07 So you are still concerned about using System Dynamics? Don't be!

Let us assume that you are (or will at some point be) involved in a dispute about disruption, and you need to choose the right method to assess it. If you have been following this series of articles, you will, by now, know about System Dynamics… but you have never used it before, and you wonder whether its results will be accepted by the other party, the arbitration tribunal or the court.[1]

This is a perfectly valid concern – so let us look at the matter in more detail, and see if we can put your fears to rest. To do this we will focus on the use of SD in formal dispute settings (arbitration or litigation), since the requirements in informal settings (negotiations) will be much less stringent. Also, to keep matters simple, for the time being we will focus solely on disruption, and we will expand our reasoning to cover delay in a later article in this series.

Three steps towards acceptance

In order for a disruption claim to be successful, the methodology used to produce the disruption assessment needs to overcome three sequential hurdles:

1. The assessment needs to be admissible as evidence – the court/tribunal needs to agree to consider it.
2. The method used needs to be effective – i.e., it needs to be able to prove the case.
3. The assessment results need to be accepted – the claim needs to convince the court/tribunal that it has proven the case.

So: Can System Dynamics help you accomplish these three things?

1. System Dynamics delivers admissible evidence

While in formal dispute settings judges and arbitrators have some discretion on the type of evidence that they will admit, the general rule for admissibility in most jurisdictions is that a party may submit any evidence to prove its claims (including expert/technical evidence like a disruption assessment), as long as it is:

a) Relevant and material to the question in the proceedings; and

b) Within the expertise of the expert.

You would think that any disruption assessment method would automatically be considered "relevant" in a disruption claim… but if you did, you would be wrong: In order for it to be considered "relevant", the method would still need to fulfil some additional requirements.

These additional requirements have been best codified in the U.S.: In 1993, the Federal Rules of Evidence regarding expert evidence (rule 702) were clarified by the court's opinion in the case of Daubert v. Merrell

[1] Of course, you may also be concerned about other issues: The time and cost required for the assessment, the data needed to carry it out… But these issues will be addressed in later articles in this series.

Dow Pharmaceuticals[2], which determined that expert evidence should be "ground[ed] in the methods and procedures of science". More specifically, the court laid out the following set of requirements:

Requirements for Admissibility	System Dynamics
The validity of the theory underlying the assessment should be testable	The "hypothesis" of the case represented by an SD simulation model is tested by checking its ability to closely reproduce the as-built performance of the project.
The theory should have been subjected to peer review or publication.	The application of SD to disruption and delay assessments has been subjected to peer review in numerous academic journals.
Known or potential error rates should have been determined.	The "error rates" of any SD assessment can be calculated by checking the deviation between the simulation and the project data, and also via a 'Fit-Constrained Monte Carlo' analysis (which we will describe later in this article.)
There need to be standards that control how the methodology is applied.	Ongoing use for over forty years has developed a standard way for applying the methodology.[3]

Table 1: Requirements for admissibility of expert evidence, and how System Dynamics fulfils them.

As shown, System Dynamics fulfils these admissibility requirements better than any other disruption assessment method currently used in the industry.[4]

System Dynamics is a fully admissible methodology for assessing disruption in most jurisdictions worldwide.

2. System Dynamics is a fully effective method

In an earlier article in this series, we described the three requirements that an assessment methodology needs to fulfil to be able to prove its case. These are summarised again in Table 2 below, together with a description of how System Dynamics fulfils each one: [5]

---

2 Daubert v. Merrell Dow Pharmaceuticals, Inc., 509 U.S. 579 (1993). The Daubert ruling affected only scientific knowledge, but this was later extended to also include technical analyses by the ruling in Kumho Tire Co. v. Carmichael, 526 U.S. 137 (1999).

3 For more information on how to use System Dynamics to assess disruption con complex projects, please see our earlier article on this matter: "05 Applying System Dynamics to Assess Disruption and Delay: The 'D3A' Approach.". This article, like all others in this series, can be found on our website at: https://www.constructiondynamics.global/publications.

4 If interested in the topic of the legal admissibility and acceptance of SD, you may also check out our paper on the matter, "Admissibility of System Dynamics Evidence in Disruption and Delay Claims. On the Use of the System Dynamics Methodology in International Arbitration.", which you can find on our website, at: https://www.constructiondynamics.global/insights.

