PAPER

# The Nature of Risk in Complex Projects

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## ABSTRACT

Risk analysis is important for complex projects; however, systemicity makes evaluating risk in real projects difficult. Looking at the causal structure of risks is a start, but causal chains need to include management actions, the motivations of project actors, and socio-political project complexities as well as intra-connectedness and feedback. Common practice based upon decomposition-type methods is often shown to point to the wrong risks. A complexity structure is used to identify systemicity and draws lessons about key risks. We describe how to analyze the systemic nature of risk and how the contractor and client can understand the ramifications of their actions.

**KEYWORDS:** complexity; systems thinking; risk; project risk analysis; mapping

Project Management Journal, Vol. 48, No. 4, 55–66

## INTRODUCTION

Business is becoming increasingly projectized or project oriented, with many billions of dollars being spent annually on projects around the world. Building new capital assets, carrying out unique large-scale enterprises, or developing new technological products, all require major projects to be undertaken. The benefits of projectization and a good approach to project management can clearly be seen in many ways: these include motivation, satisfaction, and giving meaning to the work of individuals and teams (Thomas & Mullaly, 2008). However, the reputation of project management with most people is that it is generally unsuccessful, with projects being late, overspent, and often not technically successful. The media delights in reporting on large public construction projects that have suffered huge cost or time overruns, such as the United Kingdom's Scottish Parliament ("10 times over budget and more than three years late," Tempest, 2004), or a healthcare project in the United Kingdom with "much uncertainty about the costs . . . unlikely to complete . . . anywhere near its original schedule." (House of Commons, 2007)

This article concentrates on complex projects, because the effects of risks within such projects are difficult to understand without analysis. We use the well-known Simon (1982) description of a complex system being one in which the behavior of the whole is difficult to deduce from understanding the inputs to the system. Thus, in a complex project, understanding what is likely to impact the project does not lead simply to an understanding of what that impact might be. We therefore use a structured approach to project complexity to help identify where the risks are occurring.

Although this article concentrates on complex projects, it does not imply that the uncertainties facing "complex" projects are any greater than those impacting any other type of project. Rather, these uncertainties are likely to be more interconnected, likely to change, there will need to be reactions within a highly paced project, or there will be socio-political risks whose effects are uncertain. This mixture will create a project risk that is difficult to comprehend in its totality, whose key uncertainties are difficult to detect, and for which risks are likely to compound and cause an overall greater risk picture.

Study has advanced in understanding complexity in projects (Geraldi, Maylor, & Williams, 2011) and has enabled a transactional-cost understanding of behavior within a project (Brown, Potoski, & Slyke, 2016). This work, and the study of the behavior of particular projects, has led to the realization that the consideration of risk before a project starts, and particularly the common practices in project risk analysis, are woefully inadequate for complex projects. Indeed, common practices can sometimes divert attention away from the key risks to less important ones. Understanding comes from looking at the lived experience of projects (Cicmil, Williams, Thomas, & Hodgson, 2006) along the lines of Blomquist, Hällgren, Nilsson, and Söderholm's (2010) *project-as-practice* research.

Risks set up causal chains, often involving human motivational reactions to events and decision making by the project parties. The problems are significantly exacerbated when these chains lead to positive feedback loops. Furthermore, understanding the behavior of such projects therefore becomes difficult, taking away the rational basis for decision making by the project parties that Brown et al. (2016) assumes. The risks discussed in this article are known within the project and information systems literature, and this literature already considers both residual risks and unintended consequences. However, this article shows the lack of consideration to some of the ramifications of such risks, specifically the risks that enlarge rather than mitigate through actions. Such issues will often overwhelm in size the issues described in project risk management practice and literature. These issues, therefore, need attention if the credibility of project risk management is to be salvaged and indeed the credibility of our ability to set up and manage complex projects.

This article will look at the idea of systemicity in complex projects to identify the issue and will review the current risk management thinking and practice to identify the gap. It will then follow Geraldi et al.'s article to look at the implications of complexity, and how unexpected risks can become more significant within a project.

## Projects and Systemicity

A conventional view of projects breaks them down into their constituent parts—in scope (work breakdown structure), time (critical path networks), cost (budgets), risk (risk registers), and so on. (In some of the other aspects, there has been more progress in looking holistically, but risk work still generally revolves around decomposition into individual parts). This, however, is inadequate for complex projects, as defined by Simon earlier.

There has been recognition in the literature that risks can be inter-related. Dating back to 1990, Al-Bahar and Crandall (1990) recognized the systemic structure of risks, which was continued by Williams, Ackermann, and Eden (1997) and, more recently, by Kwan and Leung (2011) for software risks and Fang, Marle, and Zio (2012) for engineering projects. Nevertheless, these are still largely single risks, recognized by standard risk identification techniques, which are then sometimes taken to be in a systemic relationship. Cavallo and Ireland (2014) working in a different field (disaster preparedness) start to consider what they call "unforeseeable risks"; they use Soft Systems Methodology (SSM) to understand the underlying system of risks. In this article, we will consider the "softer" human and socio-economic causal relationships that link these risks and approach the risks as a systemic whole.

