

IT PROJECT POSTMORTEM THEORY: IDENTIFYING ROOT CAUSES BY PROCESS TRACING

ABSTRACT: IT projects often fail. Postmortem analysis is a well-established method for investigating accidents and failures *ex post facto* to develop preventive actions against similar failures in the future. In IT project postmortems, the identification of root causes is often not explicitly based on well-developed theory for causal inference. This is significant, because strong theoretical foundations strengthen the legitimacy of recommendations based on postmortem analysis. This paper is a theoretical exploration of process tracing for causal inference in postmortem analysis. This study analyses how process tracing can provide theoretical foundations for causal inference in IT project postmortem analysis, and this study explain how the literature on IT project failure factors can be utilised for identifying root causes and eliminating rival explanations. The analysis of process tracing for IT project postmortems is new and original. The results of this study provide theoretical foundations, a theoretical framework, for postmortem analysis of failed IT projects. The results are applicable for policy makers and practitioners for the endorsement and performance of IT project postmortems.

Keywords: Project Management, Project Failure, Project Postmortem, Information Technology, Process Tracing.

1. Introduction

IT projects overspend by 73% on average, and 18% of IT projects overspend by 457% on average (Flyvbjerg et al., 2022). Additionally, significant resources are spent on IT projects that get cancelled before completion (Ahonen & Savolainen, 2010; Charette, 2005; Jones, 1995). Successful engineering is not created by “incremental accumulation of successful experience, but rather in reaction to the failure of the past” (Petroski, 1992). Postmortem analysis is a well-established method for investigating accidents and failures *ex post facto* to prevent similar failures in the future (Gawande, 2011; NTSB, 2016a, 2016b). The need for IT project postmortems is widely recognised, yet project postmortem analysis is not common practice (Ahonen & Savolainen, 2010; Boddie, 1987; Ewusi-Mensah & Przasnyski, 1995; Kasi et al., 2008; Kerth, 2001; Verner et al., 2005; Williams, 2004). This is significant, because postmortem analysis can show how to improve IT project practices.

Current methods for IT project postmortem analysis are costly (Ahonen & Savolainen, 2010), and they do not exploit recent developments in theories for causal inference. Strong theoretical foundations for causal inference will strengthen the validity of root cause analysis and enhance the legitimacy of postmortem recommendations. This paper explores and analyses leading theory on process tracing, causal modelling, and causal mechanisms as foundations for causal inference in IT project post-mortem analysis, and this paper explains

how the literature on IT project failure factors can be leveraged for expressing root cause hypotheses, and for eliminating rival explanations. Process tracing for IT project postmortem analysis is cost-effective, because it can be based primarily on archival data (already existing project documents).

The postmortem theory presented in this article supports policy makers in endorsing postmortem analysis as a reliable source of knowledge for the development of practice improvements. The process tracing methodology explored and analysed in this paper is directly applicable as a theoretical framework for practitioners conducting IT project postmortems. This paper is organised as follows: First, this paper account for the current state of IT project postmortems and process tracing in the literature. The hermeneutic literature review (Boell & Cecez-Kecmanovic, 2014) was initiated with the search criteria ‘project postmortem’ and ‘postmortem analysis’, and continued by “snowballing” (Wohlin, 2014). Next, this paper presents the research methodology, research questions, scope, and definitions. After this, process tracing is introduced in the necessary detail to evaluate its feasibility as a theoretical foundation for IT project postmortem analysis. Hereafter follows the analysis that answers the research questions. The paper closes with a summary of results and conclusions.

2. Literature and Current State

IT project postmortem methods that make extensive use of interviews and workshops (Ahonen & Savolainen,

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2010) are time consuming, expensive, and depend on individuals that may no longer be available (Glass, 2002). The systematic and inexpensive use of already available project documents for postmortem analysis is uncommon (Ahonen & Savolainen, 2010, p. 2177). Postmortem workshops are sometimes facilitated using informal causal mapping or Ishikawa diagrams originally used for quality improvement of production processes (Dingsøyr, 2005).

Although postmortem analysis of IT projects is recommended (Ahonen & Savolainen, 2010; Kasi et al., 2008; Verner et al., 2005; Williams, 2004), many organisations will not allocate the necessary resources for project postmortems, because they do not have the culture or mechanisms needed to exploit the postmortem findings and recommendations (Kasi et al., 2008; Nelson, 2008). Pan and Flynn (2003) have shown how different stakeholder groups can disagree about the causes of failure due to attribution bias (Bradley, 1978; Miller & Ross, 1975). Attribution bias can lead to an unwarranted focus on the performance of individuals, where improvements at the organisational level would be more productive. Biased and erroneous explanations of failure can have negative and self-reinforcing effects on future projects: Wrong diagnoses can lead to bad cures.

The theoretical foundations for drawing causal conclusions in IT project postmortem analysis are often not explicit in the literature (Abdel-Hamid & Madnick, 1990; Beynon-Davies, 1995, 1999; Dingsøyr, 2005; Hougham, 1996; Lehmann & Prabhakar, 2008; Myers, 1994; Myllyaho et al., 2004; Schalken, Brinkkemper, & van Vliet, 2006; Schieg, 2007). Causal modelling is often based on informal methods, criteria for causal inference are unspecified, and potential rival explanations are not systematically eliminated. Postmortem conclusions are not always convincing enough to make stakeholders give up biased alternative explanations of failure (Pan & Flynn, 2003). Unless postmortem analysis is based on strong theory and well-founded methodology, the validity, legitimacy, and value of postmortem findings are likely to be questioned. A recent postmortem analysis of a government IT project is, in fact, based on process tracing (Schmidt, 2024), but an in-depth account of the theoretical foundations for the methodology used is missing in the paper. In conclusion, the research literature does not offer a theoretical framework for IT project postmortem analysis that is based on strong theory for causal inference. This is a gap in the literature.

Project postmortems are *ipso facto* single case studies. Process tracing is a general non-experimental, theoretical,

and well-developed approach for establishing causal inferences in explanatory case studies (Beach & Pedersen, 2016; Bennett, 2008; Checkel & Bennett, 2014; Collier, 2011; Mahoney, 2012; Scriven, 1974; Trampusch & Palier, 2016; Van Evera, 1997; Waldner, 2015; Yin, 2018). Process tracing is well-established in the literature on the philosophy of social science (Byrne & Uprichard, 2012; Kincaid, 2012b) political science (Brady, 2011), and political methodology (Bennett, 2008). Additionally, process tracing can be based on archival data as the main data source (Brady & Collier, 2010; King, Keohane, & Verba, 1994), which reduces costs and the dependency on the availability of key individuals.

Process tracing is “the analysis of evidence on processes, sequences, and conjunctures of events within a case for the purposes of either developing or testing hypotheses about causal mechanisms that might causally explain the case” (Checkel & Bennett, 2014). The development of root cause hypotheses, and the elimination of rival explanations require domain-specific knowledge (Brady, 2011; Collier, Brady, & Seawright, 2010; Pearl & Mackenzie, 2018; Waldner, 2015). The literature on IT project failure factors (Schmidt, 2023) can be leveraged as background knowledge for postmortem analysis.

3. Methodology

This theoretical research paper is an exploration of process tracing as theoretical foundations, or theoretical framework (Eisenhart, 1991, p. 205), for causal inference in IT project postmortem analysis. In this section, this paper introduces the research questions, the scope of analysis, and the definitions used.

3.1. Research Questions

To guide the analysis and evaluate the feasibility of process tracing and causal mechanisms as foundations for causal inference in IT project postmortems, this paper posed the research question:

RQ1: How can process tracing be used for causal inference in IT project postmortem analysis?

The strength of causal inference made by process tracing depends on the effective elimination of rival explanations (Brady, 2011; Collier et al., 2010; Dellsén, 2016; Waldner, 2015, 2019; Wright, 1973). this paper therefore posed the additional research question:

RQ2: How can rival explanations of failure be eliminated in pro- cess tracing based IT project postmortems?

Identifying the root causes of failure in individual IT projects is valuable in itself. Postmortem analysis theory that supports the generalisation of findings have a

wider scope of application for both practice and theory development. This paper therefore posed the following additional research question:

RQ3: How can IT project postmortem findings be generalised?

3.2. Scope and Definitions

In this paper, process tracing is introduced with a view to the scope of postmortem analysis that identifies root causes of failure in IT projects.

