# Risk Management on Mega-Infrastructure Projects:

# Combatting Complexity Underestimation


## ABSTRACT

The increasing scale of construction and technology are key drivers of complexity on mega-infrastructure projects today. The challenge is how we adapt existing risk management methodology to new degrees of uncertainty. By observing the trend of cost overrun and schedule delay on rail megaprojects, this paper explores whether cost underestimation is a key concern for risk management; or whether there is scope to argue that complexity underestimation is increasing cost and time pressures for project controls professionals. A systems-thinking approach is employed to weigh existing risk methodologies against the interconnected nature of nodes in a complex system. To combat causation complexity, this paper acts as a call to action for those in risk management to *probe* over predict, seeking to understand the interactions and interfaces within a system. Ultimately the evolution of risk management will require the next generation of risk managers to experiment with agile methodologies and technologies in order to transform and future-proof the practice.

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## INTRODUCTION

Both locally and globally, the projects shaping our cities and driving infrastructure booms are known for their scale. The scale of a megaproject is defined by a budget of at least one billion; these are complex ventures which Bent Flyvbjerg (2014:7), management professor at University of Oxford's Said Business School, reports to have grown in value and scale by 1.5% to 2.5% annually over the past century.

Due to their length, megaprojects are vulnerable to entropy (Leslie 2015); making them infamous for their completion, or lack of it. Recent examples include London's *Crossrail*, delayed beyond the fixed completion date of December 2018, with total cost and time overrun yet to be realised (NAO 2019:6-8); or *Sydney Light Rail*, delayed a year from promised completion, with time costs capped at $7.5 million (O'Sullivan 2018). Historically, average cost overruns on transport megaprojects have been studied and reported at 17%, 45% , 61%, and 10-500% respectively (Flyvbjerg, Bruzelius & Rothengatter 2003:14). Notably one study in Denmark sampled 258 projects and concluded that 2 out of 10 rail project costs are underestimated (ibid). This recurring trend of underestimation need to be scrutinised, and arguably project control professionals are positioned to scrutinise, as they encompass the people, processes and systems that deliver against time, cost and scope.

## CONTEXT

Risk management has always been about uncertainty; a rise in complexity doesn't necessarily mean a rise in risk. Existing risk methodologies assume a stable environment in order to *assess-measure-adjust* or *identify-quantify-treat.* Risk thought leader, Warren Black (2016), critiques industry-recognised, brand-name risk management methodologies due to their reliance on rational, consistent operating environments. Black aligns these to Taylorism, a phenomenon that stemmed from Fredrick Taylor as he pioneered the rise of controlled, continuous improvement processes during the Industrial Age. For Black, Tayloristic principles fail to offer risk solutions in systems where emerging change is inevitable. The question, then, is whether risk managers should continue to implement ISO 13000, PMI Risk, RAMP, COSO Cube, COBIT 5, PRAM, and Prince2 Risk methodologies. It is critical to assess whether the evolution of risk has enabled the sensitivities in a system to be tested and treated.

## SYSTEMS COMPLEXITY

> ***"The more connections or links there are in a system, the greater the chance of variability, or even system breakdown"*** (Dettmer 2011:6)

Given traditional management methodologies are suited to environments of high certainty; we need to understand project complexity through the lens of systems theory. A systems-based approach stresses the interactive and interdependent nature of nodes within a system (Dettmer 2011). The Cynefin framework (Appendix 1), a sense-making model for understanding systems, notes the subtle difference between the conditions of simple, complicated, complex and chaotic domains. Arguably risk prediction echoes the conditions of a simple system where cause and effect can be determined; the process-oriented principles and tools of risk management characterised by relative stability and defined variability.

A key consideration is whether risk is more accurately aligned to a complex system, where practice is emergent due to the unordered and unexpected nature of the interactions between nodes. These conditions are commonplace on a rail megaproject, where complexity arises through the interconnected nodes of physical interfaces, third parties, contract models, integrated station developments, and client-contractor relationships.

If we look to *Crossrail* for lessons learned in this space, the National Audit Office (NAO 2019:7) notes that while a plan outlining the critical path for completion was presented in late 2018, "the plan did not adequately reflect interdependencies across the programme". This points to an emerging trend of complexity underestimation on megaprojects, not dissimilar to the tendency for cost underestimation.

