. To develop a feasible solution, appreciation was given to the digital tools and processes that are becoming commonly used on construction projects [building information modeling (BIM) and four-dimensional (4D) modeling]. The ability to use the available digital outputs as evidence in the highest legal setting, the courtroom, was explored (computer-generated exhibits), as were the opportunity to enhance understanding through technology (interactive videos) and the science behind communication (modes of presentation).

4D Modeling

Four-dimensional modeling is the process of linking a construction program to a three-dimensional (3D) virtual model to produce a sequence of the construction work (RIBA 2012). Virtual 3D models are not always produced for construction projects, and their absence has restricted the uptake of 4D modeling. However, access to object-oriented 3D virtual models has increased following the uptake of BIM on international construction projects (NBS 2014). This has provided a platform for 4D modeling and the opportunity to harness recognizable benefits, most notably in the planning and construction stages when information needs to be communicated to individuals with a lack of site-related knowledge (Mahalingam et al. 2010). Using this approach, individuals no longer have to imagine and interpret the activity sequence in their mind; instead, they are able to view a fact-driven 3D construction sequence using a single medium (Koo and Fischer 2000). Coupled with the appropriate skill set, 4D modeling can be used for effective communication to foster productive discussions for proactive management or in the early stages of different forms of alternative dispute resolution (Wing 2016). However, although BIM and 4D modeling can assist with reducing the likelihood and severity of some disputes, they do not eradicate disputes within the industry. The new processes of working and ways of communicating information can unveil different forms of dispute (Gibbs et al. 2015; Olatunji 2016).

Computer-Generated Exhibits

Demonstrative evidence, in the form of computer-generated exhibits (CGEs), has proven advantageous in the courtroom (Cooper 1999). This includes videos of virtual construction sequences, which have been identified as a way of assisting the mitigation, representation, and understanding of construction delays (Conlin and Retik 1997). Such exhibits can be classified in increasing probative value as (Burr and Pickavance 2010)

- Descriptive: not factually driven but *story*-based, on facts;
- Introductory: summary of principal issues, but can omit parts;
- Illustrative: description of something that cannot normally be seen; and
- Evidential: a different way of demonstrating primary evidence.

However, construction delays have experienced little advancement in technology (Vidogah and Ndekugri 1998) and only a small amount of research discusses the practical application of CGEs for construction claims (Pickavance 2007). To avoid affecting the admissibility of CGEs as evidence, emotive content such as that created by manipulating camera angles and adding special effects should be avoided (Schofield 2011). Further research into this field is required (Feigenson and Dunn 2003), but in an attempt to overcome these challenges and to encourage CGE use, recommendations on the creation of CGEs for the proactive control and retrospective analysis of delay have been published (Gibbs et al. 2014). The suggestions include

- Performing a cost-benefit analysis to determine the value of the CGE to the claim;
- Accurately demonstrating the delay in its clearest form;
- Producing a side-by-side comparison of as-planned and as-built CGEs with timeline; and
- Ensuring communication between the creators of the program and the virtual modeling organization.

Interactive Videos

Although visualizations can increase intuitive perception, data can be better evaluated and alternatives analyzed if the viewer is able to interact (Pensa et al. 2014). This has given rise to interactive videos, which place motion-tracking hotspots, or *tags*, on an item in the video. The tags remain fixed on the item as the video progresses, and when viewers click a tag, they can access more information about an item and influence the flow of the video (Stenzler and Eckert 1996). This concept has been employed by the advertising industry, but its benefits can assist with education because it improves understanding through the incorporation of different modes of presentation in one medium.

Modes of Presentation

When information is processed, three types of memory are required for meaningful learning to take place. Sensory memory briefly stores sights and sounds and transfers information to the working memory. Working memory is limited and so temporarily stores information to be organized; this is where viewers hold their attention (Clark and Mayer 2008). The new information is then integrated with existing knowledge to form long-term memory and understanding (Mayer 2009).

The ability to integrate information can depend on how the material is communicated. VARK modes of presentation identify that individuals learn in different ways and have a preference for one of the following (the first letters of which make up the VARK acronym) (Fleming and Mills 1992; Leite et al. 2010):

- Visual: graphical and symbolic information;
- Aural: heard information;
- Read/write: Printed information; and
- Kinesthetic: information acquired through application and multisensory experiences.

Preference for a mode of presentation is not specific to a certain type of job. For example, lawyers, who might be perceived to learn in read/write mode, actually have diverse learning styles (Boyle 2012). A combination of presentation modes may be advantageous to some individuals (Mayer and Anderson 1991; Fleming 1995) while improving the satisfaction of the task (Sung and Mayer 2012). However, in some instances individuals can report

fragmented or even no learning because the working memory is overloaded with irrelevant information (Mayer et al. 2001). To combat this, regular pauses are recommended (Spanjers et al. 2012) and rules and guidelines have been developed for the presentation of and interaction with information (Baldonado and Kuchinsky 2000).

Methodology

This research investigates if the communication of project delays can be improved by incorporating different modes of presentation into available technology. Because no literature was found that identifies whether and how VARK modes of presentation can assist with understanding project delays, two stages of assessment were undertaken. The first stage tested the appropriateness of integrating VARK modes of presentation with delay analysis through a workshop with industry experts. The second stage demonstrated how these findings can be applied in the industry through a simulation.

Workshop

Expert opinion was sought to determine the feasibility of using the VARK modes of presentation to improve understanding of project delays (Wieringa 2014). This was achieved by collecting data in a workshop. Workshops allow a researcher to engage with individuals who are concerned about a topic in order to investigate a problem and find a possible solution (Fisher 2004). To determine the appropriateness of integrating modes of presentation with delay analysis, a 30-minute workshop was held with 50 practicing Royal Institute of Chartered Surveyors (RICS) adjudicators. Adjudicators were chosen because they regularly encounter the challenge of understanding construction claim information and, although their appointment indicates a dispute, their experience offers useful insights into how construction projects are managed, the standard of claim information provided by the industry, and the level of evidence required to support a claim.

The 50 RICS adjudicators were presented with background information on the challenge of representing construction delay information, the rise and perceived benefits of CGEs, and details about learning styles. For the purpose of the workshop, CGE was described as the use of a computer to generate static or dynamic imagery of tangible construction operations, and excluded construction programs, photographs, and videos. An example CGE was presented to demonstrate its use to support a claim (Fig. 2). This example used graphs, 2D site layout, and animation to show the process of casting, shipping, storing, and installing concrete segments for construction of a viaduct. The VARK visual components demonstrated that the works were out of sequence and the impact that this had on the project. Aspects of VARK kinesthetic learning were incorporated into the CGE as the user became able to increase speed, filter information, and access further information through interaction.

At designated stages in the workshop, the participants were asked to provide binary responses to structured questions asked by the presenter (Table 1). The responses, which were recorded, prompted discussion that was captured and reported.