3.2.1. The Project as Unit of Analysis

This paper follows Morris (2011, 2013) in defining *the project* as the unit of analysis for project postmortems. A project in this paper is defined as “a temporary endeavour undertaken to create a unique product, service or result” (PMI, 2013, 2017). To Morris, the defining feature of a project is the project life cycle (personal communication, 2018). Morris’ perspective on projects and project management bifurcates into a) the temporary organisation and b) “the business undertaking”. “Both approaches - the looking at project as organizations and managing them to achieve their targets - are, of course, valid. What I argue for is indeed a bit of each: *the unit of analysis should be the project*, rather than project management processes or functions, but that, in addition to studying projects as organisational phenomena, this paper looked at how their conception, development, execution and handover can, and should, best be managed” (Morris, 2013, p. 233). In this paper, the business undertaking perspective than the temporary organisation perspective (Packendorff, 1995; Schmidt, 2023).

3.2.2. IT Projects

In this paper, IT projects are viewed as investments (Flyvbjerg et al., 2022; Morris, 2013; Schmidt, 2022, 2023). IT projects often include the delivery of a combination of hardware, software, services, and organisational implementation. IT project failure is evaluated on multiple performance criteria, including bene- fits, functionality, meeting stakeholder expectations, meeting triple constraints (budget, schedule, and scope of delivery), long-term contractor profitability, and possibly the management of termination (Morris & Hough, 1987; Schmidt, 2022).

3.2.3. Root causes

In this paper, a root cause is defined as “the *most basic* cause that can *reasonably* be identified and that management has control to *fix*.” (Atkins, 2001; Paradies & Busch, 1988). Additionally: “Any particular event may have several ‘root causes’ that need correcting to prevent recurrence of the event” (Atkins, 2001; Paradies & Busch,

1988). This definition of root cause is a contextual choice rather than a methodological limitation of what can be considered root causes. Alternative definitions could include circum- stances beyond management control, or causal powers that emerge on social structures (Elder-Vass, 2011).

4. Process Tracing

In this section, this paper introduces process tracing, causal mechanisms, and causal inference from the perspective of IT project postmortem analysis. The development of process tracing theory and methodology has multiple active contributors. For postmortem analysis this study preferred the specific approach by Waldner (Lawler & Waldner, 2023; Waldner, 2012, 2015, 2016, 2019, 2022) partly because Waldner uses Pearl’s methodology for causal modelling (Pearl, 2009, 2013; Pearl & Mackenzie, 2018). Pearl’s approach to causal modelling supports the counterfactual testing of hypothetical interventions. This is helpful for developing preventive actions (interventions), which is an important objective for project postmortem analysis.

However, process tracing is an active field of research, and academics who wish to use process tracing for project research should be aware of the details of key concepts, and the variations in key definitions. Therefore, the exploration in this section includes the work of multiple contributors to process tracing theory, including verbatim direct quotes. Process tracing is a non-experimental approach to establishing causal claims (Beach & Pedersen, 2013; Bennett, 2008; Checkel & Bennett, 2014; Collier, 2011; Mahoney, 2012; Scriven, 1974; Trampusch & Palier, 2016; Van Evera, 1997; Waldner, 2012, 2015). Waldner’s concise definition of process tracing is worth quoting at length: “I define pro- cess tracing as a mode of causal inference based on concatenation, not covariation. Pro- cess tracing uses a longitudinal research design whose data consist of a sequence of events (individual and collective acts or changes of a state) represented by non-standardised observations drawn from a single unit of analysis. Contrast this research design to the more conventional statistical model analysing a set of ordered pairs (or ordered n-tuples) of observations of independent, dependent, and control variables, taking the form of standardised observations drawn from a cross-section of units of analysis. By relying on within-case analysis, process tracing privileges internal validity over external validity; in return for this constraint on generality, process tracing has the potential to generate relatively complete explanations” (Waldner, 2012).

4.1. Causal Inference

Waldner points out three major issues regarding causal

inference that process tracing must address (Waldner, 2015, p. 239): (1) the relationship of single case studies to more general causal claims, (2) the conceptualisation of causation, (3) and the criteria of valid causal inference. These issues are addressed by Waldner’s completeness standard, which combines:

(a) causal graphs, (b) event history maps, and (c) invariant causal mechanisms. “The completeness standard [...] bridges unit-level causal inferences and average treatment effects, invokes an epistemologically warranted conceptualisation of causation, and better satisfies existing standards of causal inference by making unit homogeneity assumptions more credible” (Waldner, 2015, p. 239). Waldner distinguishes between weak causal mechanisms (mechanisms-as-events) and strong mechanisms (mechanisms-as-invariant- causal-principles) that allow general conclusions based on single-case studies.

Waldner refers to Mackie’s theory of causation. An INUS condition is “an insufficient but necessary part of a condition which is itself unnecessary but sufficient for the result” (Mackie, 1980; Waldner, 2015, p. 241). INUS conditions are ‘fully consistent with a regularity or Humean theory of causation’ (Waldner, 2015, p. 241). Mackie’s analysis of causality is fundamental to multiple accounts of causal inference in the process tracing literature. It is therefore appropriate to account for Mackie’s original definitions and example.

Mackie ponders the following problem: A house fire has damaged a home. “Experts investigate the cause of the fire, and they conclude that it was caused by an electrical short-circuit at a certain place. What is the exact force of their statement that this short-circuit caused this fire? Clearly, the experts are not saying that the short-circuit was a necessary condition for this house catching fire” (Mackie, 1965, p. 246), because the fire could have been caused by something else, Mackie argues. “Equally, they are not saying that the short-circuit was a sufficient condition for this house’s catching fire; for if the short-circuit had occurred, but there had been no inflammable material nearby, the fire would not have broken out, and even given both the short-circuit and the inflammable material, the fire would not have occurred if, say, there had been an efficient automatic sprinkler at just the right spot.” (Mackie, 1965, p. 246). So: “The short-circuit which is said to have caused the fire is thus an indispensable part of a complex sufficient (but not necessary) condition of the fire. In this case, then, the so- called cause is, and is known to be, an *insufficient* but *necessary* part of a condition which is itself *unnecessary* but *sufficient* for the

result” (Mackie, 1965, p. 245). Hence the abbreviation INUS, from the first letters of the italicised words above. Mackie’s formal definition of the INUS condition, which also defines the important “minimal sufficient condition”, goes as follows, using Mackie’s original symbols:

- A: The INUS condition, the short circuit.
- B: The presence of inflammable material.
- C: The absence of a suitably placed sprinkler.

ABC: Is then a “sufficient condition of the fire and one that contains no redundant factors; that is ABC is a *minimal sufficient condition* for the fire” (Mackie, 1965, pp. 246, emphasis added).

Mackie then defines an INUS condition as follows:

“A is an INUS condition of a result P if and only if, for some X and for some Y, (AX or Y) is a necessary and sufficient condition of P, but A is not a sufficient condition of P and X is not a sufficient condition of P” (Mackie, 1965, p. 246). Mackie does not constrain the type of phenomenon that can be a cause. In $C \rightarrow E$, meaning C causes E, Mackie does not exclude C from being anything that can take the role of C in $C \rightarrow E$, such as a condition, a causal mechanism, an event, a decision, or a human motive. Elder-Vass (2011) additionally considers causal powers that emerge from social structures.

In Collier (2011), Bennett (2010), and Van Evera (1997), this paper found a heuristic framework for hypothesis testing that, like Mackie, combines necessary and sufficient conditions. Collier’s framework is used to test the strength of a hypothesis, given the evidence available. See Figure 1 based on an illustration in Collier (2011). What is being tested is the hypothetical causal inference, $C \rightarrow E$, the validity of claiming that C caused E.

		Sufficient	
		No	Yes
Necessary	No	Straw in the wind	Smoking gun
	Yes	Hoop	Double decisive

Figure 1: Strength of Causal Inference, Sufficient and Necessary Conditions.

In Collier’s account of the model in Figure 1, adapted from Bennett (2010), “sufficient” means sufficient for affirming causal inference, and “necessary” means necessary for

affirming causal inference. Collier explains the categories in Figure 1 in the following way:

1. Straw in the wind: Non-necessary and non-sufficient conditions, i.e., weak inference. This category of inferences “affirms the relevance of hypothesis, but does not confirm it”, and slightly weakens rival hypotheses.
2. Hoop: Necessary and non-sufficient conditions. This category of inferences “affirms the relevance of hypothesis, but does not confirm it”, and somewhat weakens rival hypotheses.
3. Smoking gun: Non-necessary and sufficient conditions, i.e., strong inference. This category of inferences “confirms the hypothesis”, and substantially weakens rival hypotheses.
4. Double decisive: Necessary and sufficient conditions, i.e., conclusive inference. This category of inferences “confirms the hypothesis and eliminates others”. Collier (2011) paraphrases Bennett on double decisive inferences: “[S]ingle tests that accomplish this are rare in social science, but this leverage may be achieved by combining multiple tests, which together support one explanation and eliminate all others” (Bennett, 2010, p. 211).