Over the past 30 years, our view of the behavior of complex projects has developed in many ways, in particular, in the use of systemic modeling. This began with Cooper's work on the Ingalls Shipbuilding case (Cooper, 1980) and continued with others at PA Consulting/MIT. A second team at Strathclyde University (of which this author was a member) started with the Channel Tunnel "Shuttle Wagons" project (Ackermann, Eden, & Williams, 1997) by using mapping to structure causality and providing an interface with System Dynamics quantitative modeling (Howick, Eden, Ackermann, & Williams, 2008). A review of this body of work (Williams, 2005) and its implications showed not only that project behavior could be explained by systemic inter-related sets of causal factors rather than linking effects to single causes but, specifically, behavior (resulting from the dynamics set up) that turned into positive feedback loops, or 'vicious circles.' This positive feedback can cause significant over-spends and "runaway." The Shuttle Wagons project, for example, had a specific major change following a fire, and continuous (multiple, small) approval delays, leading to a structure such as that shown in Figure 1. In this very simplified illustrative diagram, we can see some simple positive feedback loops initiated by the delays caused by design changes and delays in owner approvals and linked to the very tight timescale. The delays led to activities being carried out more in parallel than would be appropriate in engineering terms, leading both to more delays (in a feedback loop) and also to a delay in the overall system freeze. These, in turn, mean that more work needs to be done without the necessary surrounding engineering information completed and frozen. Further, while some of this work will remain sound, some will need to be re-worked, hence exacerbating the delays and increasing the positive feedback. Lyneis and Ford (2007) provided a survey of the use of System Dynamics in modeling projects.

The idea that issues within projects arise from systemic causal sets of reasons is gaining increasing recognition (some recently described by Lefle and Loch, 2010). Keil and Mähring (2010) identified a key problem of project escalation as seeing problems as isolated incidents, so that a piecemeal approach to solving the problems is ineffective because this approach does not get to the "underlying root causes of problems." They identified many fine strategies without identifying the underlying systemicity and vicious-circle nature of the problems addressed. Merrow, basing his comments on the analysis of his large database of megaprojects, stated:

> *"In projects, bad things tend to happen in groups, not individually . . . . . Events that affect projects in major ways . . . tend to go together. Even when one of those things occurs individually, it tends to trigger a cascade of problematic effects."* (Merrow, 2011, p. 327)

Similarly, Thamhain stated:

> *"Undesirable events (contingencies) are often caused by a multitude of problems . . . these problems often cascade, compound, and become intricately linked . . . . clearly even small and anticipated contingencies . . . can lead to issues with other groups, confusion, organizational conflict, sinking team spirit, and fading commitment."* (Thamhain, 2013, p. 29)

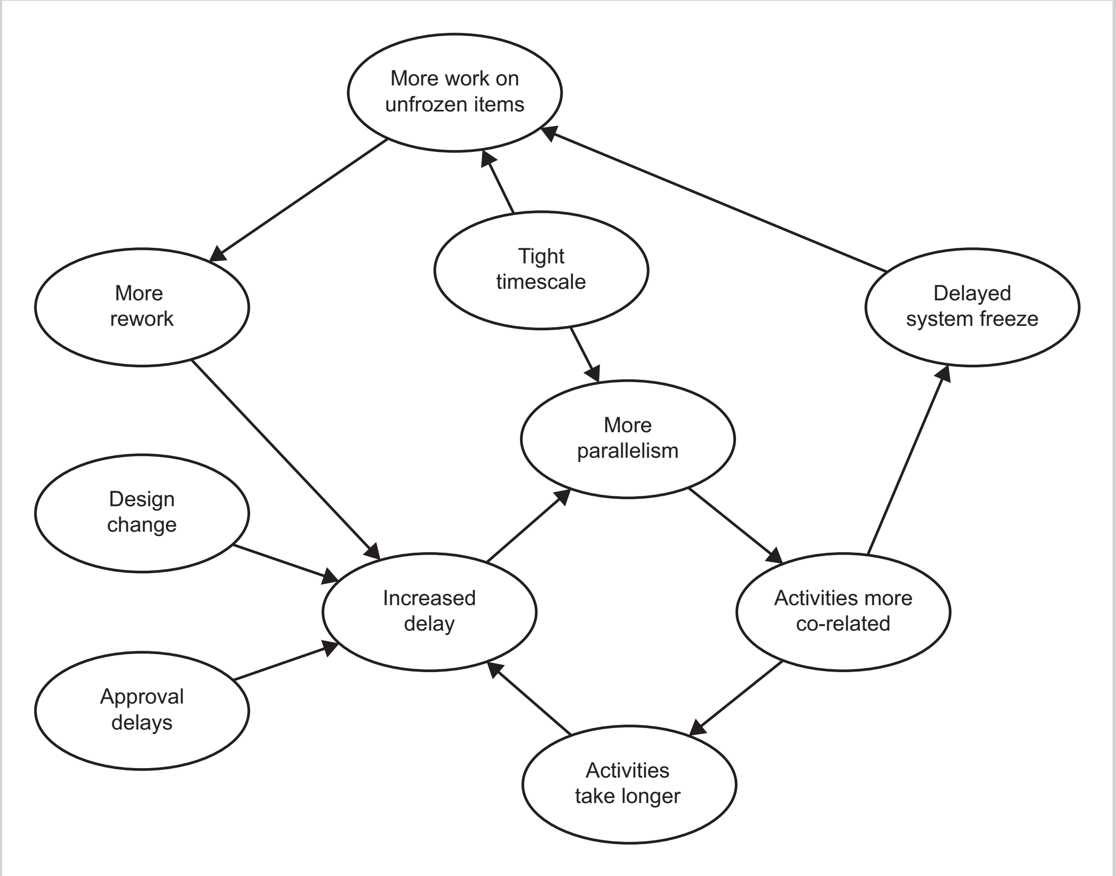

**Figure 1:** Generic delays in the Shuttle project.

Thamhein emphasized the importance of dealing with these risks early in the project life cycle; however, he also acknowledged the "enormous difficulties" of actually predicting the risk situations and understanding their systemic complexity. He also noted that senior managers rated the performance impact of risks, on average, to be 30% lower than project managers did—possibly showing the higher expectations of the project manager to manage perturbations and perhaps also revealing less understanding of the cascading nature of project risks.