Simulation

Following the experts' discussion, the second assessment developed the findings and assessed the proposed concept through a simulation. This was required to demonstrate how modes of presentation can be incorporated into delay analysis. Given the

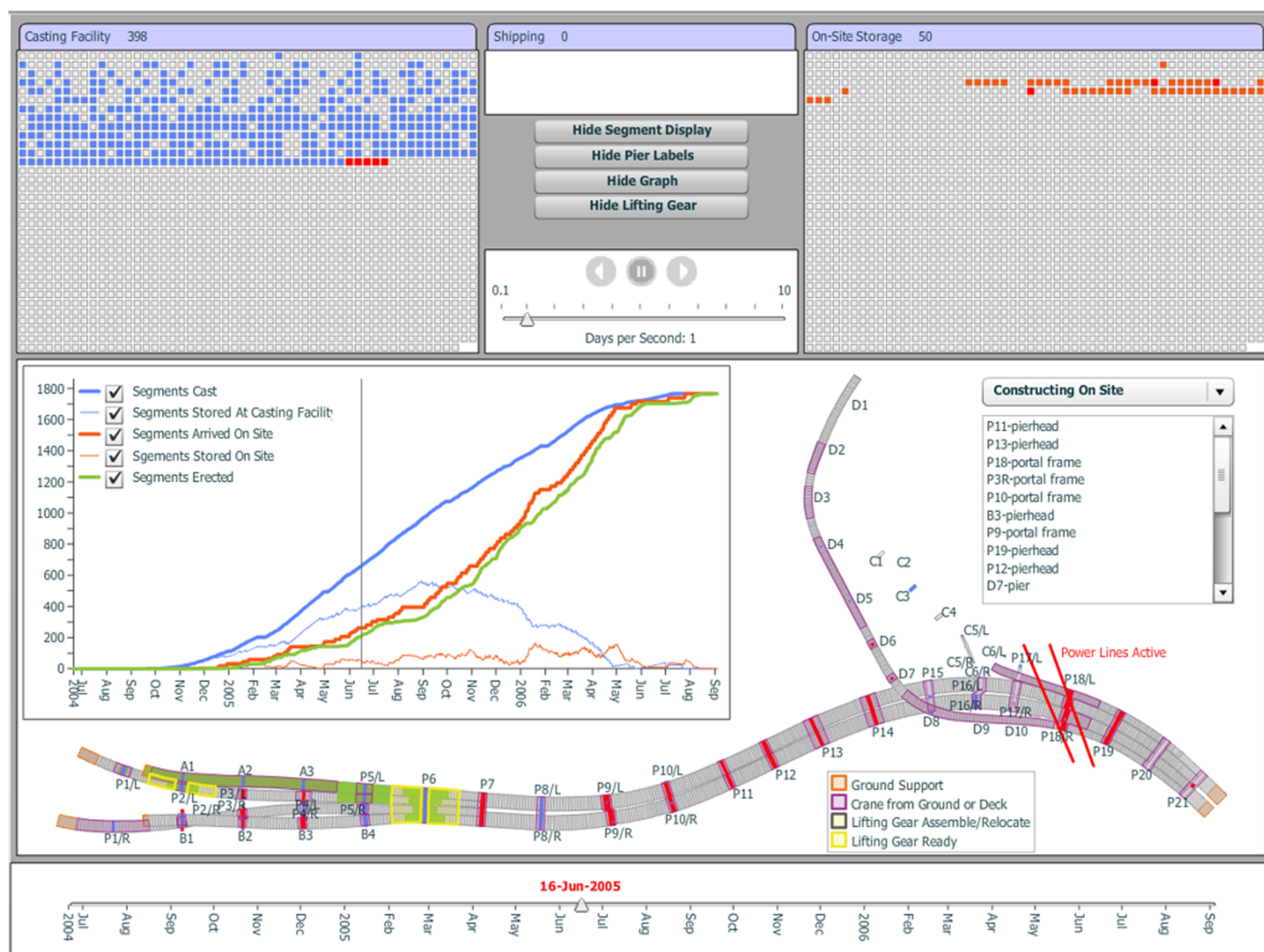


Fig. 2. CGE used to support a delay and disruption claim on the construction of a viaduct

Table 1. Summary of Workshop Results

Question number	Description	Yes response	
		Number	Percentage
1	Have you ever been provided with a CGE to support a construction claim?	16	32
1a	Was the CGE useful in assisting your judgment?	7	44
1b	Was the CGE not useful in assisting your judgment?	9	56
2	Would you find CGE, like that demonstrated, useful in assisting your understanding of a construction claim?	22	44
3	Do you feel there would be value in adding aural and read/write functions to CGEs like that demonstrated?	47	94

legal sector's need to rigorously test new technology before use, simulations were chosen because they avoid the risk of failure on a live project by creating and testing a concept in a synthetic environment (Wieringa 2014). Although there is always uncertainty about the integrity of a synthetic environment, greater credibility is given to the results obtained from testing a simulation in an environment as close as possible to the context it was intended to recreate (Zelkowitz and Wallace 1998). Therefore, to establish a realistic environment for testing, data were obtained from a case study of a construction dispute.

Case studies allow complex problems to be explored in a real-world context (Yin 2013). A synthetic environment was created using the case study of a dispute between steelwork contractors and concrete frame contractors whose works were sequential to

complete a fast-tracked multistory office building. Empirical data were obtained from claim consultants, but because of the sensitive nature of the dispute, some of the information was limited and modified to preserve anonymity. However, this did not compromise the output. The claim represented a concrete frame contractor who was required to follow a mandatory sequence of works (Fig. 3). One of the principal delay events that contributed to the 147 days' delay beyond the agreed on practical completion date was slow progress by the steelwork contractor.

A time impact analysis with one-month windows was used to analyze the delay on the project. It consisted of more than 3,500 interconnected activities. Although this approach provided a detailed mathematical analysis, it made understanding the cause and effect of delay challenging.

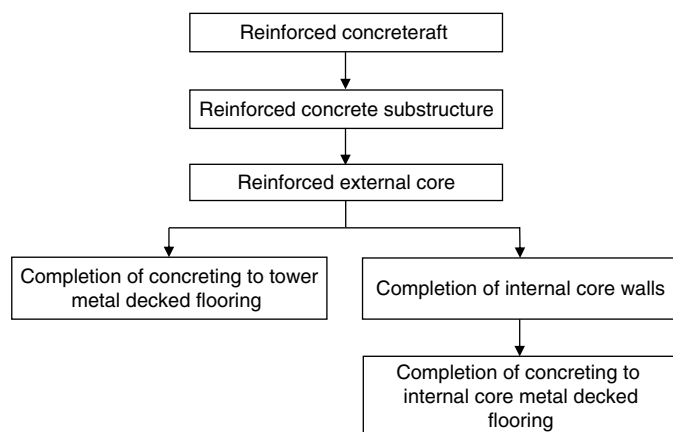


Fig. 3. Concrete frame contractor's mandatory sequence of works

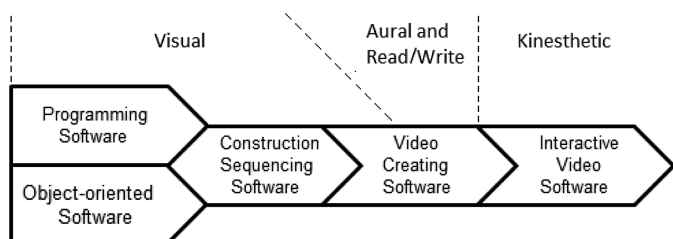


Fig. 4. Software used to develop each mode of presentation

Incorporation of Modes of Presentation

A CGE, in the form of an interactive exhibit, was produced to represent one of the monthly windows. The interactive exhibit integrated all of the VARK modes of presentation with the delay analysis, along with current and past research findings, using a variety of software packages (Fig. 4). To create a fact-driven 4D model of the delay claim, a 3D model and the construction program were required. The original delay analysis was produced in programming software that did not interface with the construction-sequencing software. Therefore, to use the delay analysis, the file was transferred through different programming packages until it could be converted into a file format that allowed it to be imported into the construction-sequencing software. Checks and modifications were undertaken to ensure that an exact replica of the analysis was presented.