The strength of causal inference can alternatively be expressed in Bayesian probabilities (Pearl, 2009; Pearl & Mackenzie, 2018; Waldner, 2015, 2019). Bayesian probabilities can be combined with the categories in Figure 1, which Waldner calls a “well-articulated and highly valuable framework of hypothesis testing”, but he warns of interpretive de- debates about hypothesis tests (Waldner, 2015, p. 244). Waldner’s solution for valid causal inference and generalisation is his completeness standard that involves (a) articulation of a causal graph, (b) articulation of an event- history map, and (c) evaluating the correspondence between the causal graph and the event-history map by descriptive inference (Waldner, 2015, pp. 247-248).

4.2. Causal Graphs

Causal graphs are DAG’s, or directed acyclic graphs (Pearl, 2009; Pearl & Mackenzie, 2018). “The causal graph is thus a complete statement of the causal relations (the average treatment effects) connecting X and Y.” (Waldner, 2015, p. 247). “Causal graphs, or directed acyclic graphs, are composed of nodes or vertices representing random variables (features of a causal system that can undergo change) and directed edges that connect nodes and thus represent relations of probabilistic causal dependence due to the ‘strong’ causal mechanism left tacit in the

graph and represented by the arrow” (Waldner, 2015, p. 247). To Waldner (2015), Pearl (2009) and Pearl and Mackenzie (2018), the causal diagram is what explicitly expresses our commitment to the causal structure of the object of study.

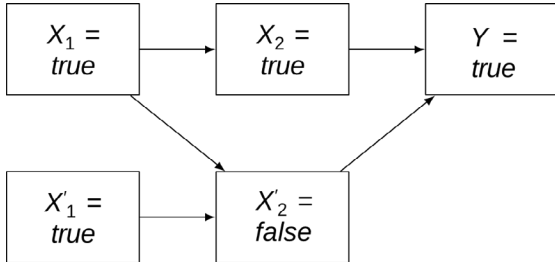


Figure 2: Causal Graph Example.

4.3. Event-history Maps

The second element of Waldner’s completeness standard is where “[...] alongside of a causal graph, process tracers articulate an event-history map for each particular case they study. Whereas causal graphs represent average treatment effects, event-history maps represent unit-level causal effects. A causal graph is an abstract representation of an historical narrative. A scholar does not trace the process depicted by the graph, but rather the process constituted by events that instantiate the graph, in all their contextual specificity. Although the syntax of the event-history map resembles that of the causal graph, the former depicts singular events and thus does not represent a joint probability distribution. The combination of a causal graph with a set of event-history maps thus bridges the gap between the search for generality and the privileging of specific historical outcomes and explanations” (Waldner, 2015, pp. 248, emphasis added).

Waldner’s event-history map is illustrated by an example from Sloman (2009) in Figure 3.

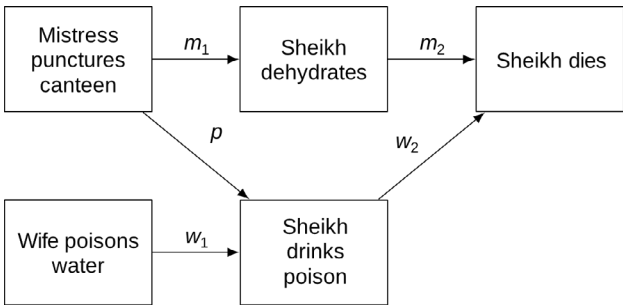


Figure 3: Modelling Causation and Prevention, Example from Sloman (2009).

In Sloman’s example (2009), a sheikh travels through the desert. The sheikh’s jealous wife poisoned his drinking water. This would have killed the sheikh, if his jealous

mistress had not punctured the sheikh's water container, which prevented (*p*) the sheikh's death by poisoning, but caused his death from dehydration instead. In Figure 3, *m*_i denotes "the mistress-path" of the causal model, and *w*_i denotes the "the wife-path". To Waldner, the more informative account in Figure 3 bridges the gap between the contextual specifics and the abstract account illustrated by the causal graph in Figure 2.

4.4. Causal Graph and Event-history Map Correspondence

The final analytical step of Waldner's completeness standard (2015) is performed by "[...] descriptive inference, which means checking the correspondence between the event-history map and the causal graph. This procedure uses the standard tools of measurement theory: construct validity, measurement reliability, and measurement validity. Do the events in the map represent the conceptual connotation of the corresponding node? Is the author's evidence sufficient to confirm the descriptive inference?" (Waldner, 2015, p. 248).

Waldner emphasises that the causal map is fundamental to his proposal of a clearly articulated standard of valid causal inference, including the elimination of rival hypotheses. Waldner argues that process tracing otherwise mainly renders inference to the best explanation (Waldner, 2019, p. 275). The causal graph represents the general configurations of the potential of "invariant causal mechanisms" and their general properties, whereas the event-history map depicts an instantiation of the causal graph that represents a specific case. The descriptive inference verifies that the event-history map is an instantiation of the causal graph, and thereby the possibility of causal identification.

In the traveling sheikh's case, the evidence seems immediately clear, valid, and re-liable. The causal graph corresponds directly to the event-history map. The causal mechanisms identified are common knowledge: Poison and dehydration can cause death. The correspondence between the causal graph and the event-history map is also simple to infer. The sheikh's wife *did* poison his water. The sheikh's mistress *did* puncture his water container. Even if the causal graph is not made explicit, the causal graph and the descriptive inference are conceptually necessary for causal identification.

Figure 3 shows additional informative features of causal modelling:

- 1. Additional evidence may inform the analysis of events based on the model: If, for example, an autopsy

- determines that the sheikh died of poisoning, then the prevention, *p*, remained a potential that did not have any causal influence on events.
- 2. If an autopsy determines that the sheikh died of a snake bite, the causal graph may still hold in its general form, but we cannot "bridge the gap" to the event-history map in the actual case (Waldner, 2015, p. 248).
- 3. The models help explain that causal analysis and culpability analysis are not the same thing: If the sheikh had died of a snake bite, the actions of the wife and the mistress would have had no causal influence on the death of the sheikh. But the wife and the mistress may still be responsible for wrongdoing. In project postmortems, "why did the project fail?" is not the same question as "who should be blamed?".
- 4. The model in Figure 3 also illustrates the non-trivial nature of proposing interventions to avoid similar events. Preventive actions for sheikhs could include checking the water supplies (blocking a causal path). Preventive actions could also include not engaging in multiple intimate relationships (removing vertices).

Collier stresses that "three other points should [...] be emphasised": (1) "Background knowledge is fundamental" for "the specification of hypotheses", and weighing pieces of evidence against one another involves interpretation and judgement (Collier, 2011, p. 825). (2) The distinctions in Figure 1 "are a useful heuristic, but should not be taken rigidly", and they "can depend on the researcher's prior knowledge" (Collier, 2011, p. 825). (3) "The decision about which test is appropriate to a particular piece of evidence thus involves different assumptions and interpretations" (Collier, 2011, p. 825). For IT project postmortems, the failure factor literature represents domain specific background knowledge, see the section *Background knowledge about the causes of IT project failure*.

4.5. Causal Mechanisms

The notion of causal mechanisms has gained much attention, also in the social sciences in connection with process tracing (Bygstad, Munkvold, & Volkoff, 2016; Craver & Tabery, 2017; Glennan, 1996; Hedström & Swedberg, 1996; Kincaid, 2012a; Kutsch & Hall, 2010; Machamer, Darden, & Craver, 2000; Waldner, 2012; Ylikoski, 2012). "In process tracing, one concatenates causally relevant events by enumerating the events constituting a process, identifying the underlying causal mechanisms generating [...] those events, and hence linking constituent events into a robust causal chain that connects one or more independent variables to the outcome in question. To claim the existence of a causal

chain is to claim that, given entities and mechanisms, one event constrained future events such that a subsequent event was bound to happen, or at least that an earlier event substantially shifted the probability distribution governing the subsequent event, making sequelae far more probable" (Waldner, 2012). Further: "Using process tracing on intervening variables is a valuable tool of causal inference and a critical ingredient of good social science. But the identification of mechanisms has been celebrated as going one step further, as adding deep explanatory knowledge (Salmon, 1998; Waldner, 2012). To conclude: "If we wish to claim that process tracing produces adequate causal explanations, we must carefully distinguish mechanisms from intervening variables. Mechanisms explain, I contend, because they embody *invariant* causal properties." (Waldner, 2012). So according to Waldner, generalisation beyond the single case hinges on the invariant properties of the mechanisms identified.

