Issues in Establishing Blame in Disrupted Projects

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Abstract:

Projects subjected to significant cost overruns that occur from disruptions and delays can often result in either the contractor or the employer making a claim against the other party. Claims are for very large sums of money and so the process of establishing blame is a serious matter and can be extremely complex. In this paper we highlight one specific issue - unravelling the interaction between disruptions - that makes establishing blame particularly problematic. Although the issue has been recognised by academics, guidance for practice has not fully acknowledged. The paper uses a simple example to illustrate the nature and significance of the issue of analysing the impact of one disruption on another. The Society for Construction Law recently launched the 2nd Edition of their Protocol that provides "practical and principled guidance on proportionate measures for dealing with delay and disruption issues that can be applied in relation to all projects, regardless of complexity or scale". The Protocol is likely to be influential in helping deal with disputes. However the Protocol provides guidance, particularly in relation to simulation modelling, that means it is likely that mis-attribution of blame will occur. We suggest a revised wording that might alleviate this concern.

1. Introduction

Complex construction projects often result in significant cost overruns (Flyvberg et al., 2002; Flyvberg et al., 2003; Kharbanda and Pinto, 1996; Segelod, 2018). These overruns are typically the consequence of disruptions and delays created by either the employer or contractor[1]. "Disruptions are events that preclude the contractor completing the work as bid, and delays involve the completion of the project being later than originally planned (disrupting the continuity)…. in both cases the ramifications are complex, and it becomes difficult to attribute `knock-on' events and delays directly to any one disruption or delay. Delays act as disruptions in their own right, and the knock-on effect means that disruptions cause delays, which in turn disrupt the project. The distinction between directly attributable additional costs and the cost of the complex consequences is difficult to determine…. Therefore, there are extensive difficulties in demonstrating the distinction between self-inflicted damages from disruption and delay [caused by the party seeking compensation] as compared to damages caused by the client [caused by the party from whom compensation is sought] (which are those to be legitimately claimed)" (quoted from Eden et al., 2000: 291; see also Cooper 1994; Love 2002; Love, Davis, Ellis & Cheung 2010).

Due to the significant cost overruns that can occur from disruptions and delays, projects subjected to them can often result in either the contractor or the employer making a claim against the other party. Many claims are for very large sums of money and so the process of establishing blame is a serious matter. A 2018 report from Arcadis analyses "global construction disputes handled by [their] team in 2017, as well as contributions from industry experts" (Cooper et al., 2018), and this shows that the global average claim in disputes was $43.4m. Although some dispute claims can be for much more significant amounts: for example, Areva-Siemens had been claiming €3.6bn from TVO for cost overruns and delays during the construction of a nuclear reactor while TVO (a Finnish company) had filed a counter-claim of €2.6bn[2].

[1] We use the terminology employed in the SCL Protocol: employer and contractor. Employer is sometimes referred to as the owner or the customer, and contractor often referred to as the supplier.
[2] https://reuters.com/article/us-tvo-areva-olkiluoto-settlement/frances-areva-to-pay-554-million-to-settle-finnish-reactor-dispute-idUSKCN1GN0R5

To provide guidance in determining the cost of disruptions and delays, the Society of Construction Law (SCL) in the UK has issued a 2nd edition of its Protocol (Society of Construction Law, 2017). “The purpose of the Protocol is to provide a means by which the parties can resolve these matters and avoid unnecessary disputes.” (SCL Protocol: 1). The introduction to the Protocol states that: “The question of who should bear the cost of delay and disruption is often Contentious” (SCL Protocol: 10) and so is expected to offer help in establishing blame. The Protocol provides admirable guidance and is likely to be influential beyond the UK in helping deal with disputes – two-thirds of the downloads of all editions of the Protocol have been from people outside of the UK, covering 141 other countries[3]. This guidance for practice is important because otherwise it is thin on the ground, the PMBOK contains on a “cryptic mention” and ISO 31000 pays lip service (Williams 2017).