A 3D model of the project was not available and had to be created using object-oriented software. It was produced using technical drawings, design information, and photographs that were provided to the claim consultants. The model was then imported into the construction-sequencing software and the activities in the programming software were linked to the 3D objects. Appropriate camera angles and visualization techniques were employed to demonstrate as-planned (baseline) progress against the as-built (time-impacted) data. The visual output was recorded and edited using video-creating software and saved as a video file.

Aural narration, which summarized the report narrative, was recorded in the video-creating software to describe what was occurring on screen. The visual and aural recordings were carried out independently and were edited to enhance presentation. Text captions were then added in the video-creating software to provide additional explanation of the delay analysis. Caption length was limited so as not to compromise the visual appearance, but additional written information could be found through kinesthetic

interaction. This was achieved by placing clickable tags on the written description of the delay event that contained additional information such as photographs, videos, graphs, and more detailed and cross-referenced descriptions.

Suitability of Proposed Concept

Workshop Findings

At the time of the workshop, the 50 participants accounted for 50% of the individuals registered on the RICS panel of adjudicators. The data obtained from the workshop's structured questions are presented in Table 1. The workshop participants stressed that a CGE should display only fact and that the information driving the visual should be seen by viewers. To determine the value of CGE, some participants indicated a preference for interrogating the exhibit, but the necessity of this created a split in opinion. The majority of participants commented that interrogation was not fundamental and that, in its most basic form, the CGE could be used to give an overall impression of a claim. One participant stated that this would be advantageous in adjudications, where an adjudicator has a short time to understand a dispute and report his or her decision. However, some participants indicated that, although CGEs might be visually appealing and useful in swaying a jury, there would always be an element of doubt that they could accurately reflect the facts.

There was consensus among the participants that it is the responsibility of the CGE's creator to tell the viewer how it can be relied on. Furthermore, there was general agreement that the CGE should be kept as simple as possible and include sufficient explanation to communicate what is occurring on screen. The participants recommended showing actual progress against what was planned and using video and pictures as supporting evidence. It was also stated that the CGE could be useful to proactively manage a project.

Workshop Discussion

Less than a third of the workshop participants had been presented with a CGE during their career, which demonstrates that CGEs are not widely used to support construction claims. Of those who had encountered a CGE, the respondents did not indicate multiple experiences.

The ability to display the information driving the CGE will vary depending on the claim. For delay claims, the delay analysis should suffice and can be included and made visible as part of the CGE. The detail of the information included and displayed in the CGE depends on its purpose. It appeared that the workshop participants were unaware of the different degrees of CGE value, and this may have contributed to the divided response on the appropriateness of CGEs as supporting evidence. Therefore, the use of a narrative to explain how the viewer can rely on the CGE would be of benefit.

There may be a lack of confidence in CGEs because of personal views and the demographic of the job role. Some individuals, particularly those who have worked a large proportion of their lives without computers, tend to question whether the CGE is accurately representing the claim information. To remove this doubt, the native file can be provided to allow interrogation of the model. Nevertheless, the value of including all modes of presentation in the CGE was recognized by the majority of participants. Nearly all agreed that enhancing the read/write functions and adding aural narration to the existing visual and kinesthetic modes of presentation in the CGE would improve its value. Given the professional status and

Table 2. Incorporating the Recommendations into the Simulation

Number	Recommendation	Description
1	Cost-benefit analysis	An evidential CGE (Burr and Pickavance 2010) was deemed most appropriate for the multimillion-pound claim
2	Clearest form	Only steel and concrete works are displayed in the 3D model. These are color-coded, and uninfluential resources are not included to avoid distraction. All four modes of presentation were used to assist with demonstrating the delay in its clearest form <ul style="list-style-type: none"> • Visual: fact-driven as-planned and as-built 3D models (see No. 3) • Aural: summarized report narrative played to describe what is occurring on screen • Read/write: text boxes provide detail about delays as they occur and act as clickable tags that, when activated, access additional text and cross-reference other evidence • Kinesthetic: clickable tags provide the viewer the opportunity to interact with the exhibit
3	Side-by-side comparison with timeline	The delay analysis is displayed and uses as-planned (baseline) progress against the as-built (time impacted) in a single Gantt chart. The delay analysis drives the as-planned and as-built 3D virtual models, which are placed side by side to allow for direct comparison
4	Communication	There was communication between the 4D modeler and the delay analyst, with a final check to ensure the output was correct

the sample size of the population, the findings indicate that modes of presentation can improve understanding of construction delays and that technology, if used correctly, can be a suitable enabler. To evaluate this concept, a simulation using case study data was developed and the research findings were applied.