In IT project postmortem analysis this paper considered three categories of mechanisms:

- 1. Common knowledge: In some cases, the generative potential of the mechanism is uncontroversial, once it has been identified. Maxwell (2004b) presents an example of an increasing number of fall accidents in a nursing home. No hypothesis seemed appropriate until observation showed that the staff had mounted wheels on the nursing home's heavy furniture. Unaware of this, residents would continue to lean against the heavy furniture- and fall. The nature of the mechanism - leaning against objects with wheels can make you fall - is trivial. The real discovery was identifying the mechanism by observation.
- 2. Contingent on domain knowledge, normative domain heuristics, practical experience, or common sense. For the IT project domain, the literature on IT project failure factors and causes offers a set of known causes of IT project failure, see the section: Background knowledge about the causes of IT project failure.
- 3. Complex: For example Vaughan's concept of "normalization of deviance in organizations" (Vaughan, 1997, p. 409) based on her study of the Challenger launch decision (Vaughan, 1997). To Vaughan, the "normalization of deviance means that people within the organization become so much accustomed to a deviant behaviour that they don't consider it as deviant, despite the fact that they far exceed their own rules", she explained in an interview quoted by Pinto (2014).

4.6. Causation, Causal Reasoning, and Counterfactuals

Currently, no definition of causation in non-causal terms is available. Causation may be un-analysable (Mumford & Anjum, 2013), a group of terms joined by family resemblance (Wittgenstein, 1953), or non-observable (Hume, 1999). Causation may be observable (Bhaskar, 2008; Maxwell, 2004a, 2012), or criteria for causation may be expressible in terms of sufficient and necessary conditions (Mackie, 1980). Pearl's expression of the effects of causation in terms of conditional probabilities and his use of directed acyclic graphs (DAGs) to symbolise causal networks are compatible with both realist, constructivist, and even idealist foundations. To Pearl, *C* causes *E* if $P(E | do(C)) > P(E)$, that is, *C* is the cause of the effect *E* if the probability of *E*, given the performance or instantiation of *C*, is higher than the probability of *E* (Pearl, 2009; Pearl & Mackenzie, 2018). So, just as this paper used Euclidian geometry without defining the meaning of "line" and "point", this paper modeled causal effects without defining causation (Pearl, 2009; Pearl & Mackenzie, 2018).

There is no need to commit to criteria for causality in terms of counterfactuals (Lewis, 1973; Menzies, 2014; Reiss, 2012). But this study was focused in the counterfactual *features* of causal relations. In postmortem analysis, this study claim, counterfactually, that different past actions would have led to different outcomes. And this paper made claims about the consequences of hypothetical events because this study was focused in the possible effects of future interventions (changes of practice, preventive actions). This is not philosophically innocent, but this study followed Pearl in remaining at the level of causal human reasoning. This study did not make commitments about the metaphysics (ontology and epistemology) of causation. This study simply followed Pearl's interpretation (2009; 2018) that a causal claim entails a counterfactual one: If the cause of some event had been absent, then something else would have happened.

5. Process Tracing for IT Project Postmortems

Process tracing can provide foundations for causal inference in IT project postmortem analysis. Waldner's three-step approach comprises of articulating a causal graph, articulating an event-history map, and checking the correspondence between them by descriptive inference. Explanations and causal inferences rest on either INUS criteria in terms of necessary and sufficient conditions (Collier, 2011), or on Bayesian probabilities (Pearl, 2009; Pearl & Mackenzie, 2018; Waldner, 2015, 2019). Causal explanations developed by process tracing can be strong

enough, and have the counterfactual quality needed, to support postmortem analysis based recommendations for altering practice.

The use of causal diagrams is well-established in academic works on project post-mortems (Ackermann, Eden, & Williams, 1997; Eden, Ackermann, & Cropper, 1992; Williams et al., 2001). Pearl, the inventor of Bayesian networks, uses directed acyclic graphs (DAGs) for formal causal modelling (Pearl, 2009, 2013; Pearl & Mackenzie, 2018). Waldner’s process tracing methodology (2012, 2015, 2019, 2022) and its theoretical foundations on Mackie’s criteria for causation (1965, 1980) uses Pearl’s formalism for causal diagrams, as demonstrated.

5.1. Background Knowledge about the Causes of IT Project Failure

Background knowledge is fundamental for process tracing (Collier, 2011, p. 825). Pearl and Mackenzie (2018) makes a similar point about the role of “prior knowledge” when deriving causal networks. Studies by several researchers spanning four decades has identified and reconfirmed a limited number of factors and causes that can lead to IT project failure (Ayat et al., 2020; Baker, Murphy, & Fisher, 1983; Brown, 2001; Cerpa & Verner, 2009; Charette, 2005; Chua, 2015; Cole, 1995; DeLone & McLean, 2016; Dwivedi et al., 2015; El Emam & Koru, 2008; Ewusi-Mensah, 2003; Fowler & Horan, 2007; Glass, 1998; Hughes, Dwivedi, &

Rana, 2017; Hughes et al., 2016; Jones, 1995; Kappelman, McKeeman, & Zhang, 2006; Keider, 1984; Keil et al., 1998; Kerzner, 2014; McManus & Wood-Harper, 2008; Meier, 2008; Morris & Hough, 1987; Pinto & Slevin, 1987; Poon & Wagner, 2001; Schmidt et al., 2001; Standish, 2014; Verner, Sampson, & Cerpa, 2008; Yardley, 2002; Yeo, 2002), see Table 1.

Sauer (1999) points out that “although practitioner analyses are typically part of the industry’s folklore rather than having been explicitly recorded, researchers have asked practitioners about the causes of failures, so their analyses are embedded in our existing research knowledge (Ewusi-Mensah & Przasnyski, 1994; Keider, 1984). This study therefore treated research findings as capturing the bulk of the IS profession’s knowledge of IS failures” (Sauer, 1999). The literature on IT project failure factors can therefore be considered as a valid representation of both theoretical and practical background knowledge. The IT project failure factor literature can be leveraged for (a) developing postmortem hypotheses and (b) for eliminating rival explanations by screening and evaluation (Dellsén, 2016). The literature that represents background knowledge for process tracing in this paper is focused on “managerially controllable” factors (Pinto & Slevin, 1987; Schmidt, 2023). This is compatible with our definition of root causes, see the section: *Scope and definitions*.

Table 1: IT Project Failure Factors and Causes in the Literature, Adapted from Schmidt (2023).

Failure Factors	Causes of Failure
1. Objectives	Unrealistic, unclear, or changing objectives
2. Senior Management	Lack of management involvement, commitment, or support.
3. Planning	Unrealistic planning, underestimation, or schedule pressure.
4. Requirements	Unclear or changing requirements.
5. Project Execution and Control	Inadequate project execution and control, inadequate change management, or inappropriate method.
6. Technology	Immature technology, technology new to the organisation, or too much customisation.
7. Software Development Method	Inadequate system engineering, excessive scale and complexity. Method and process.
8. User Involvement	Lack of user input and user involvement, lack of user training, failure to manage user expectations.
9. Staff	Lack of skills and experience, insufficient staff, unmotivated staff.
10. Contractors	Poor performance, underestimation by contractors and consultants, lack of experience in contractor management.
11. Risk Management	Inadequate analysis and management of risk.
12. Other	External changes, organisational complexity, lack of trouble-shooting capability.

5.2. Answer to RQ1

Based on this exploration and analysis of process tracing for IT project postmortem analysis, this study has shown how process tracing can support causal inference in IT project postmortem analysis by following Waldner’s completeness standard, using Pearl’s causal modelling, and leveraging the literature on IT project failure factors for generating root cause hypotheses. For example: If a causal link from ‘changing objectives’ (Table 1) to cost

overrun can be identified by process tracing, and supported by project data, then ‘changing objectives’ is a root cause that contributed to project failure. Unless other root cause hypotheses fit the project data better. This answers research question 1: How can process tracing be used for causal inference in IT project postmortem analysis?

6. Elimination of Rival Explanations

Collier et al. (2010) present the following considerations

in connection with causal inference in both qualitative and quantitative research: “A central rea- son why both qualitative and quantitative research are hard to do well is that any study based on observational (i.e. non-experimental) data faces the fundamental inferential challenge of eliminating rival explanations.” And further: “Experiments eliminate rival explanations by randomly assigning the values of the explanatory variable to the units being analysed. So, for eliminating rival causal explanations, the question is not about using quantitative or qualitative methods, but about what kind of data is available, experimental data or observational data. Collier et al. (2010) make a distinction between two types of observations: (1) Data-set observations: Arrays of “scores of specific variables for a designated sample of cases”, and (2) “observations about context, process, or mechanism [that] provide an alternative source of insight into the relationships among the explanatory variables, and between these variables and the dependent variable. [...] The strength of causal-process observations lies [...] in [...] [the] depth of insight. *Even one causal-process observation may be valuable in making inferences*” (emphasis added). So, both the use of process tracing and the possibility of generalisation from single-case studies find support in Collier et al. (2010). They emphasise the challenge of eliminating rival explanations in methods - quantitative and qualitative - that rely on non-experimental data.

