Managing Disruption and Delay Risks on Complex Projects

System Dynamics: A Quantum Leap!

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Disruption on complex projects: too many factors to consider...

Introduction

Project management is at once one of the most important and most poorly understood areas of management. Delays and cost overruns are the rule rather than the exception in construction, defence, power generation, aerospace, product development, software, and other areas: cost overruns of 100 to 200% are common, and projects are often delayed to the point where the market conditions for which they were designed have changed. Customer design changes are frequent, generating costly ripple effects which create delay and disruption throughout an entire organization.

Cost and schedule overruns on projects are very insidious: while it is relatively easy to define when a change occurs on a project, its disruptive consequences tend to acquire a life of their own, rippling through the entire project. And, since disruption tends to produce delays and these, in turn, produce additional disruption, it is also extremely difficult to trace and accurately estimate completion dates of heavily disrupted projects.

System Dynamics (‘SD’) is a computer-based simulation method, and it radically changes the way we approach disruption. Its ability to explain why and how disruption and delay arise and spread through complex projects can be used (and is being used) to explore the actual likely performance impacts of a broad range of potential project decisions, thus giving their managers a preview of their actual consequences... before the decisions are made! Thus, System Dynamics helps to prevent and/or manage disruption and delay on complex projects, mitigating their impacts and thus reducing cost and schedule overruns.

System Dynamics has been used for over 40 years to assess and manage disruption and delay on hundreds of the most complex projects, worldwide, and in all industries: construction, oil & gas, aerospace, automotive, shipbuilding, IT systems... Following the inclusion of System Dynamics in the 2nd edition of the Delay and Disruption Protocol of the Society of Construction Law (2017), the general discourse around this methodology in the construction world has focused heavily on forensic applications, supporting disruption and delay disputes. However, most project-related applications of SD have actually been proactive, helping to manage and prevent disruption while projects were still under way.

We believe that a conceptual framework in which System Dynamics models are combined with traditional project management and control tools can provide much needed and useful complementary support, and validate decisions by assessing and quantifying their impacts in a proactive and timely
manner.

**Overruns are almost inevitable in construction projects**

Disruption happens: It is a fact of project life when changes occur. It is a legally recognised set of phenomena that have been established, upheld and refined over many court cases, arbitral tribunals, and dispute negotiations.

In construction, what do we mean by ‘Disruption’? Disruption is understood to mean a reduction in expected productivity of labour and equipment – a loss of efficiency measured in reduced production of units of work within a given period of time.

Over the past 70 years, there have been no systematic improvements in cost and schedule overruns of infrastructure projects, and most complex development and infrastructure projects experience substantial cost and schedule overruns.

Cost overruns in major development projects are common all around the world. Based on a study of 258 transportation infrastructure projects across 20 nations and five continents, 90% did not achieve their planned budget objectives, with cost overruns ranging from 20% to 45%. A review of some 3,500 projects revealed that ‘overruns are the norm, being typically between 40 and 200 percent’.²

![Table showing project names and their corresponding cost overruns](image)

**Overruns on a sample of past major construction projects.**

Please also note that, while the data above refers to cost overruns, it could equally refer to schedule overruns: both really are two sides of the same coin: *delay breeds disruption, and disruption causes additional delays*.³

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Why have overruns been so difficult to foresee, manage and prevent?

Large projects are complex and nonlinear, have long planning horizons, and suffer from complex interfaces and changing conditions throughout their long lives. Disruption is difficult to assess because it is dynamic: the disruptive impact of an event will depend on the conditions on the project:

Science has not yet provided us with a way to measure just how much less productive the average worker will be when faced with a set of debilitating circumstances, none of which ever occur in exact form or combination the same way twice, although there are some supposedly empirical studies which claim to shed light on the problem.\(^4\)

Also, projects typically suffer from a multitude of disruptive events, many happening simultaneously. The disruptive interaction among multiple events has been hitherto very difficult to understand and analyse:

Frequently, different factors interact to influence productivity on the specific project. Although many studies have been done to determine, or measure, the effects of specific factors such as, temperature, overtime, crowding, and learning curves upon labour productivity, there has not been significant research for measuring how various effects interact.\(^5\)

On projects, the efficiency achieved on work done today depends on what happened before: if you have to perform rework today, it is because somebody made a mistake on a previous task; if someone makes a mistake, it may be because that person was pushed to complete a task in an unreasonably short period of time, to make up for previous delays; if the project is delayed, it could be... because someone could not perform a planned task because he had to do some rework first...

\[
\text{Disruption} \quad \text{Delay}
\]

Delay leads to disruption, and disruption leads to more delay.

This “circular” causality shows how today’s events are the consequence of those that happened yesterday, and the cause of those that will happen tomorrow. This is a fundamental characteristic of projects, but traditional management and control systems are completely unsuitable to deal with it. For this reason, disruption has often been left ‘unexplained’ on complex projects, it has been something that ‘just happens’, nobody quite knows how or why... and so preventing and managing it has been rather unsuccessful. And of course: by ignoring disruption, delay (and damages) have been systematically underestimated.