## CAUSATION COMPLEXITY

***"Organisations with poorly conceived or onerous controls will be unable to manage risk effectively within the supply chain, providing fertile ground for disputes. This effect is compounded where the illusion of control obscures the interconnection between issues, evidenced by <u>underestimation of causation complexity</u> and overconfidence in the quality and value of records"*** (Woodley 2018:14),

In order to integrate a complex-adaptive approach into existing risk methodology, we need to first deconstruct data of *causation complexity* on megaprojects; this will enable us to explore how interdependent nodes can be adequately mapped to minimise cost overrun and mitigate schedule delay. While the pattern for megaprojects to overrun their budget prior to project completion is *known*, the cause(s) of cost overrun are noted to "typically differ", revealing *unknowns* in causation (Flyvbjerg, Bruzelius & Rothengatter 2003:12). This may be why Flyvberg, Bruzelius and Rothengatter are more concerned with *consequence* than cause.

The table found in *Appendix 2* compiles learnings from case studies of megaprojects with cost overruns against commissions with claims and disputes. Notably, claims and cost overruns are not synonymous; yet both are commonplace on megaprojects, with undesirable consequence. To understand this, HKA's Crux report explores the primary and secondary causation of dispute on megaprojects. After decoding causation complexity across 257 project data sets, the maximum amount of causes on any one project reached 39 (Woodley 2018:10,11,18).

For risk managers, a key takeaway of the report is that a lone item on a risk register won't lead to a dispute between parties; rather, it is the combined effect of interdependent issues that will have a significant impact. Given this, risk managers need to extend beyond tradition cause-effect approaches to consider causation complexity. As a schedule needs to determine a critical path, risk managers need to determine interconnected nodes in a complex system where consequence may arise.

## SYSTEMS MAPPING

To future-proof risk, not only is there a need to shift from predicting to probing, but from conclusions to connections. If a system is said to be the sum of its parts, identifying the parts precedes analysing relationships between parts. If the whole is the sum, the alternative equations of the sum need to be determined. Risk and opportunity go hand-in-hand when observing conflicts and connections between parts, as it is crucial for parts that interact to be considered in collaboration, not isolation, of the system as a whole.

To deal with uncontrolled, unpredictable elements of a project requires first understanding what can be controlled and predicted. Once these "parts" are defined (e.g. time, cost, scope, contract models, interfaces, contractors, supply chain), the "whole" can be probed for missing or conflicting "parts"; and this is the domain of risk.

What this means for risk analysis is probing, tracing and mapping out the potential parts of a system that may cause a consequence through their interface. An interface in this instance refers to an interaction between parts, between causation points in and of themselves that may generate a consequence. This form of operation breaks down a system in order to better understand function and friction. Here we start, as Flyvbjerg, Bruzelius and Rothengatter (2003) suggested, with *consequence*.

## PREDICTING TO PROBING

If a risk manager asks a project manager what keeps them up at night, the answer will only analyse *present* parts of a system that are problematic. To mitigate in this environment requires turning to *cause*, and any controls implemented will be *reactive* to current conditions. Given causation complexity, to shift attention to *consequence* means the risk manager must probe *past, present* and *future* states of the system.

In simple and complicated domains, certainty allows for categorising or analysing to drive response; while a complex domain invites *probing* so uncertainty can be explored. Where earlier intervention and identification of mitigations can occur in the former domains of order, the latter requires understanding nodes and relationships in a system. The typical decision-making pattern in a complex system is *probe-sense-respond;* while a simple and complicated system is *sense-categorise-respond* and *sense-analyse-respond* (Dettmer 2011). If risk managers can proactively understand the behaviours of a system, *perceiving*– rather than *predicting* –patterns and dynamics, this may facilitate a culture of adaptive risk management.