6.1. Answer to RQ2

In addition to being a *priori* root cause candidates, the causes in Table 1 are also a quasi-finite set of causes of failure that can be used for exhaustive iterative elimination of rival explanations. This study say ‘quasi’ to acknowledge the possibility of discovering yet unknown causes of failure. For example: If ‘changing objectives’ has been identified as a root cause candidate, then all other causes in Table 1 should be tested to see if any of them have a better fit with the project data, and stronger causal inferences in the event-history maps and the causal graphs that link the cause to failure. This answers research question 2: How can rival explanations of failure be eliminated in process tracing based IT project postmortems?

7. Generalisation of Postmortem Findings

In this section, this study outlined leading scholars’ conclusions regarding the generalisation of case study findings.

7.1. General Validity of Findings in Single-case Studies

Flyvbjerg (2006) presents an argument based on Aristotelian phronesis for the validity of general findings in single-case studies. Flyvbjerg adds a characteristic twist

regarding the underrated value of contextual knowledge: “One can often generalise on the basis of a single case, and the case study may be central to scientific development via generalisation as supplement or alternative to other methods. But formal generalisation is overvalued as a source of scientific development, whereas ‘the force of example’ is underestimated” (Flyvbjerg, 2006, p. 226). Yin distinguishes between “statistical generalisation” (2009, pp. 15, 38-39) and “analytical generalisation” (2009, pp. 15, 38-39; 2011, p. 98; 2018). Analytical generalisation is a non-quantitative method for making discoveries in single-case or small-n studies, where: “Findings are likely to inform a particular set of concepts, theoretical constructs, or hypothesised sequence of events [...] and] applying the same theory to implicate other similar situations where similar concepts might be relevant” (Yin, 2011, p. 100).

On causal inference in case studies Collier et al. (2010) find that: “A long tradition of writing has explored tools and strategies of causal inference in case studies: for example, process tracing and other forms of within-case analysis”. Tools and strategies in Collier et al., include: (a) within-case analysis, (b) process tracing, (c) archival research, and (d) systematic compilation of secondary sources. Additionally: “The practice of causal inference in qualitative research is viable on its own terms”, and “inference in quantitative research can sometimes be improved through the use of tools strongly identified with the qualitative tradition” (Brady & Collier, 2010).

7.2. Generalisation based on Invariant Causal Mechanisms

According to Waldner, it is the quality of the causal mechanisms identified by process tracing that determines the external validity of findings in case studies (Waldner, 2012, 2015, 2022). A process tracing-based case study may identify event-specific, or weak mechanisms, in which case the general scope of the findings is limited. Generalisation of case study finding requires the identification of strong causal mechanisms (mechanisms-as-invariant-causal-principles).

7.3. Answer to RQ3

The possibility of generalisation based on single-case studies is well-supported (Flyvbjerg, 2006; Waldner, 2019; Yin, 2018). Waldner’s specific process tracing solution to external validity hinges on the invariant quality of the causal mechanisms identified. This is the answer to research question 3: How can IT project postmortem findings be generalised?

4. Results

The theoretical exploration in this paper confirms the appropriateness of process tracing as a foundation for

causal inference in IT project postmortem analysis, when combined with the IT project failure factor literature as background knowledge for identifying root causes, and for eliminating rival explanations. The study also explains the necessary elements of a comprehensive project postmortem analysis. The conditions for generalising postmortem findings are explained based on strong theory and a well- developed research literature. The causal modelling of process tracing using directed acyclic graphs (DAGs) supports the development and simulation of interventions based on well-developed theory. These results support IT project postmortem analysis by providing a state-of-the-art theoretic foundation, or theoretical framework, for causal inference, generalisation, and intervention design (practice improvements).

The theory explored in this paper underpins a low-cost approach to project post-mortem analysis because (1) it can be based on data in existing project documents, and because of (2) the systematic use of failure factors from the literature as *a priori* root cause hypotheses. The postmortem theory presented supports policy makers in endorsing postmortem analysis as a reliable source of practice improvements. The process tracing methodology explored and analysed in this paper is directly applicable for practitioners conducting IT project postmortems.

Artificial intelligence (AI) support for the presented approach to postmortem analysis may be feasible, because the approach is based on document analysis, systematic hypothesis testing, and formal causal modelling. It is plausible that AI, for example, can support the document based analysis of changes in budgets, schedules, requirements, and scope of work throughout the project lifecycle, which is a normal and work intensive part of postmortem analysis. AI support for the systematic testing of *a priori* root cause hypotheses may also be feasible.

9. Conclusions

This paper is a contribution to IT project postmortem theory and methodology. This study has explored and analysed process tracing, causal modelling, and causal mechanisms as theoretical foundations for causal inference in IT project postmortem analysis (RQ1). This study has shown how to combine process tracing with the literature on IT project failure factors for causal inference and the elimination of rival explanations (RQ2). This study has shown the conditions for generalising the findings of individual postmortem analyses (RQ3).

7.1. Discussion

The process tracing-based approach to IT project postmortem analysis presented in this paper avoids

attributing causes of failure to individuals and general conditions. The actions of individuals are not identified as root causes because of the strictly causal focus of the approach, which excludes explanations in terms of intent, motive, or purpose (Wright, 1973). General, or structural, conditions are not identified as causes of failure, because root cause candidates and rival explanations are systematically selected from a quasi-finite set consisting of the literature's factors and causes of failure, which are "managerially controllable" (Pinto & Slevin, 1987; Schmidt, 2022). The attribution-free feature of the process tracing based postmortem approach in this paper is, in our view, a positive discovery. Some current approaches to project postmortems in the literature focus on local- context learning, and information gathering from project participants (Birk, Dingsoyr, & Stalhane, 2002; Boddie, 1987; Dingsøyr, 2005). Other approaches render highly abstract results that are difficult to leverage for impact on other projects (Beynon-Davies, 1995; Myers, 1994). Sauer (1999) makes the related point that the original IT project failure factor literature is too abstract to have impact on practice.

The theory explored in this paper opens a way forward for IT project postmortem analysis that is neither too abstract, nor too locally specific. By process tracing, formal causal modelling, and systematic hypothesis generation, This study answered not just *why* but also *how* a project failed. Process tracing opens the causal "black box" that links causes to specific failure criteria (Schmidt, 2022) so that this study designed well-founded interventions (practice improvements). The formal causal diagrams of the process tracing approach presented are informative for evaluating which class of projects a given postmortem analysis is relevant for. Additionally, the explicit criteria for generalisation of the presented approach make it possible to evaluate the scope of validity of individual postmortem findings.

9.2. Limitations

Causal conclusions made by process tracing without reference to invariant causal mechanisms are currently still within the domain of inference to the best explanation (Waldner, 2019). Inference to the best explanation is adequate for justifying recommendations for practice changes aimed at improving future project performance. Post-mortem analysis for forensic engineering in connection with investigation of misconduct or criminal offence may need additional types of investigations of intent, motive, and purpose. The use of failure factors from the literature, which by definition are "managerially controllable" (Schmidt, 2023), and the choice of a compatible definition of root causes as causes that

"management has control to fix" (Paradies & Busch, 1988) focus the analysis on areas that are realistic to address by practice changes. The focus on areas of activity that are under management control is a strength, but clearly also a limitation, because it excludes other kinds of explanations, for example psychological (Flyvbjerg, 2007; Kahneman & Tversky, 1977), political (Flyvbjerg, 2007), and explanations involving causal powers that emerge on social structures (Elder-Vass, 2011).

9.3. Future Research

Future research will include the identification of invariant causal mechanisms (Waldner, 2015, 2019) in postmortem analyses of IT project failures. Invariant causal mechanisms behind IT project failure are potential contributions to theory. Future research will also include additional postmortem analyses of failed IT projects to add to an accumulating body of both contextual and general knowledge about IT project failure. Additionally, postmortem analysis of successful IT projects will show how successful projects have dealt with factors that led to failure in other projects. The potential of AI support for systematic project postmortem analysis should be further developed as a research opportunity.