## Current Risk Management Thinking and Practice

In this environment of complex projects, how are risks identified and managed in practice? We use the term "risk" here in the typical sense as relating to any uncertainty that has an effect on a project. We are not trying to look for definitional distinctions, but recognize two essential points. First, uncertainties are a collection of both *aleatoric* (i.e., those to which probabilities can be objectively related) and *epistemic* (i.e., those stemming from a lack of sufficient knowledge) with many combining both aspects (Williams & Samset, 2010). Second, risks might include "good" opportunities as well as downside risks.

Risk management has become a core part of project initiation and execution since its formal recognition in projects in the 1980s. However, the methods used in practice still reflect the early reliance on lists (or "risk registers") of individual risk items (Williams, 1994). The Project Management Institute's *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)* – Fifth Edition (2013) (which is an ANSI standard) in its latest version makes brief mentions of the existence of methods to deal with interrelatedness. In the United Kingdom, the Association for Project Management's *Project Risk Analysis and Management Guide* (2004) has an appendix on the issue but later publications, including their guide on *Prioritising Project Risks*] (Association for Project Management, 2008), are clearly geared toward understanding and prioritizing individual risks. Leitch (2011) points out that ISO 31000 offers no recommendations on aggregating, splitting, or combining risks. Indeed, an influential review risk management standard in 2005 made no mention of risk combinations (Raz & Hillson, 2005). These standards do not actually prohibit more systemic thinking. However, Hodgson's (2002) Foucauldian analysis shows how, although those advocating project management toolkits claim them to be "universal and politically neutral," their actual use in practice enforced by management leads to a specific way of thinking and indeed ontology inculcated into an organization, thus actually inhibiting systemic thinking.

There is some recognition in standard methodology that comprehending overall risk is needed to achieve proper understanding. PMI's *Practice Standard for Project Risk Management* (Project Management Institute, 2009) and the United Kingdom's Association for Project Management's (2012) *Body of Knowledge* have started talking about two-level definitions of risk, covering both individual risks and "overall project risk." In general, however, project risk processes still only address the former level, and there is little advice on how to address the latter. Hopkinson's (2011) *Project Risk Maturity Model* states that "achieving the highest RMM [Risk Management Maturity] level (Level 4) does depend upon the use of quantitative techniques to understand the implications of overall project risk. Using a simple qualitative approach based on managing risks on a risk-by-risk basis will therefore limit a project to having a level 3 RMM capability at best"; this, however, still only provides a passing mention in one paragraph (p. 138) to the way that complexity in projects produces systemic risks. Indeed, while cross-risk correlation is discussed, Monte Carlo schedule analysis is used without specifically modeling management activity or human reactions within the project, which is an important element in producing the systemicity. Williams (2004) shows that using Monte Carlo schedule analysis without modeling how management reacts to project events and progress provides misleading results.

The academic project literature clearly recognizes complexity within projects. Nonetheless, with the exception of those authors who were quoted in the previous section (Thamhain, 2013; Merrow, 2011), the explicit identification and analysis of risk are not typical features of the discussion, although the issues are recognized. The risk chapter of the project management "state-of-the-art" handbook by three leading academics (Winch & Maytorena, 2011) provides limited information on risk inter-relationships. The literature indeed addresses the increasing complexity and intra-connectedness of projects, yet the implications for project risk are not drawn out. For example, the chapter on project risk by Loosemore (2006) in Pryke and Smyth's work tellingly entitled "Managing Project Risks" (in the plural), has a deeper understanding of what an individual risk represents but does not consider risk combinations and the resulting causal chains involving humans. Cooke-Davies's (2011) edited book states that "complexity in projects probably has its greatest impact in the sphere of risk management," although it does not provide specific advice for the practical use of the ideas in risk management. Hass's (2009) popular book on managing complex projects describes some of the problems covered in this article, stating that "risk management is one of the most neglected aspects of managing complex projects" and suggests some useful management ideas for retaining a view of the risk systemicity. Remington and Pollack's (2008) book seeking tools for complex projects also recognizes the issue of risk inter-dependence, and indeed includes a chapter with a technique called "Risk Interdependencies," which goes some way in recognizing the issues but does not explore the ramified causal chains or the human elements of those causal chains. Ackermann, Howick, Quigley, Walls, and Houghton (2014) recognize and expand on some of these issues further.

Where complexity within project risk is recognized, some try to capture the complexity by the use of simple spreadsheets and questionnaires; Maylor, Turner, and Murray-Webster (2013) is one example. Similarly, Maynard (2013) looks at eight dimensions of project complexity, split further by a mind-map-type decomposition (although the first dimension, "Risks and opportunities," shows risk as an input to complexity, rather than uncertainty being the input and risk being the resultant issue). The Treasury Board of Canada (2013) provides a similar full scoring model but, again, this model does not capture systemicity; similarly, the spreadsheet used by the Commonwealth of Virginia, with its 15 risk questions and 16 complexity questions. Perhaps the most research-based model is the GAPPS CIFTER analysis (discussed by Aitken and Crawford, 2007). These methods offer useful pointers to decision makers, and can identify broad areas of likely complexity, but they do not help us to identify, understand, or model the systemic risks of a project and the causal chains.