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Construction dynamics drive project performance

Productivity and work quality on complex projects are influenced by a never-ending list of performance factors (as several professional organisations have confirmed\(^6\)). Some are dependent on external conditions (like, for example, the weather), but most refer to internal project conditions: the ability to follow the appropriate sequence, the experience of the crews, etc... To show the extremely nonlinear performance that can be generated by these factors, in this section we will show how a small sample of them reacts to a single disruptive event. To keep the explanation more manageable, we will focus on only five of these factors:

![Graph showing relationships between different factors affecting productivity](image)

A small sample of factors that can impact efficiency on complex projects.

To explain how disruption arises and spreads on projects, we first need to describe how projects are executed. At a very high level, projects are executed by adding manpower, working at a given productivity – and manpower is adjusted as progress is made based on perceived progress as measured against the plan:

![Graph showing a perfectly planned, perfectly executed project](image)

A perfectly planned, perfectly executed project.

Now, let us assume that this project suddenly is affected by a significant external event that is well beyond the Contractor’s control (e.g., as in the Covid-19 pandemic): an event that forces the contractor to temporarily demobilise, and later remobilise, the majority of the workforce.

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The first consequence of the project’s demobilisation is a slowdown in progress, which eventually leads to a critical delay to the project and to the need to implement acceleration measures: For example, the project managers may decide to apply schedule pressure to the work crews, to get them to work faster. Note that other typical acceleration measures (like applying additional manpower and working out-of-sequence) may not be feasible at this time because of the low availability of labour caused by the demobilisation – so all in all, the project will probably still be falling behind schedule.

Immediate disruptive consequences of de- and re-mobilisation.

While demobilised and throughout the remobilisation process, the available workforce will be in a disrupted state, working out-of-sequence: many of the crews still (or already) available will not be fully effective, because their work will depend on that of other crews that may not yet be on site. And, during the remobilisation, the workforce will need to go through a learning curve, to reacquaint themselves with the project and its processes, and this will lead to inefficiencies and thus further disruption.

Inefficiency factors lead to additional rework, and thus additional disruption and delay.

But... this is still not the end of the story – because all these factors leading to inefficiencies will also cause the workforce to make additional mistakes. These will not be done on purpose, of course, and at first, they will not be recognised as mistakes. While hidden, they will create additional confusion and
lead to even more mistakes and inefficiencies ... and then weeks, months or even years later... the mistakes will be found and then the project will be facing a mountain of rework, appearing apparently out of nowhere.

Finally, the demobilisation will also affect design and procurement, which will cause a lack of drawings and materials that will again impact construction efficiency... and so the story goes on and on.

Bottom line: one set of direct consequences of one single event leads to consequences that will keep rippling through the project a long time after the de-mobilisation and remobilisation are complete. And, their impact will also spread to all areas of the project.

Now, we need to factor in all the other disruptive events that will also affect the project while the above-mentioned dynamics are unfolding; such as the numerous design changes, the site access restrictions, the late reviews by the Engineer, etc. ... This is the reality of projects: systems made up of a lot of moving pieces, all interacting with each other, all the time. How could we possibly keep track and make sense out of it all? Well, we cannot – but computers can.

**Dynamic Project Management (‘DPM’)**

Dynamic Project Management (‘DPM’) uses System Dynamics (‘SD’), a computer-based simulation method that captures *why* and *how* overruns and delays arise on complex projects, allowing managers and stakeholders to explore the actual likely outcome of a broad range of project decisions:

- The scenarios produced by DPM are more *accurate* and *realistic*, and support better decision-making:
  - They are *consistent* with all the known information about the project.
  - They do not simply extrapolate past performance into the future, but instead take into account the *full non-linearity* caused by the dynamic nature of project dynamics.
- The scenarios produced by DPM allow you to rigorously explore:
  - The outcome of the widest possible range of high-level management decisions; and
  - The full impact of the widest possible range of unplanned events and conditions (like stakeholder changes, natural disasters, etc.)
- DPM provides an analytical platform for project managers and stakeholders to reach a common understanding of past project performance, and to explore likely outcomes of prospective alternative strategies for future actions.

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**The ‘Change Impact Assessment’ System (Fluor Corporation)**

In the early 2000’s, the Fluor Corporation decided to use System Dynamics as the basis for a new tool that would assess the full time and cost impact of any new changes proposed by Fluor’s clients, on any of their projects.

Once set up, the system allowed the company to fully price *in advance* the cost of each customer request, eliminating costly disruption and delay disputes. Also, the system allowed the company to find ways to mitigate the cost of the changes, saving money for itself and for its customers.