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References

Abdel-Hamid, T. K., & Madnick, S. E. (1990). The Elusive Silver Lining: How We Fail to Learn from Software Development Failures. *Sloan Management Review*, 32(1), 39-48. <https://www.proquest.com/openview/3a5c12fe4ca9e8c484744a550eebf004>
Ackermann, F., Eden, C., & Williams, T. (1997). Modeling for Litigation: Mixing Qualitative and Quantitative Approaches. *Interfaces*, 27(2), 48-65. <https://doi.org/10.1287/inte.27.2.48>
Ahonen, J. J., & Savolainen, P. (2010). Software engineering projects may fail before they are started: Post-mortem analysis of five cancelled projects. *Journal of Systems and Software*, 83(11), 2175-2187. <https://doi.org/10.1016/j.jss.2010.06.023>
Atkins, W. (2001). *Root Causes Analysis: Literature Review* (Contract Research Report No. 325/2001). Health and Safety Executive (HSE). [https://www.fabig.com/external-](https://www.fabig.com/external-publications/hse-crr-3252001)

[publications/hse-crr-3252001](https://www.fabig.com/external-publications/hse-crr-3252001)
Ayat, M., Imran, M., Ullah, A., & Kang, C. W. (2020). Current trends analysis and prioritization of success factors: a systematic literature review of ICT projects. *International Journal of Managing Projects in Business*, 14(3), 652-679. <https://doi.org/10.1108/IJMPB-02-2020-0075>
Baker, B. N., Murphy, D. C., & Fisher, D. (1983). *Factors Affecting Project Success*. Van Nostrand Reinhold.
Beach, D., & Pedersen, R. B. (2013). *Process-Tracing Methods: Foundations and Guidelines*. The University of Michigan Press. <https://press.umich.edu/Books/P/Process-Tracing-Methods>
Beach, D., & Pedersen, R. B. (2016). *Causal Case Study Methods: Foundations and Guidelines for Comparing, Matching, and Tracing*. The University of Michigan Press. <https://press.umich.edu/Books/C/Causal-Case-Study-Methods2>
Bennett, A. (2008). Process Tracing: a Bayesian Perspective. In J. M. Box-Steffensmeier, H. E. Brady, & D. Collier (Eds.), *The Oxford Handbook of Political Methodology* (pp. 702-721). Oxford University Press. <https://doi.org/10.1093/oxfordhb/9780199286546.003.0030>
Bennett, A. (2010). Process Tracing and Causal Inference. In H. E. Brady & D. Collier (Eds.), *Rethinking Social Inquiry: Diverse Tools, Shared Standards*. Rowman & Littlefield. <https://core.ac.uk/download/pdf/148349286.pdf>
Beynon-Davies, P. (1995). Information systems 'failure': the case of the London Ambulance Service's Computer Aided Despatch project. *European Journal of Information Systems*, 4(3), 171-184. <https://doi.org/10.1057/ejis.1995.20>
Beynon-Davies, P. (1999). Human error and information systems failure: the case of the London ambulance service computer-aided despatch system project. *Interacting with Computers*, 11(6), 699-720. [https://doi.org/10.1016/S0953-5438\(98\)00050-2](https://doi.org/10.1016/S0953-5438(98)00050-2)
Bhaskar, R. (2008). *A Realist Theory of Science*. Routledge. <https://doi.org/10.4324/9780203090732>
Birk, A., Dingsoyr, T., & Stalhane, T. (2002). Postmortem: Never leave a project without it. *IEEE Software*, 19(3), 43-45. <https://doi.org/10.1109/MS.2002.1003452>
Boddie, J. (1987). The Project Postmortem. *Computerworld*, 21(49), 77-82.
Boell, S. K., & Cecez-Kecmanovic, D. (2014). A hermeneutic approach for conducting literature reviews and literature searches. *Communications of the Association for information Systems*, 34(1), 12. <https://doi.org/10.17705/1CAIS.03412>
Bradley, G. W. (1978). Self-serving biases in the attribution process: A reexamination of the fact or fiction question. *Journal of Personality and Social Psychology*, 36(1), 56-71. <https://doi.org/10.1037/0022-3514.36.1.56>
Brady, H. E. (2011). Causation and Explanation in Social Science. In R. Goodin (Ed.), *The Oxford Handbook of*