5 For more information on the 'Triad of Proof', please see our earlier article on this matter: "04 Proving the Disruption Case: The 'Triad of Proof'".

Triad of Proof requirements	System Dynamics
Establish causation, describing the causal chain linking the damages being claimed to the event(s) that triggered them.	SD's simulation models are based on a causal framework, and this allows users to trace in the model the consequences stemming from the events in the claim, all the way to the disruption they ultimately caused.
Address liability, isolating the consequences of the events for which the other party is responsible.	The assessment process[6] using SD allows us to distinguish the ultimate consequences of each separate event or group of events, which thus clearly allows us to separate the consequences resulting from employer-risk events from those for which the contractor himself is responsible.
Quantify damages, capturing the totality of the damage (additional cost) caused by the events in the claim.	SD simulation models capture all the key mechanisms that produce disruption on complex projects, including their non-linearity and the cumulative effects that occur when multiple disruptive events affect the project simultaneously. The models can also include all types of disruptive and/or delaying events, they are applied at the project level, and they capture what actually occurred in it. In other words: SD simulation models capture all the actual additional project costs that were caused by disruptive events.

Table 2: The 'Triad of Proof', and how System Dynamics fulfils it.

In conclusion: The System Dynamics methodology is perfectly capable of proving your disruption case.

3. System Dynamics delivers credible evidence

Let us now consider the "human factor" in the equation, the true reasons why people are still concerned about the usefulness of System Dynamics in disruption claims. What are we talking about? We are talking about the fact that, in spite of all the valid points made above, contractors, engineers, clients, judges and arbitrators are human, and as such they are reluctant to (a) change the way in which things are done, and (b) believe in (or accept) something that they do not understand, just because an expert said so.[7]

Overcoming this "human factor" requires a three-pronged approach.

3a. Industry acceptance of System Dynamics

Because the methodology is still relatively unknown in the construction and engineering industries, people tend to make the assumption that they would need to be some kind of trailblazer to use System Dynamics – but this is not the case! System Dynamics has been used to assess disruption and delay since 1976, on hundreds of projects in all kinds of industries, and all over the world. And, SD assessments have also supported

[6] See footnote #3.

[7] Interestingly enough, in our experience arbitrators and judges have been rather amenable to accept System Dynamics assessments when presented to them, whereas clients, contractors and/or other consultants are generally more reluctant to produce them in the first place.

approximately 50 major claims, which (when properly conducted) have achieved significantly higher success rates than the average reported for conventional disruption assessment methods.

Track record in disputes

While information on most disputes remains confidential, some information about the use of System Dynamics is available in the public domain. For example: The first claim that was supported by an SD-based assessment ended with a settlement for the claimant of $447 million, a sum unheard of at the time.[8]

Also, some disputes in which the author(s) of this article were involved include:

a) The dispute over disruption and delay on an acrylonitrile plant in Chocolate Bayou (Texas) – the jury verdict in this case awarded Fluor (the contractor) $34.5 million in design and construction costs, an amount "very close to that requested by Fluor during the trial".[9]

b) A dispute regarding the design and construction of two drill-ships by Irish shipbuilder Harland and Wolff settled in 2003 for €110 million (plus potentially €10 million more for arbitration costs), on a total project cost overrun of €300 million.[10]

c) In 2014, an arbitration tribunal in the MENA region said the following when it awarded 100% of the disruption costs being claimed in a large commercial development project[11] (emphasis added):

> *"The Tribunal finds that the […] System Dynamics analysis [..] is appropriate and that its findings are reasoned and supported by evidence. Accordingly, **the Tribunal accepts the conclusions** […] that: (i) Employer-responsible [events] caused labour hour overruns of 46.4 million [man-hours], for 68% of which Respondent is responsible"*

Finally, this case about a U.S.-based project was reported in Lexology in 2019[12] (emphasis added):

> *"In a recently decided private arbitration case involving the construction of commercial vessels, the contractor retained a system dynamic [sic.] modeling expert to prove and quantify the disruption attributable to the vessel owner's late and changing design."*
>
> *"[T]he arbitrator […] found that the system dynamics expert and the modeling contained in the expert report and testimony "provided a reliable indication of the disruption damages." An award of over $13M was granted to the contractor for disruption part of the overall claim, which was **over 70% of the amount claimed** through the system dynamics analysis for disruption."*

Industry recognition

Almost exactly forty years after System Dynamics was first used to support a dispute, in 2017 the Society of Construction Law included System Dynamics in the list of recognised disruption assessment methods in the

8 "Litton Ends Long Fight With Navy", New York Times, June 21st 1978.