The question is, *how*; to proactively control and predict these unpredictable and problematic parts of the whole is to begin with the end in mind[1]. For example, if the final output of a megaproject is an operating railway for first passenger service, we can work backward to identify worst-case scenarios that will prevent this outcome. Exercises to cross-examine all the components of the project – particularly those that may impact milestones, budget, and baselined scope; or have reputational, environmental, and financial impact – can be facilitated by a risk manager to discover touchpoints where consequence may occur.

[1] This was identified as one of the Seven Habits of Highly Effective People, by Stephen Covey.

From here, interconnected issues can be scenario-tested, as these may compound into realised risks that drive a megaproject beyond contingency into cost overrun. Given the non-linear nature of interactions and interfaces on a railway megaproject, there is an opportunity for visualisation and digitisation tools to be harnessed in order to map these relationships and uncertainties on a project.

## COMPLEXITY TO CONSISTENCY

In risk complexity, there is a tendency for projects to focus on external threats; failing to detect internal vulnerabilities that may cause project breakdown (Bonabeau 2001).These sensitivities emerge due to localised systems-complexity, where gap risks in products, packages, processes, technologies and organisational structures can be overlooked.

To allow for systems-wide connections, risk managers need to be able to move from complexity to consistency. Where uncertainty and inconsistency collide, risk consequences can be realised. It is the co-dependencies and interconnected nature of complex systems that is often overlooked; where internal sensitivities emerge due to a lack of collaboration. Within project controls, cost and change must align to risk, or quantitative data and analysis is premature. Completeness in control will never be achieved unless there is a collaborative effort to understand complexity gaps and connections. An example of tangible tools in this space are the implementation of shared risk language and terminology. If people, processes and systems do not speak to each other, inconsistency is inevitable.

## CONTROLLED COMPLEXITY

The degree of dynamism in a complex system becomes problematic when there is unnecessary uncertainty, such as a lack of clear delineation in contingency allocation. To centralise and assess data according to *consequence*, a two-pronged model can be utilised to delineate risk[2]. This model enables decision-making and contingency allocation to be measured by degree of impact, in light of interconnected issues and interfaces, ultimately allowing priorities to be assessed against project-wide pressures (Hosman 2017). The prongs may be project versus package level, or inherent versus contingent risk categories.

For example, where multiple packages exist on a railway project, station-specific or station-wide risks may emerge. If stations share similar concerns, contract-types, or interfaces, a consistent approach can be adopted to manage risks through shared, strategic controls. The danger if the stations operate in silos is a duplication of effort, leading to cost increase and differing customer outcomes, dependant on a delivery director's decision and discretion. IRM (2013:13) have identified a similar challenge, as double-dipping may occur across base cost and risk allowance. Conversely, concern for duplicate costs can lead to omissions; which is where consistency reviews are required. Thus, the limitations of the two-pronged model emerge where there is no consistency, transparency or accountability.

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[2] Project terminology in Australia differs from that of the United Kingdom. The Australian definition of project-package is alike the United Kingdom program-project delineation.

## CATEGORISATION BY CAUSATION

While cause-effect relationships are difficult to deduce at the best of times, the ‘illusion of control’ comes when the whole is considered in isolation from its parts. For risk management to remain effective and strategic, sub-sections of a system need to be identified and treated. To categorise by causation, the Institute of Risk Management (IRM 2013: 64-66) provide a guide to developing a Risk Breakdown Structure (RBS). This can be tailored into a tangible tool for managing stakeholders and system sensitivities.

In the never-ending quest for efficiency, megaprojects are broken down into manageable parts; packages of work are contracted out as design, engineering, construction, project management and operation is outsourced to the supply chain. The preference for these contracting models is client control, but the consequence is increased interfaces and contractual obligations, where gap risks become commonplace. There are client-retained risks as well as contractor risks, where collaborative registers emerge as an effort to distribute concern and control. To operate in this environment, accountability is critical.

For the risk manager, this means providing confidence that complexity gaps are accounted for when analysis is undertaken. Implementing a RBS on a project can provide visibility of what risk registers have or haven’t accounted for. There is danger to compartmentalising parts of a system, but greater still is the danger of neglecting complex conditions within a system.