In this paper we reflect upon one serious issue we identify within the Protocol: analysing the impact of one disruption on another. We demonstrate, using a simple example project, that by following the Protocol, and not taking account of the issue, there is a likelihood that mis-attribution of blame will occur, and even this simple example demonstrates the complexity of seeking to properly attribute blame.

There are a number of “common methods” for the “calculation of lost productivity resulting from disruption events” with respect to project specific studies: measured mile analysis, earned value analysis, programme analysis, work or trade sampling, and system dynamics simulation modelling. These methods are intended to establish the extent of blame for the consequences of disruption events. The outcome of each of these methods does its job “with varying accuracy and general acceptance” and that “the preference remains for a measured mile analysis, where the requisite records are available and it is properly carried out” (SCL

[3] https://www.scl.org.uk/resources/delay-disruption-protocol

Protocol: 3). However the measured mile analysis "requires an undisrupted beginning to the project and the ''mile'' needs to be long enough for there to be a reliable measure" (Eden et al., 2005: 135) and for many disrupted projects the disruption event occurs before, or soon after, the project has started.

When a disruption event occurs on a project, an important consequence can be the loss of productivity (Cooper, 1994). For example, productivity may be lost due to increased amounts of rework that prevent workers progressing new work or interruptions to the work flow that result from disruptive events (Eden et al. 2000). When applying a method for the calculation of the lost productivity resulting from disruption events, one approach that is presented in the Protocol is to establish the cost of the project 'but for' the disruptions and then subtract this from the actual cost of the project. For example, the "loss of efficiency approach calculates 'what it cost with the disruption' LESS 'what it should have cost without the disruption' EQUALS 'disruption damages' (Cushman et al., 1996: 5-15). Similarly, the "total cost method", "modified total cost method", "measured mile approach" and "should cost estimates" all imply reducing the actual cost by some notion of the cost of the disruption. Thus, in most instances the methods encompass some notion of what would have happened in the project 'but-for' the disruption events.

A disrupted project usually involves some disruptions attributed to the employer *and* some to the contractor. Thus, the idea of a 'but for' claim now becomes 'what the project cost with all of the disruptions – the total cost' LESS 'the cost of the disruptions *caused by the defendant'*. This calculation requires separation of the consequences of disruption events caused by the defendant from those that are self-inflicted by the plaintiff. But, as we shall demonstrate through example, the consequences of one disruption event affects the consequences of another disruption event – they interact. Establishing the extent of blame now becomes significantly more complex.

In this paper we discuss the significant issues in isolating the consequences (cost) of one disruption event without explicitly accounting for the consequences of another disruption event on the first. We are concerned with the implications of analysis and understanding of the impact of disruption events and how this might properly inform attribution of blame – that is a disruption analysis rather than a delay analysis. This focus on analysis recognises that either the nature of the claim or the award are matters for a tribunal or negotiation. We argue that it is not possible to establish a fair attribution of blame through the obvious notion of a 'but for' analysis. We shall demonstrate that it is highly likely that using such a 'but for' the cost of the disruptions made by only one party will mis-attribute blame. In particular, we discuss the nature of the complexity of computing a fair claim through both the use of a simple generic example, and with reference to the use of System Dynamics simulation modelling which has been presented as particularly appropriate for dealing with complex disruptions (Goodchild, 2018).

The structure of the paper is as follows: first we exemplify the complexity of the separation of multiple disruption events using data from a simple project with disruption events from both employer and contractor; we then go on to consider the use of System Dynamics simulation; we close with some general statements about the use of the 'but-for' approach. We conclude with a warning about aspects of the recently introduced Society for Construction Law (SCL) Protocol, and particularly the use of simulation in the manner recommended by the SCL Protocol. We show that this Protocol, as written, presents a significant possibility that a wrong claim can be justified.