- Political Science* (pp. 1054-1107). Oxford University Press. <https://doi.org/10.1093/oxfordhb/9780199604456.013.0049>
- Brady, H. E., & Collier, D. (2010). *Rethinking Social Inquiry: Diverse Tools, Shared Standards* (2nd ed.). Rowman & Littlefield Publishers.
- Brown, T. (2001). Modernisation or Failure? IT Development Projects in the UK Public Sector. *Financial Accountability & Management*, 17(4), 363-381. <https://doi.org/10.1111/1468-0408.00139>
- Bygstad, B., Munkvold, B. E., & Volkoff, O. (2016). Identifying Generative Mechanisms through Affordances: A Framework for Critical Realist Data Analysis. *Journal of Information Technology*, 31(1), 83-96. <https://doi.org/10.1057/jit.2015.13>
- Byrne, D., & Uprichard, E. (2012). Useful Complex Causality. In H. Kincaid (Ed.), *The Oxford Handbook of Philosophy of Social Science* (pp. 109-129). Oxford University Press. <https://doi.org/10.1093/oxfordhb/9780195392753.013.0006>
- Cerpa, N., & Verner, J. M. (2009). Why did your project fail? *Communications of the ACM*, 52(12), 130-134. <https://doi.org/10.1145/1610252.1610286>
- Charette, R. N. (2005). Why software fails [software failure]. *IEEE Spectrum*, 42(9), 42-49. <https://doi.org/10.1109/MSPEC.2005.1502528>
- Checkel, J. T., & Bennett, A. (2014). *Process Tracing: From Metaphor to Analytic Tool*. Cambridge University Press. <https://doi.org/10.1017/CBO9781139858472>
- Chua, A. Y. K. (2015). Exhuming it Projects from Their Graves: An Analysis of Eight Failure Cases and Their Risk Factors. *Journal of Computer Information Systems*, 49(3), 31-39. <https://doi.org/10.1080/08874417.2009.11645321>
- Cole, A. (1995). Runaway projects: cause and effects. *Software World*, 26(3), 3-5.
- Collier, D. (2011). Understanding Process Tracing. *PS: Political Science & Politics*, 44(4), 823-830. <https://doi.org/10.1017/S1049096511001429>
- Collier, D., Brady, H. E., & Seawright, J. (2010). Outdated Views of Qualitative Methods: Time to Move On. *Political Analysis*, 18(4), 506-513. <https://doi.org/10.1093/pan/mpq022>
- Craver, C., & Tabery, J. (2017). Mechanisms in Science. In E. N. Walta (Ed.), *The Stanford Encyclopedia of Philosophy*. Stanford University. <https://plato.stanford.edu/archives/spr2017/entries/science-mechanisms>
- Dellsén, F. (2016). Explanatory Rivals and the Ultimate Argument. *Theoria*, 82(3), 217-237. <https://doi.org/10.1111/theo.12084>
- DeLone, W. H., & McLean, E. R. (2016). Information Systems Success Measurement. *Foundations and Trends® in Information Systems*, 2(1), 1-116. <https://doi.org/10.1561/29000000005>
- Dingsøyr, T. (2005). Postmortem reviews: purpose and approaches in software engineering. *Information and Software Technology*, 47(5), 293-303. <https://doi.org/10.1016/j.infsof.2004.08.008>
- Dwivedi, Y. K., Wastell, D., Laumer, S., Henriksen, H. Z., Myers, M. D., Bunker, D., et al. (2015). Research on information systems failures and successes: Status update and future directions. *Information Systems Frontiers*, 17(1), 143-157. <https://doi.org/10.1007/s10796-014-9500-y>
- Eden, C., Ackermann, F., & Cropper, S. (1992). The Analysis of Cause Maps. *Journal of Management Studies*, 29(3), 309-324. <https://doi.org/10.1111/j.1467-6486.1992.tb00667.x>
- Eisenhart, M. (1991). Conceptual Frameworks for Research Circa 1991: Ideas From a Cultural Anthropologist; Implications for Mathematics Education Rese. In R. G. Under-Hill (Ed.), *Psychology of Mathematics Education* (pp. 202-219). Christiansburg Printing Company, Inc. https://nepc.colorado.edu/sites/default/files/Eisenhart_ConceptualFrameworksforResearch.pdf
- El Emam, K., & Koru, A. G. (2008). A Replicated Survey of IT Software Project Failures. *IEEE Software*, 25(5), 84-90. <https://doi.org/10.1109/MS.2008.107>
- Elder-Vass, D. (2011). *The Causal Power of Social Structures: Emergence, Structure and Agency*. Cambridge University Press. <https://doi.org/10.1017/CBO9780511761720>
- Ewusi-Mensah, K. (2003). *Software Development Failures*. MIT Press. <https://mitpress.mit.edu/9780262050722/software-development-failures>
- Ewusi-Mensah, K., & Przasnyski, Z. H. (1994). Factors Contributing to the Abandonment of Information Systems Development Projects. *Journal of Information Technology*, 9(3), 185-201. <https://doi.org/10.1177/026839629400900303>
- Ewusi-Mensah, K., & Przasnyski, Z. H. (1995). Learning from Abandoned Information Systems Development Projects. *Journal of Information Technology*, 10(1), 3-14. <https://doi.org/10.1177/026839629501000102>
- Flyvbjerg, B. (2006). Five Misunderstandings About Case-Study Research. *Qualitative Inquiry*, 12(2), 219-245. <https://doi.org/10.1177/1077800405284363>
- Flyvbjerg, B. (2007). Curbing Optimism Bias and Strategic Misrepresentation in Planning: Reference Class Forecasting in Practice. *European Planning Studies*, 16(1), 3-21. <https://doi.org/10.1080/09654310701747936>
- Flyvbjerg, B., Budzier, A., Lee, J. S., Keil, M., Lunn, D., & Bester, D. W. (2022). The Empirical Reality of IT Project Cost Overruns: Discovering A Power-Law Distribution. *Journal of Management Information Systems*, 39(3), 607-639. <https://doi.org/10.1080/07421222.2022.2096544>
- Fowler, J. J., & Horan, P. (2007). Are Information Systems' Success and Failure Factors Related? An Exploratory Study. *Journal of Organizational and End User Computing (JOEUC)*, 19(2), 1-22. <https://doi.org/10.4018/joeuc.2007040101>
- Gawande, A. (2011). *The Checklist Manifesto: How to Get Things Right*. Picador Usa.
- Glass, R. L. (1998). *Software Runaways-Lessons Learned From Massive Software Project Failures*. Prentice Hall.
- Glass, R. L. (2002). Project retrospectives, and why they never happen. *IEEE Software*, 19(5), 112. <https://doi.org/10.1109/MS.2002.1032872>
- Glennan, S. S. (1996). Mechanisms and the Nature of Causation. *Erkenntnis*, 44(1), 49-71. <https://doi.org/10.1007/BF00172853>
- Hedström, P., & Swedberg, R. (1996). Social Mechanisms. *Acta Sociologica*, 39(3), 281-308. <https://doi.org/10.1177/000169939603900302>
- Hougham, M. (1996). London Ambulance Service computer-aided despatch system. *International Journal of Project Management*, 14(2), 103-110. [https://doi.org/10.1016/0263-7863\(95\)00067-4](https://doi.org/10.1016/0263-7863(95)00067-4)
- Hughes, D. L., Dwivedi, Y. K., & Rana, N. P. (2017). Mapping IS failure factors on PRINCE2® stages: an application of Interpretive Ranking Process (IRP). *Production Planning & Control*, 28(9), 776-790. <https://doi.org/10.1080/09537287.2017.1311431>
- Hughes, D. L., Dwivedi, Y. K., Rana, N. P., & Simintiras, A. C. (2016). Information systems project failure – analysis of causal links using interpretive structural modelling. *Production Planning & Control*, 27(16), 1313-1333. <https://doi.org/10.1080/09537287.2016.1217571>
- Hume, D. (1999). An Enquiry concerning Human Understanding. 1748. *Classics of Western Philosophy*, 763-828.
- Jones, C. (1995). Patterns of large software systems: failure and success. *Computer*, 28(3), 86-87. <https://doi.org/10.1109/2.366170>
- Kahneman, D., & Tversky, A. (1977). *Intuitive Prediction: Biases and Corrective Procedures*. Technical Report Defence Advanced Research Projects Agency. <https://apps.dtic.mil/sti/tr/pdf/ADA047747.pdf>
- Kappelman, L. A., McKeeman, R., & Zhang, L. (2006). Early Warning Signs of it Project Failure: The Dominant Dozen. *Information Systems Management*, 23(4), 31-36. <https://doi.org/10.1201/1078.10580530/46352.23.4.2006.0901/95110.4>
- Kasi, V., Keil, M., Mathiassen, L., & Pedersen, K. (2008). The post mortem paradox: a Delphi study of IT specialist perceptions. *European Journal of Information Systems*, 17(1), 62-78. <https://doi.org/10.1057/palgrave.ejis.3000727>
- Keider, S. P. (1984). Why Systems Development Projects Fail. *Journal of Information Systems Management*, 1(3), 33-38. <https://doi.org/10.1080/07399019408963043>
- Keil, M., Cule, P. E., Lyytinen, K., & Schmidt, R. C. (1998). A framework for identifying software project risks. *Communications of the ACM*, 41(11), 76-83. <https://doi.org/10.1145/287831.287843>
- Kerth, H. (2001). *Project Retrospectives: A Handbook for Team Reviews*. Dorset House Publishing. <https://www.dorsethouse.com/books/pr.html>
- Kerzner, H. R. (2014). *Project Management Best Practices*
- Achieving Global Excellence* (3rd ed.). Wiley.
- Kincaid, H. (2012a). Mechanisms, Causal Modeling, and the Limitations of Traditional Multiple Regression. In H. Kincaid (Ed.), *The Oxford Handbook of Philosophy of Social Science* (pp. 46-64). Oxford University Press. <https://doi.org/10.1093/oxfordhb/9780195392753.013.0003>
- Kincaid, H. (2012b). *The Oxford Handbook of Philosophy of Social Science*. Oxford University Press. <https://doi.org/10.1093/oxfordhb/9780195392753.001.0001>
- King, G., Keohane, R. O., & Verba, S. (1994). *Designing Social Inquiry: Scientific Inference in Qualitative Research*. Princeton University Press.
- Kutsch, E., & Hall, M. (2010). Deliberate ignorance in project risk management. *International Journal of Project Management*, 28(3), 245-255. <https://doi.org/10.1016/j.jiproman.2009.05.003>
- Lawler, J., & Waldner, D. (2023). Interpretivism versus Positivism in an Age of Causal Inference. In H. Kincaid & J. Van Bouwel (Eds.), *The Oxford Handbook of Philosophy of Political Science* (pp. 221-242). Oxford University Press. <https://doi.org/10.1093/oxfordhb/9780197519806.013.11>
- Lehmann, U., & Prabhakar, G. P. (2008). A Post-Mortem Evaluation of an IT project a Case Study of a Process Enhancement IT-Project in a Maintenance, Repair and Overhaul Company. *International Journal of Business and Management*, 3(6), 57-70. <https://doi.org/10.5539/ijbm.v3n6p57>
- Lewis, D. (1973). Causation. *The Journal of Philosophy*, 70(17), 556-567. <https://doi.org/10.2307/2025310>
- Machamer, P., Darden, L., & Craver, C. F. (2000). Thinking about Mechanisms. *Philosophy of Science*, 67(1), 1-25. <https://doi.org/10.1086/392759>
- Mackie, J. L. (1965). Causes and Conditions. *American Philosophical Quarterly*, 2(4), 245-264. <https://www.jstor.org/stable/20009173>
- Mackie, J. L. (1980). *The Cement of the Universe: A Study of Causation*. Clarendon Press. <https://doi.org/10.1093/0198246420.001.0001>
- Mahoney, J. (2012). The Logic of Process Tracing Tests in the Social Sciences. *Sociological Methods & Research*, 41(4), 570-597. <https://doi.org/10.1177/0049124112437709>
- Maxwell, J. A. (2004a). Causal Explanation, Qualitative Research, and Scientific Inquiry in Education. *Educational Researcher*, 33(2), 3-11. <https://doi.org/10.3102/0013189x033002003>
- Maxwell, J. A. (2004b). Using Qualitative Methods for Causal Explanation. *Field Methods*, 16(3), 243-264. <https://doi.org/10.1177/1525822x04266831>
- Maxwell, J. A. (2012). *A Realist Approach for Qualitative Research*. SAGE Publications Ltd.
- McManus, J., & Wood-Harper, T. (2008). *A Study in Project Failure*. The Chartered Institute for IT. <https://www.bcs.org/articles-opinion-and-research/a-study-in-project-failure>