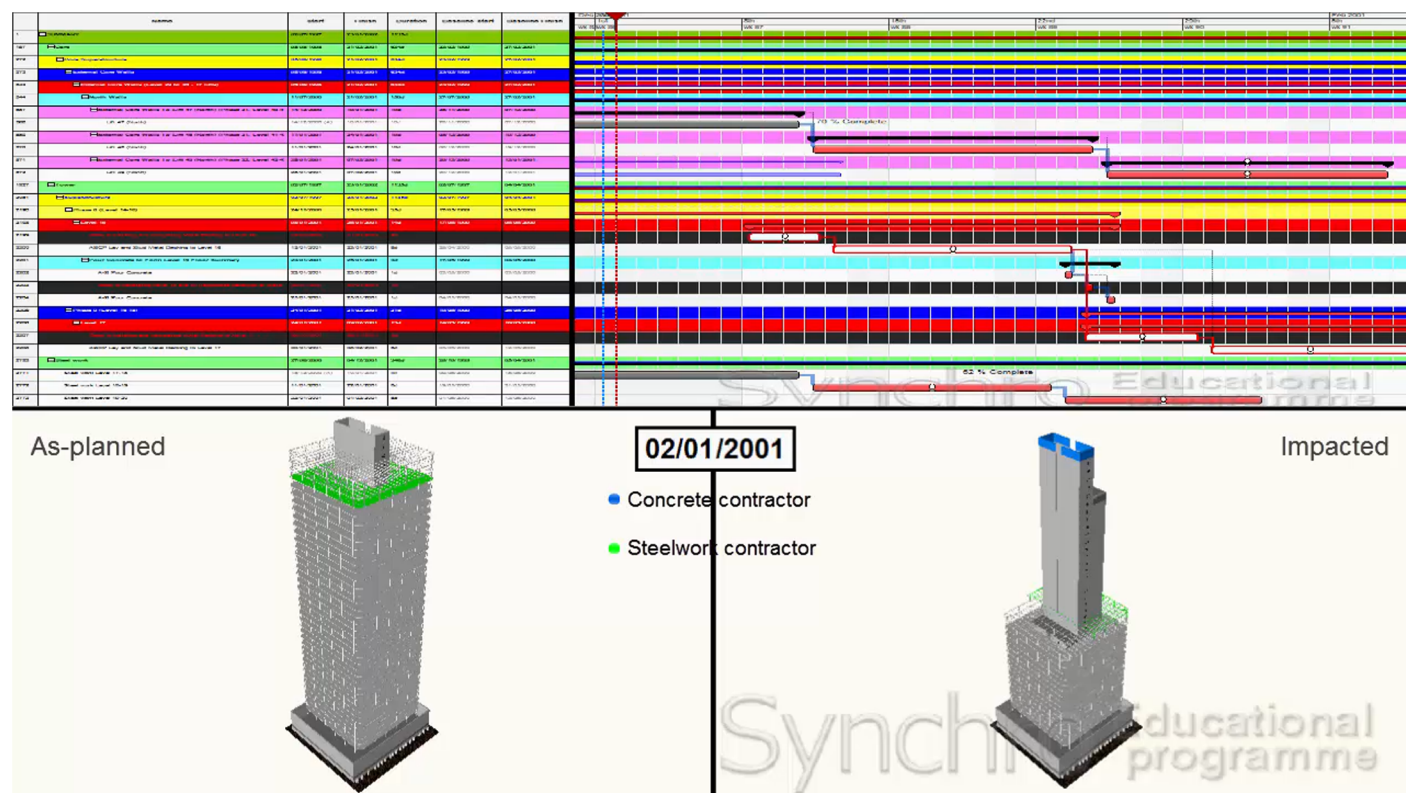
**Fig. 5.** Interactive exhibit at 00:01

Simulation of Proposed Concept

Proposed Interactive Exhibit

The innovation considers the technological capabilities of the legal system to provide a practical solution. The output, the interactive exhibit, incorporates the workshop findings and the recommendations found in related literature (Gibbs et al. 2014), as outlined in Table 2. These recommendations are applied and described in the Figs. 5–9 for specific times in the interactive exhibit to demonstrate how the slow progress of the steelwork contractor caused delay for the concrete frame contractor during one window of analysis.

- 00 min 01 s: an aural description explains how the interactive exhibit can be used and provides background information for the delay claim; aural description of what is occurring on screen is provided throughout the exhibit;