2. The Analysis of a Simple Project

In this section we present the issues in establishing blame by using reference to an example of a simple project that is subject to disruption. The example is used in order to move discussions of these issue from abstract argument to a 'reality'. The example describes a very simple project that is subject to disruption events from both the Contractor and Employer. The Contractor has estimated how long it will take to complete each product, and with no productivity benefits expected from repeated products (no learning curve). There is a contractual agreement for the date of delivery of the products. Based on a mutually agreed schedule, the Employer has contractually agreed to pay the Contractor for the Contractor estimated hours of labour.

This reflects the requirement that "the Contractor should submit and the CA should accept a programme showing the manner and sequence in which the Contractor plans to carry out the works, which becomes the Accepted Programme." where CA refers to the Contract Administrator. (SCL Protocol: 17).

The SCL Protocol implies that analysis of only the consequence of disruptions that make up the claim, which is normally events caused by one party, is appropriate for attributing blame. However, the BUT-FOR ANALYSIS example demonstrates the importance of explicitly analysing the consequences of *all* significant disruption events, thus including those caused by *both parties*.

In this simple project the attribution of hours to the Employer advised by the SCL Protocol is more than the hours that are attributed to the Employer when also explicitly analysing, and removing, the impact of the Contractor induced disruption event. We show how using the advice from the SCL Protocol produces a bigger claim on the Employer than when account is taken of the impact of a disruption event caused by the contractor, and so the SCL Protocol can lead to mis-attribution of blame.

> The example describes a very simple project that is subject to a disruption event from both the Contractor and Employer. We consider that a Contractor has been contracted by an Employer to build 100 products. The Contractor has estimated that each product will take 7 hours to complete, and with no productivity benefits from repeated

products (no learning curve). There is a contractual agreement for the Contractor to deliver the 100 products after the 10th day of the project. The Contractor has therefore allocated 70 hours of labour per day to the project. Figure 1 shows the schedule for the work. Based on this schedule, the Employer has contractually agreed to pay the Contractor for 700 hours of labour. This reflects the requirement that "the Contractor should submit and the CA should accept a programme showing the manner and sequence in which the Contractor plans to carry out the works, which becomes the Accepted Programme." where CA refers to the Contract Administrator. (SCL Protocol: 17).

Day	Hours available	Products completed per day	Total products completed
1	70	10	10
2	70	10	20
3	70	10	30
4	70	10	40
5	70	10	50
6	70	10	60
7	70	10	70
8	70	10	80
9	70	10	90
10	70	10	100
Total hours planned	700		

Figure 1: The schedule developed by the Contractor on the basis of their own estimates and the contractual agreement to deliver 100 products at the end of the 10th day

However, the project did not unfold as the Contractor had expected:

Contractor inflicted Disruption Event: The Contractor underestimates the work that is required to be done. He identifies the underestimation once the actual project data settles. In response to the underestimation, the Contractor reschedules the work to keep to delivery by increasing labour available to the project.

The Contractor underestimated how long each product will take to build. The products actually take 10 hours each to build, rather than 7 hours. At the end of day 2 the Contractor realises that this is the case as only 14 products have been completed. (The Contractor's concerns were raised after day 1, but wondered if this may be a peculiarity with the first day of the project, but then recognised that all products were taking longer to complete after day 2). As the Contractor does not wish to deliver the products late, the Contractor reschedules.

As there are 86 products still to complete in the remaining 8 days, with each now expected to require 10 hours of labour, there is 860 hours of work still to be completed in 8 days. The project therefore needs sufficient labour allocated to it in order to complete 107.5 hours (=860/8) of work each day. The Contractor makes this amount of labour available to the project.

Employer inflicted Disruption Event: The Employer changes the product specification and thus rework is required. The Contractor reschedules to keep to the delivery date taking account of the rework that is required by increasing the labour available to the project.