Given the lack of information in the standard methodologies then, does it mean that the topic of this article is unimportant? There are mixed views on the extent to which current risk management has an effect on project success. Some authors (for example, de Bakker, Boonstra, & Wortmann, 2010; Cooke-Davies, 2000) show that, not surprisingly, even some levels of attention to project risk help projects achieve their objectives. de Bakker, Boonstra, and Wortmann (2012) point to the simple identification of risks as having the most effect. Beyond this, however, the evidence about the relationship between risk management and project success is at best mixed (Zwikael & Globerson, 2006, describe it as a "low impact process"; see also, e.g., Ropponen & Lyytinen, 1997). This suggests that current methods are not convincing users of the successful handling of risk and perhaps not providing understanding of the overall risk to the project. We will now therefore try to understand in a more structured way what risk means in a complex project.

Hardy and MacGuire (2016) draw upon the work of Foucault and explore the "implications of organizations' being situated in a dominant discourse of risk" and the difficulties of changing those ways, even when it is known that they are ineffective. The established norms of (separate) risk identification and management risk-by-risk, undertaken by particular actors who have legitimacy to identify, quantify, and manage those risks, means that risk becomes (quoting, Gephart, Van Maanen, & Oberlechner, 2009, p. 143) "identifiable through scientific measurement and calculation, and [can] be controlled using such knowledge." Changing this dominant discourse means "challenging the privileged position" of risk "experts" and drawing on "alternative discourses," particularly in the case of systemic risks where causality is less clear.

## The Structure of Complexity

A contingency view of projects recognizes the need to take project complexity into account. Williams (2005) calls for different ways of understanding and managing projects in situations of high structural complexity, high uncertainty, and high pace. Similarly, Shenhar's "Diamond" model (Shenhar & Dvir, 2007) divides projects (and thus what is needed to manage them) by project (structural) complexity, pace, novelty, and technology (although this does not have the underlying basis of the systemicity reasoning as described earlier). As our guide for this article, we refer to Geraldi et al. (2011), who try to define this overall set of concepts that describe the complexity of projects according to five dimensions: structural, uncertainty, dynamics, pace, and socio-political. What then are the implications for how we regard risk?

Structural complexity implies multiple interacting elements. Where there are uncertainty and dynamics in the system, then multiple interacting risks will be present. Thus, the first straightforward implication is:

*(1) Technical complexity means a system view of risk needs to be taken.*

However, when the system is further disrupted by pace so that acceleration decisions need to be made, the internal socio-complexity of the project needs to be considered—in other words, the fact that projects are carried out by teams of humans. There are two key elements that need to be considered.

The first and perhaps more straightforward element is that human project managers will react to perturbations in the project. An example of this is the move to increased parallelism or working on unfrozen items as shown in Figure 1. Indeed, it is the ramifications of such actions within systemicity that means that sometimes they have apparently counter-intuitive effects (Eden, Williams, Ackermann, & Howick, 2000). This is particularly so in projects subject to high pace or high time constraints. In such projects, attempts to accelerate the project increase the parallelism and make the project even more difficult to manage and less stable, and so costs spiral out of control, making it difficult to relate project spend to individual parts of the project (Eden, Ackermann, & Williams, 2005).

More complex is that the project workforce will react to perturbations within the project. For example, there can be an increase in nugatory work, making this work less meaningful, increasing errors and, in Thamhein's words above, there is "confusion, organizational conflict, sinking team spirit, and fading commitment." In recent years, there has been increasing emphasis on the importance of effective experience in motivating work. Seo, Barrett, and Bartunek (2004) demonstrate the implications on goal performance of a "pleasant" core effect or, conversely, the effect of a negative emotional reaction when project events occur. Where project workers become disheartened, or fatigued, or start to make mistakes, then these effects are keys to the progress of the project. Even if these clearly identified aspects are avoided, creativity and innovation will decrease. Disruption (under high "pace") can cause a project team to lose its "conceptual slack" and its ability to sensemake (Grabher & Thiel, 2014), and a negative mood if combined with a lack of empowerment diminishes creativity (To, Fisher, & Ashkanasy, 2015). Interpersonal conflict, within the project or with the client, damages project performance through negative emotions (Zhang & Huo, 2015). In the backs of many project workers' minds, when there are signs that a project is not proceeding well, there is the fear of project failure (Shepherd & Cardon, 2009). Theories of human behavior, such as that by Bourdieu (1998) (see a discussion of how this can be used in the understanding of project behavior in O'Leary, 2012) can be useful in understanding the human aspects of project behavior. However, more work is needed to quantify the relationships between drivers, such as changes or conflict and outcomes such as productivity or error-rate, and the role of emotions within these relationships. Nevertheless, it is a key feature of the system modeling of projects above, that such human aspects are essential links in the causal chains that explain the behavior of projects. Thus, the second implication:

*(2) The human reactions to events need to be accounted for in analyzing risk.*

The fifth dimension of socio-political risk acknowledges the increasingly recognized political effects within projects. This is especially so for "softer" types of projects, such as IT-enabled change (e.g., see the analysis of the UK Government so-called "Phoenix programme" [O'Leary & Williams, 2013]). For mega-projects in particular, the (permanent) political environment within which the (temporary) projects sit becomes increasingly important to give the project, and thus the work within the project, meaning. In general, the actions of the two parties (client and contractor) within that environment can have a significant effect on projects. In the transaction-cost structure expounded by Brown et al. (2016), a key to success of a contract is whether each party acts in a "perfunctory" or "consummate" manner (the former conforms to the "letter" of the contract but has small gains for the party but greater losses for the other side; the latter conforms to the spirit of "win-win" and has small losses for the party but greater gains for the other side). How the parties react to project events and risk outturns has a strong effect on the project out-turn. Under conditions of complexity, this is particularly problematic, as often the ramifications of those reactions is not clear to the party undertaking them, so the party might not realize the damaging effects that it is setting up. Thus, the third implication is:

*(3) The contracting parties' reactions to events need to be accounted for in analyzing risk.*

However, even these do not fully account for the complexity of risk outturns in a project. As described above, where risks set up causal chains—which might include human motivational reactions to events and/or decision making by the project parties—these can be significantly exacerbated when these chains lead to positive feedback loops. Indeed, some systems modelers will say that the feedback system provides a good explanation of how the system will behave. That is, where the project is in homeostasis (Thurston, 2016) the project is under control, but once unwanted positive feedback loops (or "vicious circles") are set up, the project becomes out of control. In this way, seemingly quite small risks, if they come about, can have effects that are exacerbated with ramifications far greater than the original risk. When identified, the first goal should be to consider how to "break" such loops—in other words, management actions that can remove one or more of the causal loops that form the loop (such as considering a system freeze as shown in Figure 1). Thus, the fourth implication is:

*(4) Detrimental positive feedback needs to be identified in analyzing risk.*

The implication therefore is that risk needs to be treated differently within complex projects. The discussion above therefore facilitates a structured understanding of why:

- Structural complexity implies multiple interacting elements; where there are uncertainty and dynamics in the system, risks will then have causal chains of ramifications, and risks will interact in multiple inter-connecting ways.
- When the system is further disrupted by pace, acceleration becomes both necessary and problematic because actions will interact with the causal chains of these ramifications.
- These interactions include socio-complexity in the causal chains of ramifications from human reactions to events.
- These causal chains can interact with ramifications from the socio-political complexity of the project environment, in particular reactions to events from the contracting parties.
- All of these ramified causal chains make the understanding of risk difficult and requires analysis; however, an extra dimension of complexity comes where these causal chains combine into detrimental positive feedback. In this way, risks collectively become a serious significant overall risk.

## Key Risks in a Project

A main conclusion of this article is that the risks identified by current methods as the most important risks might not actually be the key risks in a project. When risks are identified and analyzed in a conventional risk analysis, it is those risks with the greatest direct impact, when considered on their own, that are always placed as the most important, and which thus gain the most attention of management. In a complex project, however, the ramifications of risks might be greater than the direct impacts. Examples are reviewed next, in the order as discussed above.

### 1. *The Combination of Risks and Human Reactions*

A project in which the author was involved in was an arbitration that involved the manufacture of a ship, of a type which was technologically advanced and whose design was far from finalized. Thus, the two risks were: the state-of-the-art technology being used and the immaturity of the design. There were two additional sources of risk within the project: first, the acceptance criteria were not well-defined; and second, (a probably unidentified risk) the client's inspection team were (the contractor felt) unreasonably demanding. Each of these four risks, except for possibly the first, would probably not have appeared as major risks on a risk register. The combination of all of them, however, meant that the inspection and acceptance process proved very problematic, as demanding inspectors could claim that novel items, with some aspects not agreed on pre-contract due to the immature design, did not meet their stringent interpretation of the ill-defined criteria. Furthermore, as well as the risks themselves interacting, the causal chains emanating from these combinations included designers disagreeing with inspectors, being over-ruled, having to re-work, becoming disheartened and thus lowering productivity and increasing error rates, and so on (see Figure 2). Each risk individually might have been manageable; when they are combined with the resulting human reactions then they are not manageable. Following the logic discussed earlier meant that some of these items looped back to create vicious circles.

Sometimes significant risks are simply increases in the degree of risks that are accepted as normal project issues: The approval delays depicted in Figure 1 were simply an increase of delays over and above the contracted limit, the cumulative effect of which would be difficult to assess. The extreme example of 15,000 design changes is quoted below.

### 2. *Pace and Management Actions*

The "Shuttle Wagons" work referred to earlier (Ackermann et al., 1997) describes the need to make management decisions in a high-pace project