9 "Fluor Victorious in Project Trial", https://investor.fluor.com/news-releases, September 16th 2002.

10 "€110m for Harland and Wolff as dispute ends", https://www.independent.ie/business, February 2nd 2003.

11 Please note that confidentiality obligations prevent us from providing a reference.

12 "Quantifying Disruption Damages Using Systems Dynamics Modeling", https://www.lexology.com/library, May 31st 2019.

Second Edition of its "Delay and Disruption Protocol". More specifically, it included SD in its list of the preferred type of disruption assessment methods, "project-specific studies", as shown in Figure 1 below:

Productivity-based methods	Cost-based methods
1. Project-specific studies:	1. Estimated v incurred labour
(a) Measured mile analysis	2. Estimated v used cost
(b) Earned value analysis	
(c) Programme analysis	
(d) Work or trade sampling	
(e) System dynamics modelling	
2. Project-comparison studies	
3. Industry studies	

Figure 1: List of disruption assessment methods, SCL Protocol.[13]

Here are some other examples of the recognition given to SD by the construction and engineering industries:

- The "Wiley Guide to Managing Projects" was published in 2004, a chapter of which was written by System Dynamics experts and from a System Dynamics perspective.[14]
- In 2009, the Engineering Construction Risk Institute ('ECRI') named System Dynamics "industry best practice" to deal with the secondary impacts of project changes.
- In 2017, the joint second prize in the Society of Construction Law's Hudson essay competition was awarded to a paper describing the use of System Dynamics in disruption disputes.[15]
- In 2018, "Construction Law International" published an article comparing the Measured Mile and System Dynamics.[16]
- In 2020, the American Society of Civil Engineers ('ASCE') awarded its prestigious Thomas Fitch-Rowland award to a paper that used System Dynamics to look at disruption caused by out-of-sequence work.[17]

Beyond these examples, the words "System Dynamics" are appearing more and more often in publications and presentations by industry experts (claims specialists and legal experts), and professional organisations. However, as they say, "*the proof of the pudding is in the eating*", and for us the "definitive" (albeit subjective) proof that System Dynamics is becoming part of the industry mainstream is the skyrocketing number of

[13] "Delay and Disruption Protocol", Society of Construction Law, 2nd Edition (2017), p.46.

[14] "The Wiley Guide to Managing Projects", edited by Peter W. G. Morris and Jeffrey K. Pinto, 2004, John Wiley & Sons, Inc. Chapter 31, "Project Changes: Sources, Impacts, Mitigation, Pricing, Litigation, and Excellence", was written by Kenneth G. Cooper and Kimberly Sklar Reichelt.

[15] Goodchild, R., "Proven by Computer? System Dynamics and Disruption Claims", September 2018, Society of Construction Law.

[16] Voigt, A., Khalaf, M., Clements, A. and Mattar, S.: "Assessing disruption on construction projects – 'measured mile' versus 'system dynamics': a comparison", Construction Law International, Vol 13 Issue 3, November 2018, IBA International.

[17] Abotaleb, I., and El-adaway, I., "First Attempt Toward a Holistic Understanding of the Interdependent Rippled Impacts Associated with Out-of-Sequence Work in Construction Projects: System Dynamics Modeling Approach", Journal of Construction Engineering and Management, 2018, 144(9).

attendees to our webinars and presentations who were already aware of the methodology, and keen to learn more about it.

3b. Accepting model results: Peeking inside the 'black box'

The biggest concern of people deciding whether to use System Dynamics to prove their case is that the judge(s) that will decide their case may see the simulation model as a "black box", something so complex so as to make it virtually impossible to understand what is happening within it.[18] And, clearly, without understanding there can be no acceptance.

As is the case in most misunderstandings, at the core of this concern lies a grain of truth: SD simulation models are indeed complex – not because their different parts are difficult to understand, but rather because they contain so many parts and they are all interconnected. What does make this situation a misunderstanding, though, is the implicit assumption that non-experts (contractors, engineers, lawyers, judges) need to master all the models' complexities in order to achieve sufficient understanding to decide on the validity of the models' results. This assumption, thankfully, is wrong.