After day 5, the Employer makes a change to the product. The change will require 20% of each product that has been completed to be reworked. This additional rework will need to be completed in the remaining 5 days of the project. The Contractor calculates that there now needs to be 125.92 hours of labour available each day in order to complete the project by the 10^{th} day. He has calculated this as follows: 20% of each of the 46.3 products that have been completed requires rework plus there are 53.7 remaining products to be completed (0.2*46.3 + 53.7 = 62.96 products to be completed). Each product takes 10 hours to complete and there are 5 days in which to complete the work (62.96 *10/5 =125.92).

The Contractor makes these labour hours available and the project is completed after 10 days.

Figure 2 shows how the labour hours and product completion on the project actually occurred.

Day	Hours available	Products completed per day	Total products completed	
1	70	7	7.0	
2	70	7	14.0	Contractor realises each product taking longer than expected and reschedules
3	107.5	10.75	24.8	
4	107.5	10.75	35.5	
5	107.5	10.75	46.3	Employer changes 20% of the product. Contractor reschedules
6	125.92	12.59	49.6	
7	125.92	12.59	62.2	
8	125.92	12.59	74.8	
9	125.92	12.59	87.4	
10	125.92	12.59	100.0	
Total hours used	1092.1			

Figure 2: How the actual hours and product completion unfolded on the project

As the contractual agreement was for the Employer to pay for 700 hours of labour, the Contractor may wish to claim for additional labour hours due to the Employer induced disruption event that is the change that was made to the product. According to the SCL Protocol, calculating the additional hours that accrued due to the change in the product would involve calculating the hours that would have accrued without the change, comparing this against the actual hours that accrued (1092.1 hours) and claiming the difference. To do this we recalculate the hours that would have accrued if the change by the Employer had not happened. The Contractor would, therefore, not have been required to reschedule the project after day 5 and the labour hours and product completion would be calculated as shown in Figure 3.

Day	**Hours available**	**Products completed per day**	**Total products completed**	
1	70	7	7	
2	70	7	14	Contractor realises each product taking longer than expected and reschedules
3	107.5	10.75	24.75	
4	107.5	10.75	35.5	
5	107.5	10.75	46.3	
6	107.5	10.75	57.0	
7	107.5	10.75	67.8	
8	107.5	10.75	78.5	
9	107.5	10.75	89.3	
10	107.5	10.75	100.0	

Total hours used	1000

Figure 3: How the project would have unfolded if the change by the Employer had not occurred

Based on the above data, the attribution of hours to the Employer advised by the SCL Protocol is more than the hours that are attributed to the Employer when removing the impact of the Contractor induced disruption event. This is demonstrated as follows:

> Following the SCL Protocol, the Contractor would claim for 1092.1 – 1000 = *92.1 labour hours.* However, the project has also been impacted by the consequences of the Contractor's underestimation of the time it takes to build a product. If this had not occurred, then the Employer's change would have had a different impact on the project. Figure 4 represents how the project would have unfolded if the planned 7 hours per product had been sufficient time to complete each product.

Day	Hours available	Products completed per day	Total products completed	
1	70	10	10	
2	70	10	20	
3	70	10	30	
4	70	10	40	
				Employer changes 20% of the product.
5	70	10	50	Contractor reschedules.
6	84	12	52.0	
7	84	12	64	
8	84	12	76	
9	84	12	88	
10	84	12	100	
Total hours used	770			

Figure 4: How the project would have unfolded if the planned hours per product had been sufficient time to complete each product

If the planned hours per product had been accurate, then the Contractor would have been able to progress work more quickly. Therefore when the Employer made a change to the product on day 5 more products would have been completed (as compared to what actually happened) and thus more products would have required reworking. However, each product would have required less rework as each product only requires 20% of 7 hours of work, rather than 20% of 10 hours of work. Figure 4 shows that the total hours used, when only the consequences of the Employer's change are considered, is 770 hours, which is 70 hours more than what had been planned. This is a different attribution to that advised by the SCL Protocol (92.1 hours).