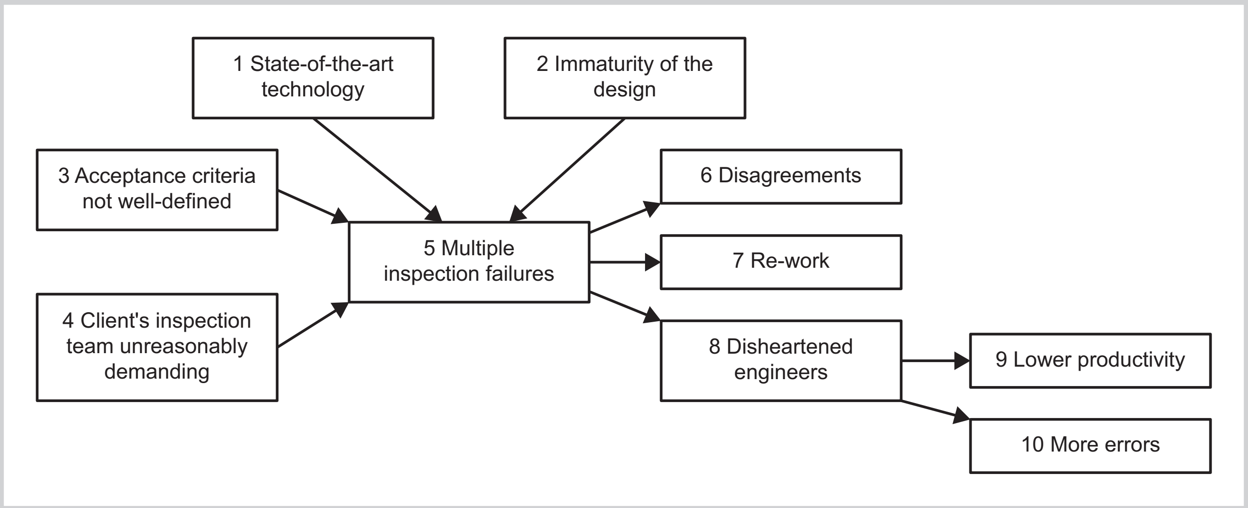

**Figure 2:** Combinations of risks and the resulting human reactions.

(see Figure 1). In this case, this included parallel working and pre-emptive designs, which exacerbated the positive feedback loops of work-arounds, rework, and subsequent disruptions and delays. In this way, initiating risks, which are manageable in themselves (such as the effects of the London fire referred to earlier), create causal loops that have effects much greater than expected.

### 3. *Individuals within the Parties*

The construction of the Scottish Parliament infamously resulted in a cost ten times higher than the original (underestimated) budget. At the public enquiry in 2004, the project manager was reported as stating that there had been 15,000 design changes to the building (British Broadcasting Corporation [BBC], 2004). Each individual change would have had little effect on the project; on the other hand, the effect of a deluge of temporally overlapping design changes caused considerable problems. These were both engineering problems and designers' reactions to multiple changes, with their work sometimes becoming futile. It is interesting to reflect on whether "lack of governance within the client" (which was perhaps what allowed the users to specify changes continuously) would or should have been a risk identified at the start of the project, let alone its true impact. (Further, even if a client had been aware of the changes, would he or she have been aware of the effects of the changes on the project?)

### 4. *Inter-Personal Relationships between the Project Parties*

Some of the risks themselves can be interpersonal rather than technical; thus the character of the project manager, for example, can cause problems in agreeing on designs, changes, and client acceptance. The need for trust between client and contractor (Kadefors, 2004) and within an alliance (Krishnan, Martin, & Noorderhaven, 2006) and the effect of lack of trust on the performance of the project are well-known. A difficult character, or troubled interpersonal relationships, can produce delays and the need for additional work, which dishearten the team, disrupt the project, and set up vicious circles of delay and disruption. Indeed, some would say that trust between the contractor and owner is one of the most important contributors to project success, yet trust rarely appears on a risk register. Eden, Ackermann, and Williams (2005) present an example of a paper mill project, in which there were "endless" talking and meetings, slowing the rate of production and a customer who insisted on unnecessary benchmarking and changing documents late in the process, and so on.

### 5. *Contracts between the Project Parties*

Risks can result from different interpretations of contracts between the customer and contractor. Eden et al. (2005) present an example of a rolling-stock project, in which the passenger doors were not sufficiently watertight to satisfy the customer, because under extreme test conditions there was a small amount of water ingress. The contractor argued that no train had ever met these criteria, and it was clear that the contract was ambiguous on the performance specification. This led to many tests, studies by independent experts in the field, and a final solution, but this caused many designs to be revisited and changed, which created ripple effects and schedule delays. Again, there was a small initiating risk, but there were also major ramifications.

### 6. *Culture within the Project Parties*

In cases in which the industrial sector has moved from the public sector to the private sector, it can be said that contractual relationships have changed to reflect the new environment, yet culture and working practices have not. Where a public-sector client is used to being part of the same organization executing a project, the associated behavior may not match the demands of a well-defined contractual relationship. A culture that is used to continuous design review or ongoing changes mid-project is at odds with a fixed-price contract. This can lead to redesign and rework as a project tries to meet increasingly unrealistic fixed time- and cost-targets, while requirements keep changing, leading to a cycle of increased work, more delay, frustration, loss of control and/or meaning felt by designers and engineers, and increased workarounds.

### *7. Changes to the Project Parties*

Changes in the client's strategy can be a significant risk. In December 1994, following direction from the U.S. government, Amtrak was given the goal of eliminating its need for federal operating subsidies. Working through the implications of this meant that Amtrak had to rethink their strategy; at the same time, it was engaged in a project to design and produce the new Northeast Corridor Acela trains. It has been suggested, therefore, that it is no coincidence that there were major changes to this project and thus rework; thus causing all the natural human reactions to major changes to work already done in a project and subsequent significant disruption to the project. Again, the client's change in strategic direction is unlikely to have been on the original project risk register, but can cause major ramifications.