## AGILITY IN COMPLEXITY

In the absence of control mechanisms, probing will lack the necessary foundation for agile management to occur. The key to probing and preventing risk on megaprojects now, and into the future, will be to ensure complexity underestimation is combatted. Risk managers are pivotally positioned to connect-the-dots between cause-effect and cause-cause in new ways, with agile strategies in play. For agility to exist in risk methodology will require new ways of working. Imagine a day-in-life where risk reviews are transformed into design-thinking workshops, where ideation, prototyping and testing of risk treatment is encouraged. Imagine a risk manager who can facilitate ignorance-mapping, with the ability to identify shared interfaces, create collaborative risk registers, and conduct virtual risk sessions.

There is opportunity for further discussion in this space. We must challenge whether complexity underestimation can be mitigated earlier in the project lifecycle. Flyvbjerg (2003:14) notes that mega-infrastructure projects in transport have “the tendency towards a significant underestimation of costs during project appraisal”. While cost and time are key drivers of a project baseline, arguably causation complexity and interdependencies on a megaproject are also underestimated during project appraisal. This presents a critical scope to drive intervention and prevention of risk from project conception.

## CONCLUSION

To close, this paper acts as a disciplinary mitigation to retain the relevance of risk management and project controls on megaprojects. To future-proof the practice, it will be necessary to not only to adapt and respond, but to probe and pre-empt. The next generation of risk managers will need to be proactive in their treatment and understanding of complexity beyond baselined knowledge. Arguably, digital disruption and agile strategies will reshape how risk management plans and processes are implemented, improving the micro-level cultural acceptance of the practice and macro-level risk appetite for enterprises and projects. The art of sense-making and probing are key characteristics risk management must adopt for the ambiguity and complexity of today to be written into the methodology of tomorrow.