The attribution of hours to the Employer advised by the SCL Protocol is more than *30% greater* than the hours that are attributed to the Employer when removing the impact of the Contractor induced disruption event.

All of the above raises a number of questions when considering the appropriate number of hours that should be attributed to the disruption events caused by both parties:

1. Should the Employer pay for the underestimation of the product as they are receiving a product worth 10 hours of work?
2. If the Employer should pay for the underestimated hours, then the Contractor may wish to claim for all of the hours that accrued in excess of the planned hours. The part of the claim associated with the Employer's change would be *92.1 hours*, as advised by the SCL Protocol.
3. If the Employer shouldn't pay for the additional underestimated hours, then how much should they pay for the change in the product?
4. If the Employer only pays for the impact of the change (see figure 4) then should they pay for reworking more products than actually required rework? Figure 4 suggests the Employer should pay for *70 hours* of additional work (reworking 20% of 50 products), but if they were to only pay for the changes required to the actual number

of products that were reworked this would be 20% of 46.3 products (see Figure 2) that is, *64.82 labour hours.*

By following the approach recommended by the SCL Protocol it would not be possible to consider questions 3 or 4.

The example represents a very simple project and yet it demonstrates how the consequences of one disruption event can impact upon the consequences of a second disruption event. Indeed, this effect has been demonstrated without even considering the possible full consequences of a disruption event. For example, depending upon the nature of the tasks that are being carried out it is often not effective to continue to add workers onto a project as overcrowding can occur (Cooper and Reichelt, 2007). This may result in reduced productivity as the increased number of workers compete against each other for space in which to carry out their tasks. What would have happened in our simple project if overcrowding had occurred? Figure 5 shows the project outcome with overcrowding.

Day	Hours available	Products completed per day	Total products completed	
1	70	7	7	
2	70	7	14	Contractor realises each product taking longer than expected and reschedules
3	107.5	10.75	24.8	
4	107.5	10.75	35.5	
5	107.5	10.75	46.3	Employer changes 20% of the product. Contractor reschedules.
6	125.92	8.994	46.0	
7	125.92	8.994	55.0	Contractor realises taking too long so reorganises and reduces time to complete product to 12 hours
8	180.05	15.004	70.0	
9	180.05	15.004	85.0	
10	180.05	15.004	100.0	
Total hours used	1254.48			

Figure 5: How the project unfolded when the disruptions caused overcrowding

When the Contractor makes additional labour hours available following the Employer's change to the product in week 5, this causes overcrowding which results in reduced productivity. Each product now takes 14 hours to complete. After week 7 the Contractor recognises that work is taking too long and reorganises the tasks and is able to reduce the time to complete a product to 12 hours. However, this also requires further labour hours to be made available each day, which again may create further overcrowding…. However, for purposes of simplicity we will not consider the impact of this further overcrowding in our example.

The total hours used on the project are 1254.48. This means that 162.38 additional hours accrued due to overcrowding (when compared to the original outcome of 1092.1 hours for the project given in figure 2). The question that now needs to be considered is to which party should the additional labour hours be attributed?

Overcrowding occurred due to the additional hours that resulted from both the Contractors underestimation of the task and the Employer's product change. Therefore the occurrence, and impact, of overcrowding cannot be recognised unless both Employer and Contractor disruptions are considered. The SCL Protocol would suggest that only the claimed, in this case the Employer induced, disruptions should be removed. But what portion of the impact of overcrowding should be attributed to the Employer? An understanding of all disruptions that attributed to overcrowding is required to enable a fair attribution of blame.

For any project that is more complex than this example the interactions between different disruptions are likely to become even more complex and more difficult to unravel. By only explicitly considering the consequences of some disruption events (for example, those that are claimed) it is not possible to gain an insight into how they interact with other disruptions and this may lead to an incorrect attribution of their consequences.