**Fig. 6.** Interactive exhibit at 00:50

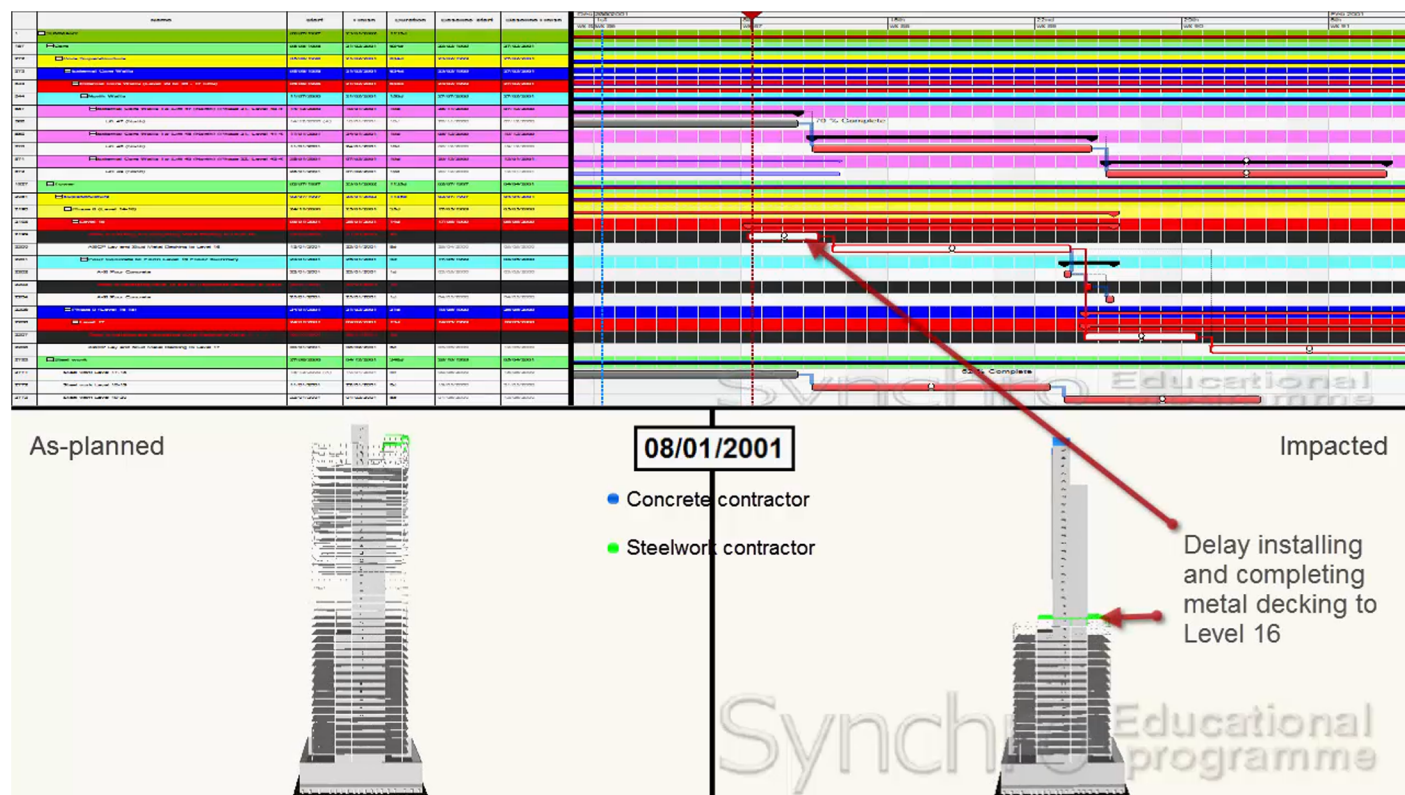


Fig. 7. Interactive exhibit at 01:06

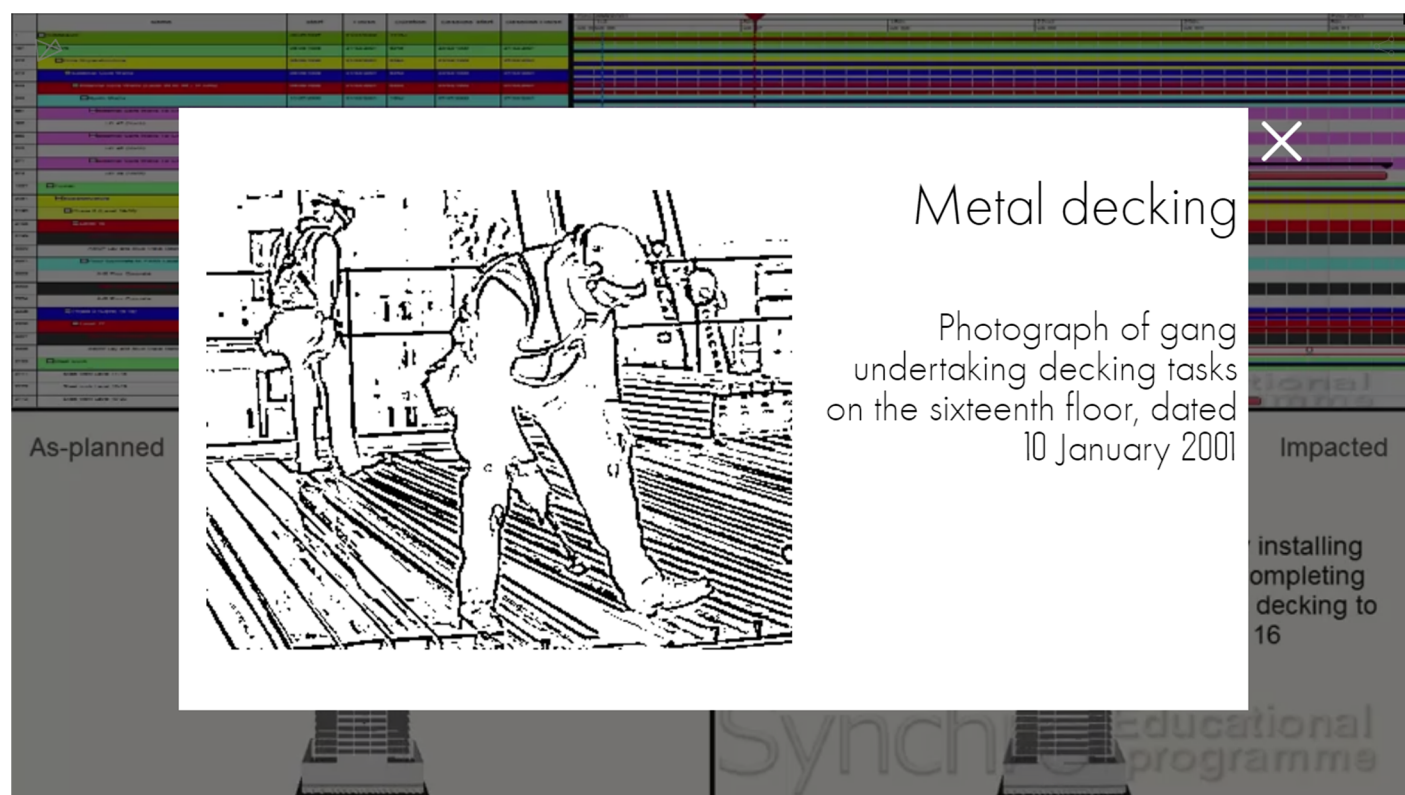


Fig. 8. Interactive exhibit at 01:06 (interactive tag clicked)

- 00 min 50 s: a side-by-side visual analysis of as-planned and as-built progress is presented; as the timeline progresses through the delay analysis, the camera angle pans both virtual models; activities performed by each trade are color coded to assist with differentiation: blue for the concrete contractor works and green for the steelwork contractor works;
- 01 min 06 s: delay events are marked on the Gantt chart in black; for the duration of the delay event, black text boxes appear to

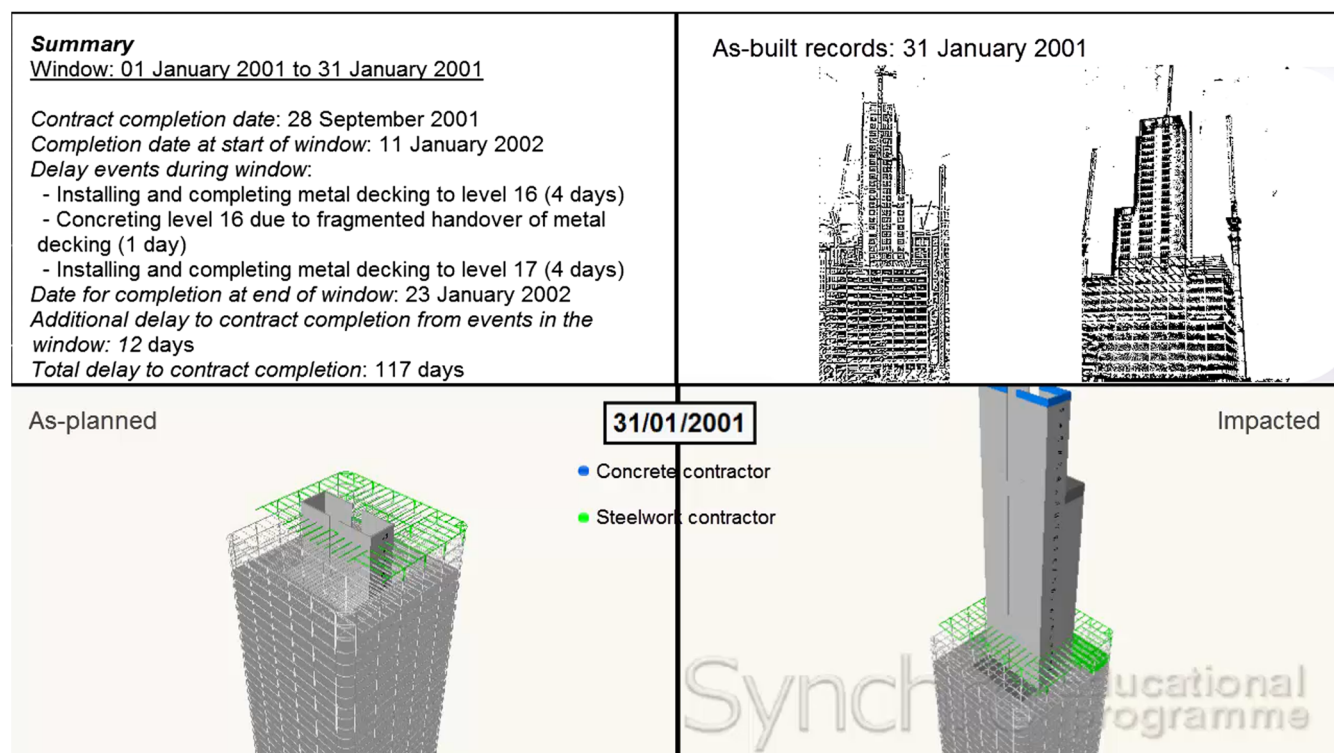


Fig. 9. Interactive exhibit at 02:39

provide a description of the delay; they act as the clickable tags that make the video interactive;

- 01 min 06 s: when the tag is clicked, the exhibit is paused and a box containing additional information, such as pictures, videos, or text references to the report narrative, is displayed; if the tag is not clicked, the exhibit progresses as normal;
- 02 min 39 s: at the end of the exhibit, a summary is provided to show the effects of delay during the window; as-built records are included to allow comparison with the as-built 3D virtual model, which helps to ensure the integrity of the dealy claim.