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**ACRONYMS**

**IRM:** *Institute of Risk Management*

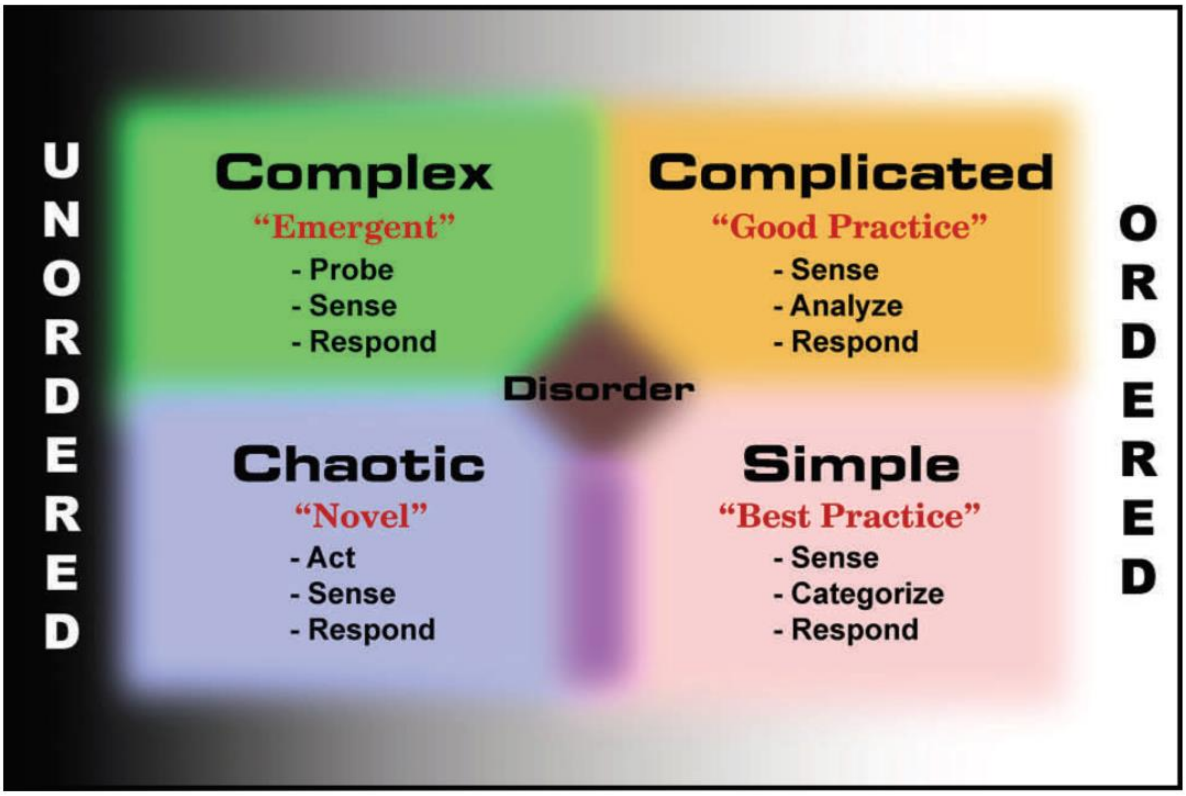
**NAO:** *National Audit Office*

**QRA:** *Quantitative Risk Analysis*

**RBS:** *Risk Breakdown Structure*

**APPENDICES**

**APPENDIX 1:** ***Cynefin Framework*** (Dettmer 2011:9)




**APPENDIX 2:** ***Causation Complexity***

| CAUSATION COMPLEXITY | |
|---|---|
| **COST OVERRUNS** | **CLAIMS AND DISPUTE (CRUX)** |
| **Case Study 1: Crossrail (NAO Audit)**<br><br>a) Scope Creep<br>b) Certification<br>c) Parallel activities on the critical path<br>d) Degree of contracts (thirty-six total)<br>e) Sub-optimal asset condition<br>f) Interface access<br>g) Interface management<br>h) Cost of accelerating work<br>i) Geographical locations<br>j) Tunnelling works<br>k) Existing network<br>l) New software specifications (three signalling systems across the line)<br>m) Product requirements (new rolling stock)<br>n) Renegotiating main contracts (commercial)<br>o) Substantial contingency drawdown (risk)<br><br>**Collation of Case Studies**<br>**(Flyvbjerg, Bruzeliu & Rothengatter 2003)**<br><br>This report reviews four studies that provide percentages of cost overrun on megaprojects: a) *Auditor-General of Sweden* (15pr.) b) *US Department of Transportation* (10pr.) c) *UK Transport and Road Research Laboratory* (21pr.) d) *Aalborg University, Denmark* (254 pr.)<br><br>While the report does not provide causations, the authors comment on “risk trends” that often translate into cost increases to include: underestimated schedule delays, changes to project specifications and designs, geological risks, exchange rates, expropriation costs, safety and environmental demands (p12).<br><br>Causation examples include: changes to safety requirements, environmental demands, urban complications. | **Group #1: Contractor:**<br>a) Slow progress<br>b) Extensions of time<br>c) Failure to comply with contract<br>d) Poorly presented claims<br>e) Deficiency in tender<br>f) Staffing<br>g) Financial failure of contractor or subcontractor<br><br>**Group #2: Design**<br>a) Design<br>b) Late availability of information/design<br>c) Design errors/buildability<br>d) Quality of design<br>e) Inadequate/incomplete/ambiguous drawings/specs<br>f) Design co-ordination breakdown<br><br>**Group #3: Skills**<br>a) Skills<br>b) Managing – time / Managing – cost / Managing – risk<br>c) Collaboration [lack of]<br>d) Managing – quality<br>e) Leadership<br><br>**Group #4: Owner**<br>a) Owner<br>b) Variations<br>c) Change of scope<br>d) Late giving of possession<br>e) Payment delays<br>f) Acceleration<br>g) Staffing<br><br>**Group #5: Contract**<br>a) Contract<br>b) Different interpretations of the contract provisions<br>c) Contract administration<br>d) Ambiguities in contract documents<br>e) Risk allocation<br><br>**Group #6: Behaviour**<br>a) Behaviour<br>b) Adversarial/controversial culture<br>c) Lack of communication<br>d) Quality of leadership<br>e) Information overload/data volume<br>f) Overconfidence<br>g) Poor morale<br><br>**Group #7: Other**<br>a) Unforeseeable change<br>b) Political, legal or economic factors<br>c) Ground conditions<br>d) Extremes of weather<br>e) Temporary works<br>f) Information technology |

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*Note: the author has prescribed to Harvard Referencing*


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