If we omit the impact of overcrowding, according to the SCL Protocol the Employer change would lead to a claim of 92.1 additional hours, whereas a more appropriate claim is 70 or 64.82 labour hours (a difference of at least 30%). *Only* by considering the consequences of both of the disruption events can an understanding be gained of how one disruption impacts another and therefore an understanding of the different considerations that need to be taken into account when arriving at the most appropriate claim for any individual disruption. This is the proper approach to calculating the "additional loss and expense over and above that which would have been incurred were it not for the disruption events" (SCL Protocol: 44) so that the number of hours attributed to a disruption event is not distorted by the impact of another disruption events. "The objective of a disruption analysis is to demonstrate the loss of productivity and hence additional loss and expense over and above that which would have been incurred were it not for the disruption events for which the Employer is responsible." (SCL Protocol: 43) – this objective can only be achieved if an explicit analysis of the interaction between disruptions is undertaken. In our example, the impact of overcrowding shows that some consequences on a project are created by a combination of disruptions and thus all disruptions contributing to the consequence need to be considered and understood to be able to consider how blame should be attributed.

In summary, for the example presented in this paper the attribution of hours to the Employer advised by the SCL Protocol is more than the hours that are attributed to the Employer when removing the impact of the Contractor induced disruption event. We have shown how using the advice from SCL produces a bigger claim than when account is taken of the impact of under-estimation on rework, and so the SCL Protocol can lead to mis-attribution of blame. This mis-attribution occurs because the two disruptions interact (Cooper and Reichelt, 2007), and unless the impact of the interaction is recognised explicitly mis-attribution occurs.

Indeed, for most disrupted projects, the interaction between disruption events are even more complex than indicated above because they generate feedback where a disruptive event causes management to accelerate the project, which in turn generates consequential disruption (Graves, 1989; Howick and Eden, 2001; Williams et al., 1995). This creates a dynamic in the system where the feedback sustains disruption. The 'rework cycle' is perhaps the best-known feedback dynamic where the amount of rework is determined by the quality of the work being undertaken (Cooper, 1993). However, quality of work will be impacted by disruption events and the additional rework created increases the amount of work to do and thus management accelerate the project to accommodate for this additional work which causes further disruptions and further rework.

3. Explicitly acknowledging feedback in projects: System Dynamics simulation

System dynamics simulation modelling is one established approach to seeking to unravel the complex dynamic consequences of disruption events in complex projects (for example, Ackermann et al., 1997; Cooper 1980; Cooper, 1997; Godlewski et al., 2012; Lyneis and Ford, 2007; Rodrigues and Bowers, 1996). A system dynamics model focuses on explicitly acknowledging the role of feedback and so is particularly appropriate when i) a contractor is forced to accelerate a project in order to maintain contract completion date and the acceleration actions consequently disrupt the project further, and ii) where a rework cycle is evidenced. System dynamics simulation modelling is a method that starts "with the identification and description of an event (a cause) and thereafter seek to establish its impact (the effect) – these are cause and effect type analyses" (SCL Protocol: 32). The method seeks to establish the cause-effect relationships/network between all aspects of a project and then quantify these relationships.

For example, often there are disruptions to a project that occur very early on in a project such as a basic or preliminary conceptual design being incomplete at the start of the project. A disruption of this type can introduce design uncertainty into the management of the project for both employer and contractor. In this situation the contractor may be unable to produce the quality of documents expected by either party, but in order to progress the project these documents are delivered to the employer for approval. This situation leads to the employer taking longer than expected to approve the submitted documents and in addition means that the employer returns the documents with more queries and comments than planned for by the contractor. As a result, the design uncertainty is reinforced – a vicious cycle and feedback dynamic. A dynamic of this type will create rework and so a rework cycle. It is this type of situation that System Dynamics simulation models can capture with ease.