So, how do System Dynamics experts give project managers and other stakeholders a peek into the figurative "black box"? They do so by weaving the model logic and the simulation results into a detailed narrative that explains what happened on the project… and why. Indeed, in our professional experience, these "project narratives" can be hugely compelling: Time and time again we have seen the lightbulb going on in people's minds, when they see how System Dynamics' causal framework finally allows them to assemble the multitude of project data items into a consistent framework, in a way that makes sense.

A good example of this occurred on a recent claim in the Middle East: During a joint review session, project managers were shown how adding the testing and commissioning phase to the project simulation model had allowed it to reproduce the slowdown in construction progress that occurred right at this time. With only a little prompting, the managers quickly understood that the slowdown in progress could be explained by people focusing more on doing rework during this period; and, they further understood that this, in turn, was because the testing process had discovered a raft of errors and omissions committed months before, but that had hitherto remained undetected. This explanation immediately clicked with the managers, and not one of them felt the need to understand the equations in the simulation model to be convinced that it was faithfully recreating what had really happened on the project.

Returning now to our thread, our earlier description may have made it look like it is the SD expert who produces this "project narrative", and then explains it to the remaining stakeholders in the claim. In reality, though, the narrative is developed through the interaction of all claim stakeholders, with each one offering his/her particular information or expertise, and the SD simulation model acting as the testing bed that determines whether the project narrative is OK as it is, or whether there are still pieces of information that do not quite fit. Thanks to this interaction, when the narrative is finally presented to the other party or to a tribunal, it will have become the most consistent, compelling and plausible explanation of what happened on the project… and why.

[18] In informal dispute settings, replace "judge(s)" with "opposing party".

3c. Gaining confidence in model results

Confidence in the results of a System Dynamics assessment comes from several different sources – and some of these we have already discussed:

a) The model's good calibration, that accurately re-creates the project's actual performance;

b) Our ability to plainly explain the logic of the simulation model, and how this logic, together with project data, shapes the "project narrative" and determines the assessment's results.

However, there is still one last hurdle that must be cleared to ensure confidence in our efforts: Even if people agree that the model and the results make intuitive sense, they may still wonder: How can we be sure that these results are indeed "correct"? I.e.: How can we be sure that there could not be a different model that would (i) also match the project data, yet (ii) lead to radically different results… and (iii) still feel as "correct" as our current model?

Sorry… this was actually a trick question: Science cannot prove a negative. So, if we want an answer grounded in science, then we need to re-phrase our question to something like this: How (un)likely would such an alternate model be… and how different could its results reasonably get?

But this question is still too broad, and so in order to reach an answer that we can work with we will first need to narrow it down a bit – by assuming that the causal model underlying the simulation model is valid. (Since simulation models based on this framework have been successfully used to assess hundreds of different projects over the last four decades, this seems like a fair assumption to make.)

This, then, narrows down our question to the following: How sure can we be that the causal framework was implemented soundly when using it to assess the disruption that occurred in our project? And in order to be able to answer "Very sure!", the field of System Dynamics has done the following: It has adopted "best practice" procedures to set up and calibrate simulation models, and it has developed a series of technical tests to check that these models function properly.

We already discussed the process of how to use SD in disruption claims in an earlier article in this series[19], and we hope to expand on some of the more interesting and/or controversial steps (like, perhaps, calibration?) in other articles in the near future – thus, we will not go over these issues again here.

Describing in detail the array of technical tests performed to ensure the validity of System Dynamics simulation models also exceeds the scope of this article – if interested, the reader may find a thorough discussion on the matter in John Sterman's "Business Dynamics" textbook[20]. Suffice it to say here that these tests cover all key aspects of modelling. For example:

- Variables are checked for "dimensional consistency" (so that their units of measurement are all consistent with each other);
- The model is tested under "extreme conditions" (to ensure that its behaviour remains reasonable);

[19] Please see our earlier article in this series: "05 Applying System Dynamics to Assess Disruption and Delay: The 'D3A' Approach".

[20] Sterman, John D., "Business Dynamics: Systems Thinking and Modeling for a Complex World", Irwin McGraw-Hill (2001), p.858 and on.

- Parameter consistency is checked to ensure the consistency of all modelling assumptions made;
- Models are simulating using different time increments to find the one that delivers the most accurate results;
- Etc.