It is likely that none of these risks would appear on a risk register, let alone a list of "top ten" risks; however, by setting up vicious circles of disruption, they can cause much more damage to project performance than simple one-off risks. The risks likely to produce vicious circles are those likely to produce the most risk to the project. An individual risk whose effect can be contained will only have that effect on the project. Where a risk sets up causal chains of effects through human reactions to the events, and whose ramifications are multiplied by unwanted positive feedback, with management actions exacerbating these feedback loops, its effects will be much greater. Humans have significant difficulty in estimating the probabilities and impacts of epistemic risks (see, for example the, discussion in Winch & Maytorena, 2011, pp. 350–351). It could therefore be argued that the degree of positive feedback from a risk is a more reliable indicator of importance to the project, although the organization must be set up to comprehend the full implications of a risk rather than a siloed view of direct consequences.

## One Aid: Mapping Risk

As an aid to looking at risks with the features just described, a natural method is to structure the risks in a "risk map." This term is used here to denote a causal map capturing systemicity (rather than simplistic probability-impact grids, for example, Jordan, Jorgenese, and Mitterhofer, 2013). Mapping project effects is a recognized part of systemic modeling work, and indeed has recently been extended into other uses in understanding projects (Ackermann & Alexander, 2016). Initial mapping is often loose, dealing with rough concepts; to trace causality, however, this needs to be honed into a map of clearly defined variables. This should be at least a "Stage 2 Cause Map" and working toward the "Stage 3 Influence Diagram" of Howick et al. (2008); being able to put "+" for a positive influence (or "−" for a negative influence) is an essential part of identifying positive feedback (see Sterman, 2000). Some positive feedback may be beneficial ("virtuous circles"), but it is the detrimental positive feedback that needs to be identified.

Risk mapping carried out by an individual can start from the risks that would form a risk register and the project objectives that will be affected by "risk." Then, by considering causal chains between items on the map, and "so what if this happens" and "what would make this happen" (i.e., the causal chains both up to and following an item), a causal map of the possible occurrences within a project can be built. The key is to include within the map the mitigation actions that would be taken (whether or not by conscious decision) by the project team and the expected behavior of the project participants since, as discussed above, these can often be critical elements in the causality.

The process of developing the risk map is as useful as the output and requires clarity, because thought is given to the chaining, yet it also enhances creativity as different future pathways are suggested. Positive feedback loops can be identified, as well as synergistic actions that will ameliorate a set of risks. Figure 3 illustrates a small example of a map with three risks (with no border), causing chains of consequences—four of which (with no border but italic) are human responses to the risks—resulting in two outcomes (in oval borders). (This simple map has multiple loops, although removing the element "Engineers disheartened" removes one third of them.)

"Individuals only ever have a partial view of risk" (Hardy & McGuire, 2016). The method becomes particularly useful in a group, as it aids communication and brings out interactions as well as cultural differences between groups, thus providing a richer set of knowledge. This requires the group to be suitably heterogeneous, and within the group there needs to be an overview of the whole project and an understanding of the management and team's likely reactions to events. Discussion can lead to paradigmatic differences or even incompatibilities as heterogeneous risks (including, for example, both engineering and psychological concepts) are combined—but this in itself aids intragroup communication and establishment of the overall risk picture.

The information on the map is valuable in various ways (Ackermann et al., 2014), including the following:

(1) The information contains knowledge of the systemicity.