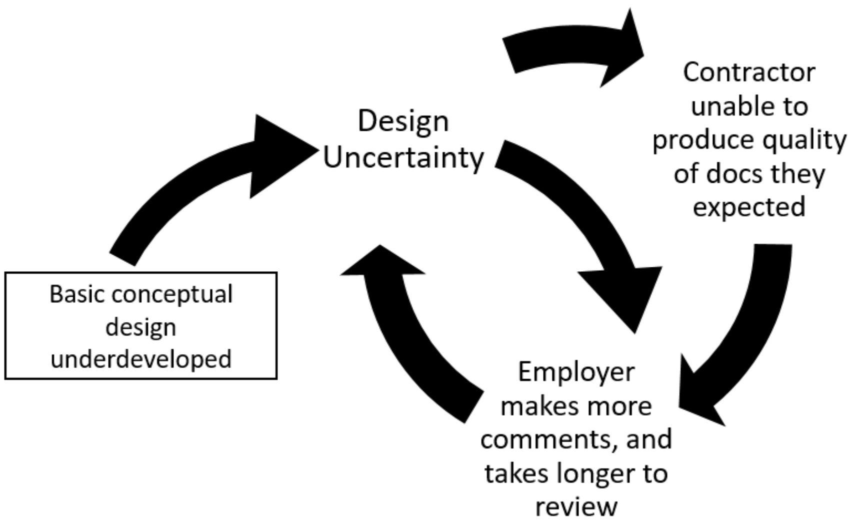

Figure 6: Feedback in Disrupted Projects

Figure 6 shows an example of the consequences of a disruption event generating two vicious cycles. In this example the triggering of the feedback loops follows from an early event: basic conceptual design underdeveloped. However, by the time blame is in dispute two other disruption events will have been established: the contractor claims the impact of the employer making more comments and taking too long to review; and the employer claims the impact of the contractor producing poor quality documents on their own review resourcing. As figure 6 shows, the interactions are complex, and could both be the consequence ONLY of the initial disruption, and so the ONLY legitimate claim might be from the employer to the contractor. Of course the contractor may produce poor quality documents not just because of design uncertainty, and the employer might make more comments than is reasonable not just because of design uncertainty.

When using a system dynamics simulation model the SCL Protocol states: "System dynamics modelling: this is a computer simulation approach using specialist software to produce a model of the disrupted project. That model replicates the complex network of relationships and interactions that influence labour productivity and rework including the various stages of the project (design, approvals, procurement or manufacturing, installation, construction, commissioning and taking over), the different parts of the works, workflows and project participants, and the direct effects of the claim events. The model reproduces the actual labour hour expenditures (including the as built programme and added variations and other changes). *The project is then re-simulated in the absence of the claim items resulting in a 'but- for' model.* The robustness of the conclusions derived from this analysis is dependent upon: (a) the accuracy and completeness of the source input data and hence the quality and availability of project records; (b) the reasonableness of the analyst judgements in establishing the model; and (c) the transparency of the analytical process carried out by the specialist software. Given these challenges and the complexity and cost involved in carrying out this analysis, it is not as commonly used as other methods in calculating loss of productivity" (our emphasis).

As the above approach requires the model to reproduce the actual labour hours on the project and the labour hours excluding the claim items, this only requires an explicit understanding and modelling of the claimed events. However, we have demonstrated in our simple example, with no feedback, that without an adequate explicit understanding of the story of the project a claim cannot be assessed. Without an adequate story that explicitly explores *all significant disruptions* and *their impact on one another* it is not possible to *understand and assess how the project would have unfolded without any particular disruptions.* The assessment requires *explicit* modelling of *all* significant disruptive events and their impact on both the employer and contractor, whereas the protocol focuses only on claim items.