Interactive Exhibit Observations

The interactive exhibit provides an innovative way of understanding Gantt chart information. Instead of converting the data into a

meaningful mental image to compare planned and actual progress, the need for this conceptualization is reduced and the proposed concept enhances understanding by incorporating modes of presentation into the analysis. The application of these modes of presentation into the interactive exhibit is summarized, and their benefits and limitations are presented in Table 3.

The development of the 4D model demonstrated the need for consistency between the granularity of the virtual model and the construction program. This is easier to achieve but less useful if undertaken retrospectively. Nevertheless, communication between the program creator and the 4D model developer is critical, and an appreciation of the different disciplines is beneficial; otherwise, problems can arise. For example, in the case study some of the steel columns stretched from the ground floor to the roof and the 3D model had to be reengineered for compatibility with the

Table 3. Summary, Benefits, and Limitations of Each VARK Mode of Presentation in the Interactive Exhibit

Mode	Summary	Benefits	Limitations
Visual	Simulation of delay analysis showing the side-by-side analysis of as-planned (baseline) progress and the as-built (time impacted)	<ul style="list-style-type: none"> • Demonstrates the complex interdependency between trades • Side-by-side analysis shows change events and the effect on the project 	<ul style="list-style-type: none"> • If 3D and 4D models do not exist, creating them can be resource intensive • Issues with interoperability of software packages
Aural	Aural explanation of what is occurring on screen, likely a summary of the written report narrative	<ul style="list-style-type: none"> • Can be turned on/off at viewer's discretion 	<ul style="list-style-type: none"> • Detail might not be sufficient as a stand-alone item • Cannot be turned on/off when interactive exhibit is created
Read/write	Text captions summarize key events and pieces of information	<ul style="list-style-type: none"> • Summarizes and draws attention to key items 	<ul style="list-style-type: none"> • Detail might not be sufficient as a stand-alone item
Kinesthetic	Novel way for the viewer to interact with the simulation and gain additional information using clickable tags	<ul style="list-style-type: none"> • Simple and effective way to interact with the exhibit to gain additional information • Can be played on a handheld device to enhance Kinesthetic learning 	<ul style="list-style-type: none"> • All senses cannot interact with digital technology for full Kinesthetic learning • Interaction is limited; viewer cannot navigate the model • Data held on a server external to servers involved in the project

construction program's installation sequence. In contrast, some of the items in the delay analysis were too detailed and did not add value to the 4D model. This included noninfluential handover dates, which were hidden in the interactive exhibit to reduce on-screen distraction. Despite this, the text on the Gantt chart in the interactive exhibit remained small and difficult to read because it was required to be displayed in one view.

Further software challenges were encountered with the interoperability of software packages. Although the 3D virtual model was imported into the construction-sequencing software as required, the delay analysis and the construction-sequencing software did not directly interface. As a consequence, the native delay analysis file was transferred through different software packages to create a compatible file format. This resulted in data distortion, so alterations and checks were necessary to ensure consistency with the native file, which made for a timely process. To reduce doubt about the integrity of the analysis, the summary box at the end of the exhibit compared as-built photographs with the virtual model.

Once the visual aspect of the model was developed, the video-creating software made the incorporation of the read/write and aural modes of presentation straightforward. A soundtrack was not included in the exhibit because it might have distracted viewers, and slower speech and regular pauses were incorporated to allow time for information to be processed. This balance was achieved by editing the aural file in the video-creating software. To improve the impact of the exhibit, read/write and aural descriptions were limited, and any additional information required was made accessible via the interactive tags. If the information behind the tags were not to offer the required information to support a claim, a report narrative would have to be provided with the appropriate detail.

Nevertheless, the clickable tags promote kinesthetic learning through user interaction, and this learning style can be enhanced by viewing the interactive exhibit on a mobile device, allowing viewers to understand information away from their desk. This option is supported through private online access; however, it requires that the data be held on a third-party server, which might create a barrier to adoption. Even so, it is anticipated that alternative ways of creating and viewing interactive exhibits will become available in the future.

Given the nature of video, the primary mode of presentation for the exhibit was shown to be visual with the other modes (aural, read/write, and kinesthetic) providing secondary support. Because it is impossible for all senses to interact with digital technology, incorporating kinesthetic modes of presentation into the delay analysis posed the greatest challenge. Furthermore, a video was required to support the aural and read/write modes. This eliminated the ability to interrogate the delay analysis in a 4D environment, which would have benefited kinesthetic learning. For this reason, a native file of the 4D model might be provided in addition to the interactive exhibit to allow for interrogation and enhanced kinesthetic learning.

Generally the time impact analysis demonstrates how the VARK modes of presentation can assist with proactive control and retrospective analysis. The interactive exhibit appears the most suitable for construction claims; however, the resources required to produce it for proactive control may outweigh the overall value gained. Proactive control of delays requires fast decisions, but the interactive exhibit requires time and resources for its creation. Furthermore, those involved with decision making at this stage may not significantly benefit from improved understanding because they are likely to be familiar with the details of the project. Therefore, although recording the effects of change is important, some individuals might argue that time and resources would be better focused on overcoming delays than on reporting their effects in the form of an

interactive exhibit. Still, the visual mode incorporating side-by-side comparison of as-planned and as-built 4D models might, in isolation, be used to proactively manage delays.

Overall, the interactive exhibit can address some of the challenges individuals face when trying to understand the effects of delay. The various VARK modes of presentation should enhance understanding for an individual with limited project or delay knowledge, which can improve the clarity of the claim and shift the balance of probabilities in a party's favor. Thus, it can be used to avoid the likelihood and severity of disputes.

Conclusions and Future Research

This research demonstrates how interactive exhibits can be used to improve understanding of delays for proactive control and retrospective analysis. Taking into account the level of information technology use in the legal sector, a practical solution was developed through two stages of assessment.

The first stage of assessment confirmed the suitability of using VARK modes of presentation to improve understanding of construction claims, and it produced requirements for future development. In line with the literature, industry experts identified that CGEs are not common forms of evidence for construction claims (Vidogah and Ndekugri 1998) and when they have been used to support claims, they have not always been helpful. The experts' suggestions for improvement were consistent with previous research (Gibbs et al. 2014), and their concerns mirrored some of the issues presented in the literature (Schofield 2011). This included informing viewers of how they can rely on the CGE for the reason that not all individuals are familiar with the different CGE categories (Burr and Pickavance 2010). If this is not communicated, it can cause the CGE's integrity to be questioned, a situation that can be exacerbated if the CGE cannot be interrogated. To avoid doubt, it is recommended that the native 4D file be made available so the data can be independently analyzed if required. The integrity of the CGE as evidence could be assisted by the inclusion of the VARK modes of presentation, which can be used to explain and cross-reference what is occurring on screen.