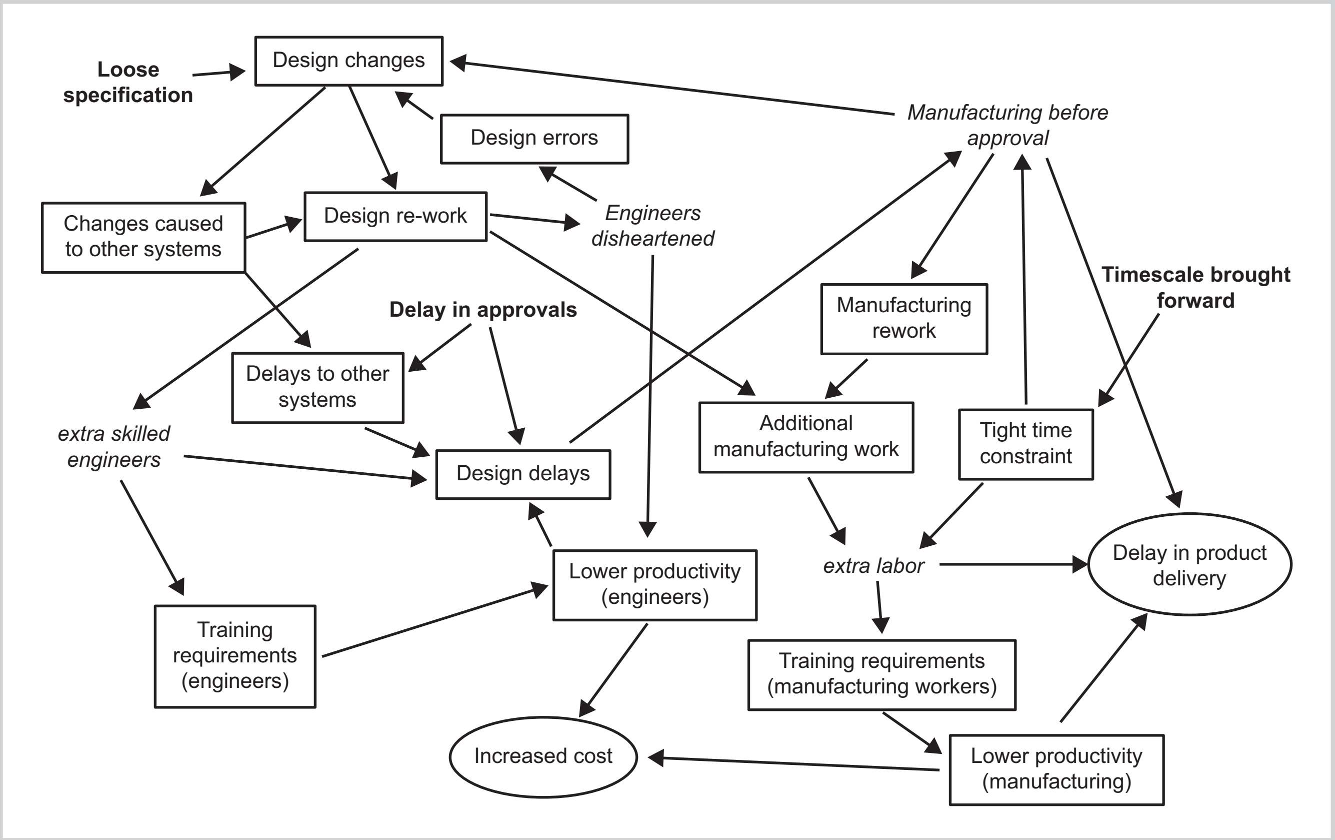

**Figure 3:** An example risk map (using Decision Explorer® Banxia Software, UK).

(2) Use of mapping software can categorize the risks in various ways (e.g., as shown in Figure 3) and show the "big picture" or detail.
(3) The map provides understanding, traceability of the information, and the identification of synergistic risk mitigation actions.
(4) The map can be used to identify prospective feedback loops and prompt questions on how to 'break' such loops.
(5) The map can help in scenario analysis as the likely effects of outcomes are explored.
(6) The map can underpin project categorization (Ackermann et al., 2007).

The map can also provide a foundation for quantification. This can be a major task, which has been used more in *post-hoc* arbitration than in *a priori* risk analysis. It can provide a traceable structured basis for system dynamics analysis (Howick et al., 2008), which can help us understand how causalities are likely to interact or predict the likely behavior of an upcoming project (Rodrigues & Williams, 1998). It can also provide a useful basis for risk assessment, particularly since assessing subjective probabilities is fraught with difficulty if the causes are not split out explicitly or if the item whose probability is being assessed is part of a positive feedback loop (so its very presence makes itself more likely). For example, consider that we need to assess a probability that a client will delay design approvals too much; in this case, however, there is positive feedback (as shown in Figure 4) and the probability needs very careful definition to estimate. In this type of situation, the input causes need to be split out (probabilities associated with the different arrows in Figure 4 assessed separately) or the probability needs to be identified as at time zero, or some other clear definition of the probabilities to be estimated. In practice, if a significant detrimental positive-feedback loop is identified, then the first discussion will be about how to 'break' that feedback loop; once that has been done, the remaining risk can be quantified.

## Conclusions

Front-end analysis and preparation are becoming increasingly important in the management of complex projects (Williams & Samset, 2012). A vital part of this is understanding the risks that the project faces. Standard methodologies evaluate these risks individually and without considering the human ramifications of each risk. Our understanding of complex projects shows us that risks affect projects in combinations

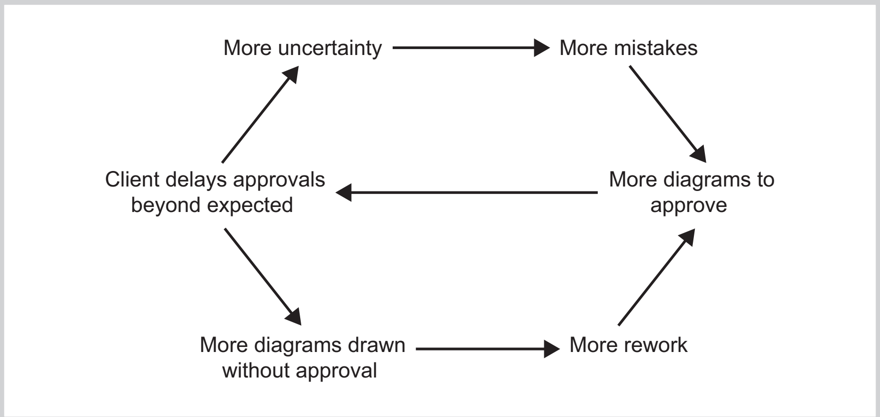

**Figure 4:** Risks within feedback loops.

and structures of risks. While this has been recognized to some extent in the literature, the key here is that the important causal linkages are the reactions to risks; in particular, there are reactions by the project manager in the context of needing to make fast decisions in the heat of the project, and reactions by the project team in terms of motivation and fatigue. Often the risks that cause project runaway are not individual, separate risks, but rather combinations of risks in causal chains that, along with management actions and team reactions considered, build up "vicious circles" of disruption. If one looks at a typical risk register in practice, the types of risks discussed in this article often don't appear at all, although they might be the critical risks that will bring a project to, or near, failure. We have used Geraldi et al. (2011) to structure where such risks might arise. We provide mechanisms for understanding such risks, which could inform the client and contractor alike and who, otherwise would not be able to fully understand the ramifications of their actions, and therefore not have a basis for acting "commensurately" (Brown et al., 2016), even if so inclined. The logic in this article highlights the effort to identifying positive feedback loops in risk structures and considering how to "break" these as a significant step in risk analysis. And, finally, we have encouraged a view of risk as a system rather than individual risks to understand properly the risk to projects.

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