4. Discussion and Conclusion

Whilst the SCL Protocol is not wrong in presenting the 'but-for' analysis as a way of establishing the impact of the disruption caused by one party, it can be misleading. As our example demonstrate the Protocol focuses simply on the 'but-for', without explaining that the ‘but-for’ analysis must be determined by taking full and explicit account of the impact of the disruptions caused by the other party. Unless the analysis reflects the interaction between disruption consequences then a simple but-for analysis is likely to mis-attribute blame. In our example, the mis-attribution was in favour of the contractor, but this misattribution could be in either direction.

It is noteworthy that under-estimation is a common trigger for disruption at the start of a project (Segelod, 2018) where the task of unravelling the ramifications of under-estimation from subsequent disruptive consequences is immense. Indeed in our experience, which includes the analysis of 10 major projects as a part of dispute claims worth many billions of dollars, the most significant, and common, disruption that interacts with future disruptions is that of under-estimation. For example, Memon et al. (2012) report that two of the major causes of construction cost overruns in Malaysia are (1) “inadequate planning”; (2) “inaccurate time and cost estimates”. As Eden et al (2005) have argued in their analysis of the ‘amoebic growth’ of project costs, under-estimation often occurs when a contractor ignores the careful estimates produced by their own estimators and senior management become too optimistic about productivity improvements that can be made. The original estimates become modified for commercial reasons and subsequently used for planning purposes (Cushman et al., 1996: 2-16).

In our first example, we showed how the disruption of under-estimation by the contractor interacts with a later disruption caused by the customer, leading to a supposed cost of the later disruption that is over-estimated. In the second example, we showed that with only a little more complexity in the interaction then blame now becomes extremely difficult to allocate with certainty. Although there is some acknowledgement in the literature of the interaction between disruptions, there is no presentation of the issues of unravelling these interactions and the potential complexity in establishing blame. Both of these examples are extremely simple and yet the analysis is demonstrably not straightforward. It is our firm view that as long as the SCL Protocol does not reflect these issues then it is offering misleading advice. At the least the Protocol should say that a 'but-for' analysis must account for interactions between the disruptions of the parties involved in a project.

We are particularly concerned about the section of the protocol that addresses the use of System Dynamics simulation models - specifically seeking to account for feedback and vicious cycles such as the well know rework cycle. We suggest a revision to the Protocol, so that the advice is less likely to be misleading and so lead to mis-attribution of blame (the revisions are shown in italics):

> System dynamics modelling: This is a computer simulation approach using specialist software to produce a model of the disrupted project. That model replicates, *over time,* the changing complex network of relationships *between the state of different aspects of the project:* interactions *and decision making processes* that influence labour

productivity and rework. *The model is likely to include*: (a) the various stages of the project (*planning*, design, approvals, procurement or manufacturing, installation, construction, commissioning and taking over), (b) the different parts of the works, workflows *and project management*, and (c) the direct *and indirect* effects of *disruption* events. *Dynamic simulation attempts to model the project in a way that allows the impact of specific disruption events on the project to be identified. The simulation shows how the consequence of disruption events interact and so permits 'what-if' explorations by comparing a simulation in which the disruption event is included, with a simulation in which the disruption event is not included. As the number of labour hours that accrue due to a claimed disruption can be impacted by the existence of other significant disruptions, the project is simulated including all significant disruptions and also in the absence of (i) claimed disruptions (ii) non-claimed disruptions and (iii) both claimed and non-claimed disruptions. These explorations allow for the sole contribution of a disruption event to be quantified, without being impacted by non-claimed items.*

This paper has shown that analysing a disrupted project requires a full acknowledgment that fairly establishing blame must require an explicit analysis of the interaction between the consequences of disruptions. It is usually the case that both contractor and employer are culpable and so separating the interaction between the disruptions of each party is crucial. Such analyses are themselves complex, and, as our example illustrates, will often lead to an unclear conclusion. Ignoring the need to account explicitly for interactions between the consequences of disruptions will undoubtedly lead usually to the wrong conclusion.

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