The second stage of assessment developed the workshop findings and demonstrated that all four VARK modes of presentation can be successfully integrated into an interactive exhibit. However, doing so was not without its challenges. Integrating the different modes of presentation evenly into the CGE is restricted by technology. In the proposed concept, the visual mode appears to be primary, with the other modes attached. Therefore, some of the perceived benefits of the interactive exhibit may be attributable to the side-by-side comparison of as-planned and as-built progress. Another challenge is interoperability. Literature on interoperability for 4D modeling is lacking, and although the current study goes some way to demonstrate the challenges, additional research into software interoperability and the granularity of detail for the simultaneous production of a program and 3D virtual model is required.

The time impact analysis demonstrates how the proposed concept can be used for both proactive control and retrospective analysis, but the research exemplifies the challenge of creating a holistic tool (Scott 1990). It is perceived that the interactive exhibit will add the greatest value to construction claims because it can assist with communicating causality, responsibility, and quantum in its clearest form. This is consistent with literature on 4D modeling applicability that finds that the modeling's greatest value is to those with a lack of site-related knowledge (Mahalingam et al. 2010). Therefore, the interactive exhibit can improve the standard of evidence and tip the balance of probabilities; however, further research is required to

test the concept in practice and additional value can be gained through analysis of nonlinear projects with different methods/classifications of delay analysis that require different levels of communication (Ng et al. 2004). Further research is also required to determine the added value of the interactive exhibit for proactive control.

Overall, the research aim, reducing the likelihood and severity of construction disputes, is addressed through the development of the interactive exhibit, which can be used to accelerate and improve understanding of project delay through the VARK modes of presentation. It is suggested that the interactive exhibit be used as a supportive tool and not as a replacement for conventional methods. Before the proposed concept is incorporated into practice, additional stages of assessment should be undertaken.

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References

List of Cases

- Balfour Beatty Construction v. Lambeth London Borough Council (2002) EWHC 597.
 Clydebank Engineering Co. v. Don Jose Yzquierdo y Castaneda (1905) AC 6.
 Hadley v. Baxendale (1854) EWHC Exch J70.
 Hunte v. E Bottomley & Sons (2007) EWCA Civ 1168.
 National Museums and Galleries on Merseyside Board of Trustees v. AEW Architects and Designers Ltd. (2013) EWHC 3025 (TCC).
 Robinson v. Harman (1848) 1 Exch 850; 154 E.R.

Works Cited

- AACE (Association for the Advancement of Cost Engineering). (2011). "Forensic schedule analysis. TCM framework: 6.4—Forensic performance assessment." *AACE Int. Recommended Practice No. 29R-03*, Morgantown, WV.
 Alkass, S., Mazerolle, M., Tribaldos, E., and Harris, F. (1995). "Computer aided construction delay analysis and claims preparation." *Constr. Manage. Econ.*, 13(4), 335–352.
 Arcadis. (2015). "Global construction dispute report 2015: The higher the stakes, the bigger the risk." Amsterdam, the Netherlands.
 Arditi, D., and Pattanakitchamroon, T. (2006). "Selecting a delay analysis method in resolving construction claims." *Int. J. Project Manage.*, 24(2), 145–155.
 Baldonado, M., and Kuchinsky, A. (2000). "Guidelines for using multiple views in information visualization." *Proc., Advanced Visual Interfaces Conf.*, ACM, New York, 110–119.
 Bayraktar, M., Arif, F., Hastak, M., and Gad, N. (2012). "Judiciary's use of the critical path method to resolve construction claims." *J. Legal Affairs Dispute Resolut. Eng. Constr.*, 10.1061/(ASCE)LA.1943-4170.0000079, 10–16.
 Boyle, R. (2012). "Applying learning-styles theory in the workplace: How to maximize learning-styles strengths to improve work performance in law practice." *St John's Law Review*, 79(1), 97–126.
 Braimah, N. (2013). "Construction delay analysis techniques—A review of application issues and improvement needs." *Buildings*, 3(3), 506–531.

- Braimah, N., and Ndekugri, I. (2008). "Factors influencing the selection of delay analysis methodologies." *Int. J. Project Manage.*, 26(8), 789–799.
 Burr, A., and Pickavance, K. (2010). "The use of visualisations in case presentation and evidence." *Constr. Law J.*, 26(1), 3–17.
 CIOB (Chartered Institute of Building). (2008). "Managing the risk of delayed completion in the 21st century." Berkshire, U.K.
 CIOB (Chartered Institute of Building). (2011). *Guide to good practice in the management of time in complex projects*, Wiley-Blackwell, West Sussex, U.K.
 Clark, R., and Mayer, R. (2008). *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning*, 2nd Ed., Pfeiffer, San Francisco.
 Conlin, J., and Retik, A. (1997). "The applicability of project management software and advanced IT techniques in construction delays mitigation." *Int. J. Project Manage.*, 15(2), 107–120.
 Cooper, M. (1999). "The use of demonstrative exhibits at trial: Practitioner's guide." *Tulsa Law J.*, 34(3), 567–578.
 CRC (Cooperative Research Centre). (2007). "Dispute avoidance and resolution: A literature review." *Rep. No. 1*, Brisbane, QLD, Australia.
 Farrow, T. (2001). "Delay analysis—Methodology and mythology." Society of Construction Law, Leicestershire, U.K.
 Feigenson, N., and Dunn, M. (2003). "New visual technologies in court: Directions for research." *Law Human Behav.*, 27(1), 109–126.
 Feigenson, N., and Spiesel, C. (2011). *Law on display*, NYU Press, New York.
 Fenwick Elliott. (2012). *Dictionary of construction terms*, Informa Law, London.
 Fisher, R. (2004). "The problem-solving workshop as a method of research." *Int. Negotiation*, 9(3), 385–396.
 Fleming, N. (1995). "I'm different; not dumb. Modes of presentation (VARK) in the tertiary classroom." *Proc., 1995 Annual Conf. of the Higher Education and Research Development Society of Australasia (HERDSA)*, Vol. 18, HERDSA, Hammondville, NSW, Australia, 308–313.
 Fleming, N. D., and Mills, C. (1992). "Not another inventory, rather a catalyst for reflection." *Improve the academy*, Univ. of Nebraska, Lincoln, NE, 137–146.
 Flyvberg, B. (2014). "What you should know about megaprojects and why: An overview." *Project Manage. J.*, 45(2), 6–19.
 Gibbs, D., Emmitt, S., Ruikar, K., and Lord, W. (2013). "An investigation into whether building information modelling (BIM) can assist with construction delay claims." *Int. J. 3-D Inform. Model.*, 2(1), 45–52.
 Gibbs, D., Emmitt, S., Ruikar, K., and Lord, W. (2014). "Recommendations on the creation of computer generated exhibits for construction delay claims." *Constr. Law J.*, 30(4), 236–248.
 Gibbs, D., Lord, W., Emmitt, S., and Ruikar, K. (2015). "Building information modelling." *Constr. Law J.*, 31(3), 167–179.
 Girbacia, F. (2012). "Evaluation of cognitive effort in the perception of engineering drawings as 3D models." *Proc., 2012 Int. Conf. on Advances in Computer-Human Interactions*, IEEE, New York, 247–250.
 Haidar, A., and Barnes, P. (2011). *Delay and disruption claims in construction: A practical approach*, ICE, London.
 Kangari, R. (1995). "Construction documentation in arbitration." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(1995)121:2(201), 201–208.
 Kelley, J. (1961). "Critical-path planning and scheduling: Mathematical basis." *Oper. Res.*, 9(3), 296–320.
 Koo, B., and Fischer, M. (2000). "Feasibility study of 4D CAD in commercial construction." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2000)126:4(251), 251–260.
 Kumaraswamy, M. (1997). "Conflicts, claims and disputes in construction." *Eng. Constr. Archit. Manage.*, 4(2), 95–111.
 Lazarus, D., and Clifton, R. (2001). "Managing project change: A best practice guide." Construction Industry Research and Information Association (CIRIA), Westminster, U.K.
 Leite, W., Svinicki, M., and Shi, Y. (2010). "Attempted validation of the scores of the VARK: Learning styles inventory with multitrait-multimethod confirmatory factor analysis models." *Educ. Psychol. Meas.*, 70(2), 323–339.