All in all, Fluor claims to have saved over $800 million over a five-year period.
Making a hard decision on the “Pollard Park” project

The Pollard Park project has been subject to a temporary demobilisation of its workforce, and management needs to decide on the best re-mobilisation strategy. Specifically, management is tempted to re-mobilise as quickly as possible, but fears that this might cause much disruption, and turn out to be counter-productive.

The team had been using a System Dynamics model to support decision-making on the project, and now they used it to explore this particular option. To do so, they compared the base simulation scenario (which assumes a rapid re-mobilisation) to a “what if...?” scenario proposing a slower re-mobilisation.

The outcome of the analysis was counterintuitive... at first: it showed that a slower re-mobilisation would not only be more efficient (saving costs) ... but that it would also allow for an earlier project completion date! After a thorough review of the findings of the analysis and of the state of the project, the consensus view of the management group was to use a “slow” re-mobilisation approach.

Why? Because the analysis highlighted two realities of the project, which are known to both managers and stakeholders... but whose impact has been overlooked so far:

- An aggressive re-mobilisation would lead to subcontractors returning to site “semi-randomly”, since not all would be able to re-mobilise at the same speed.
- A quick re-mobilisation would also require an acceleration of the supply chain... which was already stretched before the demobilisation event and has fallen farther behind since.

The analysis showed how these (and other) factors would lead to severe disruption, causing loss of productivity. There would also be significant amounts of rework, and so much chaos that the maximum size of the workforce that could be used would be limited.

The conclusion was clear and, in hindsight, not counterintuitive at all: a slower ramp-up would delay progress at first but, by drastically reducing disruption, it would allow for much better performance later on – eventually saving both time and money.
System Dynamics – A proven computer-based methodology

While System Dynamics has only recently become a well-known methodology to support construction claims, its history is based in academic research and decades of high-profile construction projects.

Created by Professor Jay Forrester at Massachusetts Institute of Technology’s (MIT) Sloan School of Management in the late 1950s, System Dynamics (SD) was later described by MIT’s Professor John D. Sterman as:

“System Dynamics is grounded in the mathematics of dynamic systems and engineering control theory. Its models are particularly suited to capturing the interactions, feedbacks, time delays, nonlinearities, and impacts of human factors that are of central importance in determining the dynamics and outcomes of complex socio-technical systems, that is, systems in which human behaviour plays an important role and in which people interact with physical and technical subsystems. Such systems include organisations, businesses, markets, economies - and large-scale complex projects that have been delayed and disrupted.”

SD was initially applied to the study of global macroeconomic and development forces, but it has been used to support complex projects since 1976. Over the last four decades it has been used to analyse the performance of hundreds of global construction, aerospace, engineering, automotive, oil and gas, software and shipbuilding projects, and it has been the basis for over 40 major disruption and delay claims.

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System Dynamics: an established subject of academic study, taught at universities around the world.  

System Dynamics: a well-regarded method in the construction world.

A sample of professional journals featuring articles on SD.

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8 System Dynamics Society System Dynamics Degree Courses Around the World: Where Can I Study System Dynamics?  
https://www.systemdynamics.org/degree-courses
Construction Dynamics Solutions LLC

Construction Dynamics Solutions (‘CDS’) is a specialised consultancy dedicated to the assessment of disruption and delay on major construction projects. CDS’ analytical approach, ‘Dynamic Disruption and Delay Analysis’ (‘D3A’), brings together a profound understanding of the construction world and leading-edge expertise in System Dynamics simulation.

Since its inception in 2017, CDS has been retained to support several major disruption and delay claims in the MENA region, it has published papers and articles in prestigious journals like Construction Law International, and it is routinely invited to make presentations on the application of System Dynamics to disruption and delay disputes at international conferences and events.

CDS is led by Dr. Sam Mattar and Mr. Alexander Voigt:

With over 40 years’ experience in construction industry, Dr. Sam Mattar has been engaged as a professor, Chief Technical Advisor to UNCHS (HABITAT), programme director and project / contract manager, engineer, claims specialist, and arbitrator in North America, Europe the MENA region and Africa. Dr Mattar worked for the United Nations, for the World Bank, and before forming CDS, he was Senior Contracts Manager for CCC (an ENR Top-20 International Contractor.) Dr Mattar has published over 40 papers in refereed journals, and he is the recipient of awards from the Distinguished Service Award from the Project Management Institute (1984), and the American Society of Civil Engineers (Thomas Fitch Rowland Award -1985.)

Mr. Alexander Voigt has over 20 years’ experience in applying System Dynamics to address complex managerial issues, focusing especially on the assessment of disruption and delay on complex projects. Mr. Voigt holds a master’s degree in aeronautical engineering and an MBA from MIT/Sloan, and he has supported projects with dynamic analyses in four continents and in many industries: commercial developments, oil and gas infrastructure, energy generation plants, transport infrastructure, automation, shipbuilding and aerospace. Mr. Voigt has also taught graduate courses in System Dynamics and Project Management, he is a regular speaker at international conferences and events.