Of course, discussing modelling approaches and technical tests is often beyond the ability of contractors, engineers and lawyers, and also beyond that of members of a tribunal. Therefore, sometimes independent SD experts (generally from the world of academia) are called in to reassure claim stakeholders and validate the adequacy of the simulation model, and that of the method followed to produce it.

The Fit-Constrained Monte Carlo analysis

If all the previous checks and procedures are followed, the likelihood that the claim calculation may be way off should be minimal. However, sceptical minds could still ask the following question: Even if we accepted all of the above, who can assure us that a different SD expert, following the same standard process and using the same project data, would not have calibrated the model differently (still accurately re-creating the project's as-built performance), and that thus he/she would have arrived at a completely different claim value?

The scientific way to determine how unlikely this scenario would be is the "Fit-Constrained Monte Carlo" ('FCMC') analysis, which is graphically depicted in Figure 2:[21]

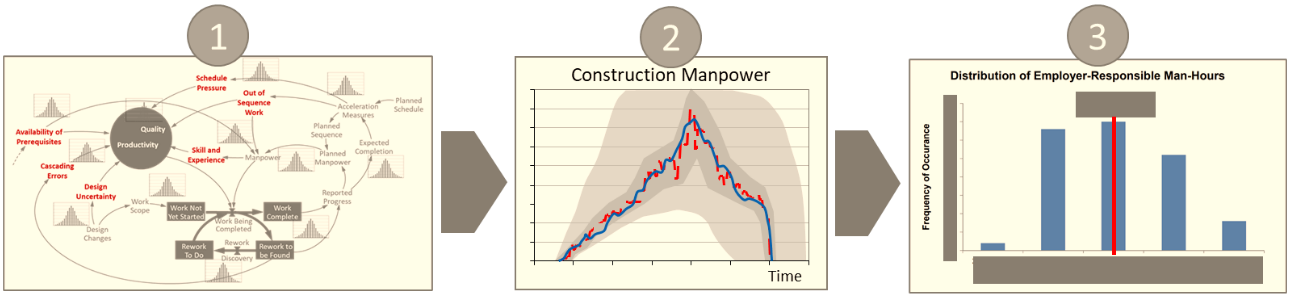

Figure 2: The Fit-Constrained Monte Carlo analysis process.

FCMC analyses consist of three steps:

1. All parameter values in the model not backed up by hard data are allowed to vary randomly within certain pre-defined ranges.
2. The model is run, producing a new simulation. If the simulation is "close enough" to the as-built data for the project, the simulation is deemed a valid "Alternative As Built" scenario, and it is kept. If this is not the case, the simulation is deemed "not valid", and it is discarded.

   Steps 1 and 2 are then repeated multiple times (tens, or even hundreds of thousands of times), in order to produce a sufficiently large (representative) sample of "Alternative As Built" scenarios.

[21] For additional information on the Fit-Constrained Monte Carlo analysis, please see: "Using Fit-Constrained Monte Carlo Trials to Quantify Confidence in Simulation Model Outcomes", Graham, Alan K., Choi, Carol Y., and Mullen, Thomas W., Proceedings of the 35th Hawaii International Conference on Systems Sciences (2002.)

3. For each "Alternative As Built" scenario, a corresponding "Alternative But For" scenario is run (by removing any respondent-responsible events), and thus an "alternative claim value" is calculated. These "alternative claim values" are then analysed statistically to determine the uncertainty surrounding the claim estimate.

Figure 2 above shows this process graphically – but Step 3 shows the results from an actual FCMC analysis used in international arbitration (properly anonymised.) That analysis showed that the distribution of possible claim values was centred around the base claim estimate (red line), and that (with 90% certainty) claim values could range between -16% and plus 10% of the base value. In other words: the actual value of the disruption caused on this project was highly likely to lie between 84% and 110% of the amount being claimed.

Concluding thoughts

We hope that this article will have shown why and how System Dynamics (when properly applied!) is so successful in construction and engineering disputes. But just to put things into their proper context: Nothing in this article is meant to imply that System Dynamics is always the hands-down perfect choice for all disruption assessments – it is simply arguing that System Dynamics should be considered… and that it may often indeed be the best choice.

And this is precisely going to be the topic that we will cover in our next article in this series: What are the *pros* and *cons* of using the two most sophisticated disruption assessment methods, 'Measured Mile' and System Dynamics?

For more information, please contact us at:
info@constructiondynamics.global
or visit our website:
www.constructiondynamics.global/publications