- Love, P., Davis, P., Ellis, J., and Cheung, S. (2010). "Dispute causation: Identification of pathogenic influences in construction." *Eng. Constr. Archit. Manage.*, 17(4), 404–423.
- LSN (Legal Support Network). (2015). "Legal IT landscapes 2015: Tomorrow's technologies for competitiveness and efficiency." Surrey, U.K.
- Mahalingam, A., Kashyap, R., and Mahajan, C. (2010). "An evaluation of the applicability of 4D CAD on construction projects." *Autom. Constr.*, 19(2), 148–159.
- Mayer, R. (2009). *Multimedia learning*, 2nd Ed., Cambridge University Press, New York.
- Mayer, R., and Anderson, R. (1991). "Animations need narrations: An experimental test of a dual-coding hypothesis." *J. Educ. Psychol.*, 83(4), 484–490.
- Mayer, R., Heiser, J., and Lonn, S. (2001). "Cognitive constraints on multimedia learning: When presenting more material results in less understanding." *J. Educ. Psychol.*, 93(1), 187–198.
- MoJ (Ministry of Justice). (2013). "Transforming the CJS: A strategy and action plan to reform the criminal justice system." The Stationery Office, Norwich, U.K.
- MoJ (Ministry of Justice). (2014). "Transforming the criminal justice system: Strategy and action plan—Implementation update." The Stationery Office, Norwich, U.K.
- Moosavi, S., and Moselhi, O. (2014). "Review of detailed schedules in building construction." *J. Legal Affairs Dispute Resolut. Eng. Constr.*, 10.1061/(ASCE)LA.1943-4170.0000142, 05014001.
- Narayanan, A., and Hibbin, S. (2001). "Can animations be safely used in court?" *Artif. Intell. Law*, 9(4), 271–294.
- NBS (National Building Specification). (2014). "NBS international BIM report 2013." RIBA Enterprises, London.
- NBS (National Building Specification). (2015). "National construction contracts and law survey 2015." RIBA Enterprises, London.
- Ng, S., Skitmore, M., Deng, M., and Nadeem, A. (2004). "Improving existing delay analysis techniques for the establishment of delay liabilities." *Constr. Innovation*, 4(1), 3–17.
- Olatunji, O. (2016). "Constructing dispute scenarios in building information modeling." *J. Legal Affairs Dispute Resolut. Eng. Constr.*, 10.1061/(ASCE)LA.1943-4170.0000165, C4515001.
- Pensa, S., Masala, E., Lami, I., and Rosa, A. (2014). "Seeing is knowing: Data exploration as a support to planning." *Proc. Inst. Civ. Eng.*, 167(5), 3–8.
- Pickavance, K. (2007). "Using advanced forensic animations to resolve complex disruption claims." Society of Construction Law, Leicestershire, U.K.
- Pickavance, K. (2010). *Delay and disruption in construction contracts*, 4th Ed., Sweet & Maxwell, London.
- Ramanathan, C., Narayanan, S., and Idrus, A. (2012). "Construction delays causing risks on time and cost—A critical review." *Aust. J. Constr. Econ. Build.*, 12(1), 37–57.
- RIBA (Royal Institute of British Architects). (2012). "BIM overlay to the RIBA outline plan of work." London.
- Schofield, D. (2011). "Playing with evidence: Using video games in the courtroom." *Entertain. Comput.*, 2(1), 47–58.
- SCL (Society of Construction Law). (2002). "Delay and disruption protocol." Leicestershire, U.K.
- SCL (Society of Construction Law). (2015). "Rider 1: The society of construction law delay and disruption protocol." Leicestershire, U.K.
- Scott, S. (1990). "Keeping better site records." *Project Manage.*, 8(4), 243–249.
- Spanjers, I., Gog, T., Wouters, P., and Merriënboer, J. (2012). "Explaining the segmentation effect in learning from animations: The role of pausing and temporal cueing." *Comput. Educ.*, 59(2), 274–280.
- Stenzler, M., and Eckert, R. (1996). "Interactive video." *SIGCHI Bull.*, 28(2), 76–81.
- Sung, E., and Mayer, R. (2012). "When graphics improve liking but not learning from online lessons." *Comput. Human Behav.*, 28(5), 1618–1625.
- Tieder, J. (2009). "Methods of delay analysis and how they are viewed by the United States legal system." Society of Construction Law, Leicestershire, U.K.
- Trauner, T., Manginelli, W., Lowe, J., Nagata, M., and Furniss, B. (2009). *Construction delays: Understanding them clearly, analysing them correctly*, 2nd Ed., Elsevier, London.
- Vidogah, W., and Ndekugri, I. (1998). "A review of the role of information technology in construction claims management." *Comput. Ind.*, 35(1), 77–85.
- Whatley, P. (2014). *The project planning handbook*, Troubador, Leicester, U.K.
- Wieringa, R. (2014). "Empirical research methods for technology validation: Scaling up to practice." *J. Syst. Software*, 95, 19–31.
- Williams, T., Ackermann, F., and Eden, C. (2003). "Structuring a delay and disruption claim: An application of cause-mapping and system dynamics." *Eur. J. Oper. Res.*, 148(1), 192–204.
- Williams, T., Eden, C., Ackermann, F., and Tait, A. (1995). "The effects of design changes and delays on project costs." *J. Oper. Res. Soc.*, 46(7), 809–818.
- Wing, T. (2016). "A timeless motto for dispute resolution: Prevention is better than cure." *J. Legal Affairs Dispute Resolut. Eng. Constr.*, 10.1061/(ASCE)LA.1943-4170.0000169, C1815001.
- Yin, R. (2013). "Validity and generalization in future case study evaluations." *Evaluation*, 19(3), 321–332.
- Zelkowitz, M., and Wallace, D. (1998). "Experimental models for validating technology." *Computer*, 31(5), 23–31.