- Meier, S. R. (2008). Best Project Management and Systems Engineering Practices in the Preacquisition Phase for Federal Intelligence and Defense Agencies. *Project Management Journal*, 39(1), 59-71. <https://doi.org/10.1002/pmj.20035>
- Menzies, P. (2014). Counterfactual Theories of Causation. In *The Stanford Encyclopedia of Philosophy* (pp. 1-51). The Metaphysics Research Lab, Center for the Study of Language and Information, Stanford University, Stanford CA 94305-4115.
- Miller, D. T., & Ross, M. (1975). Self-Serving Biases in the Attribution of Causality: Fact or Fiction? *Psychological Bulletin*, 82(2), 213-225. <https://doi.org/10.1037/h0076486>
- Morris, P. (2011). Managing the Front-End: Back to the Beginning. *Project Perspectives*, 33, 4-9. <https://www.scribd.com/document/275408946/Managing-the-Front-End-Back-to-the-Beginning>
- Morris, P. (2013). *Reconstructing Project Management*. Wiley-Blackwell.
- Morris, P., & Hough, G. (1987). *The Anatomy of Major Projects*. Chichester: Wiley and Sons.
- Mumford, S., & Anjum, R. L. (2013). *Causation: A Very Short Introduction*. Oxford University Press. <https://doi.org/10.1093/acrade/9780199684434.001.0001>
- Myers, M. D. (1994). A disaster for everyone to see: An interpretive analysis of a failed is project. *Accounting, Management and Information Technologies*, 4(4), 185-201. [https://doi.org/10.1016/0959-8022\(94\)90022-1](https://doi.org/10.1016/0959-8022(94)90022-1)
- Myllyaho, M., Salo, O., Kääriäinen, J., Hyysalo, J., & Koskela, J. (2004). A Review of Small and Large Post-Mortem Analysis Methods. In *Software & systems engineering and their applications: 17th international conference: proceeding* (pp. 1-8). CNAM. <https://cris.vtt.fi/en/publications/a-review-of-small-and-large-post-mortem-analysis-methods>
- Nelson, R. R. (2008). Project Retrospectives: Evaluating Project Success, Failure, and Everything in Between. *MIS Quarterly Executive*, 4(3), 5. <https://aisel.aisnet.org/misqe/vol4/iss3/5>
- NTSB. (2016a). *History of The National Transportation Safety Board*. Technical Report National Transportation Safety Board. <https://www.nts.gov/about/history/Pages/default.aspx>
- NTSB. (2016b). *Mission Statement of The National Transportation Safety Board*. Technical Report National Transportation Safety Board. <https://www.nts.gov/safety/safety-recs/recletters/A-16-020-029.pdf>
- Packendorff, J. (1995). Inquiring into the temporary organization: New directions for project management research. *Scandinavian Journal of Management*, 11(4), 319-333. [https://doi.org/10.1016/0956-5221\(95\)00018-Q](https://doi.org/10.1016/0956-5221(95)00018-Q)
- Pan, G., & Flynn, D. (2003). Why Information Systems Project Postmortems Fail: An Attribution Perspective Based on a Case Study Analysis. *ICIS 2003 Proceedings*, 31. <https://aisel.aisnet.org/icis2003/31>
- Paradies, M., & Busch, D. (1988). Root cause analysis at Savannah River plant (nuclear power station). In *Conference Record for 1988 IEEE Fourth Conference on Human Factors and Power Plants* (pp. 479-483). IEEE. <https://doi.org/10.1109/HFPP.1988.27547>
- Pearl, J. (2009). *Causality: Models, Reasoning, and Inference* (2nd ed.). Cambridge University Press. <https://doi.org/10.1017/CBO9780511803161>
- Pearl, J. (2013). Structural Counterfactuals: A Brief Introduction. *Cognitive Science*, 37(6), 977-985. <https://doi.org/10.1111/cogs.12065>
- Pearl, J., & Mackenzie, D. (2018). *The Book of Why*. Allen Lane, Penguin Books. <https://www.penguin.co.uk/books/289825/the-book-of-why-by-judea-pearl-and-dana-mackenzie/9780141982410>
- Petroski, H. (1992). *To Engineer is Human: The Role of Failure in Successful Design*. Vintage Books.
- Pinto, J. K. (2014). Project management, governance, and the normalization of deviance. *International Journal of Project Management*, 32(3), 376-387. <https://doi.org/10.1016/j.jiproman.2013.06.004>
- Pinto, J. K., & Slevin, D. P. (1987). Critical Factors in Successful Project Implementation. *IEEE Transactions on Engineering Management*, EM-34(1), 22-27. <https://doi.org/10.1109/TEM.1987.6498856>
- PMI. (2013). *A Guide to the Project Management Body of Knowledge* (5th ed.). Project Management Institute.
- PMI. (2017). *A Guide to the Project Management Body of Knowledge* (6th ed.). Project Management Institute.
- Poon, P., & Wagner, C. (2001). Critical success factors revisited: success and failure cases of information systems for senior executives. *Decision Support Systems*, 30(4), 393-418. [https://doi.org/10.1016/S0167-9236\(00\)00069-5](https://doi.org/10.1016/S0167-9236(00)00069-5)
- Reiss, J. (2012). Counterfactuals. In H. Kincaid (Ed.), *The Oxford Handbook of Philosophy of Social Science* (pp. 154-183). Oxford University Press. <http://eprints.lse.ac.uk/id/eprint/36506>
- Salmon, W. C. (1998). *Causality and Explanation*. Oxford University Press. <https://doi.org/10.1093/0195108647.001.0001>
- Sauer, C. (1999). Deciding the future for IS failures: not the choice you might think. In W. Currie & B. Galliers (Eds.), *Rethinking management information systems* (pp. 279-309). Oxford University Press. <https://doi.org/10.1093/oso/9780198775331.003.0015>
- Schalken, J., Brinkkemper, S., & van Vliet, H. (2006). A method to draw lessons from project postmortem databases. *Software Process: Improvement and Practice*, 11(1), 35-46. <https://doi.org/10.1002/spip.251>
- Schieg, M. (2007). Post-mortem analysis on the analysis and evaluation of risks in construction project management. *Journal of Business Economics and Management*, 8(2), 145-153. <https://doi.org/10.1080/16111699.2007.9636162>
- Schmidt, J. (2022). IT project failure, termination, and the marginal cost trap. *Journal of Modern Project Management*, 10, 255-275. <https://journalmodernpm.com/article-view/?id=536>
- Schmidt, J. (2023). Mitigating risk of failure in information technology projects: Causes and mechanisms. *Project Leadership and Society*, 4, 100097. <https://doi.org/10.1016/j.plas.2023.100097>
- Schmidt, J. (2024). An IT project postmortem: identifying root causes and eliminating rival explanations. *Journal of Information Technology Case and Application Research*, 26(4), 318-364. <https://doi.org/10.1080/15228053.2024.2426965>
- Schmidt, R., Lyytinen, K., Keil, M., & Cule, P. (2001). Identifying Software Project Risks: An International Delphi Study. *Journal of Management Information Systems*, 17(4), 5-36. <https://doi.org/10.1080/07421222.2001.11045662>
- Scriven, M. (1974). Maximizing the Power of Causal Investigations: The Modus Operandi Method. In W. J. Popham (Ed.), *Evaluation in Education: Current Applications* (pp. 68-84). Mccutchan Publication Corporation.
- Sloman, S. (2009). *Causal Models: How People Think About the World and Its Alternatives*. Oxford University Press.
- Standish. (2014). *The Standish Group Report*. The Standish Group. <https://simpleisbetterthancomplex.com/media/2016/10/chaos-report.pdf>
- Trampusch, C., & Palier, B. (2016). Between X and Y: how process tracing contributes to opening the black box of causality. *New Political Economy*, 21(5), 437-454. <https://doi.org/10.1080/13563467.2015.1134465>
- Van Evera, S. (1997). *Guide to Methods for Students of Political Science*. Cornell University Press. <https://www.cornellpress.cornell.edu/book/9780801484575/guide-to-methods-for-students-of-political-science>
- Vaughan, D. (1997). *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA*. University of Chicago Press.
- Verner, J., Cox, K., Bleistein, S., & Cerpa, N. (2005). Requirements Engineering and Software Project Success: an industrial survey in Australia and the U.S. *Australasian Journal of Information Systems*, 13(1), 225-238. <https://doi.org/10.3127/ajis.v13i1.73>
- Verner, J., Sampson, J., & Cerpa, N. (2008). What factors lead to software project failure? In *2008 second international conference on research challenges in information science* (pp. 71-80). IEEE. <https://doi.org/10.1109/RCIS.2008.4632095>
- Waldner, D. (2012). Process Tracing and Causal Mechanisms. In H. Kincaid (Ed.), *The Oxford Handbook of Philosophy of Social Science* (pp. 65-84). Oxford University Press. <https://doi.org/10.1093/oxfordhb/9780195392753.013.0004>
- Waldner, D. (2015). Process Tracing and Qualitative Causal Inference. *Security Studies*, 24(2), 239-250. <https://doi.org/10.1080/09636412.2015.1036624>
- Waldner, D. (2016). Invariant Causal Mechanisms. *Qualitative & Multi-Method Research*, 14(1-2), 28-33. <https://core.ac.uk/download/pdf/144827969.pdf>
- Waldner, D. (2019). Causal Mechanisms and Qualitative Causal Inference in the Social Sciences. In M. Nagatsu & A. Ruzzene (Eds.), *Contemporary Philosophy and Social Science: An Interdisciplinary Dialogue* (pp. 275-300). Bloomsbury Academic.
- Waldner, D. (2022). Qualitative Causal Inference and Critical Junctures: The Problem of Backdoor Paths. In D. Collier & G. L. Munck (Eds.), *Critical Junctures and Historical Legacies: Insights and Methods for Comparative Social Science* (pp. 159-182). Rowman & Littlefield Publishers.
- Williams, T. (2004). Identifying the hard lessons from projects – easily. *International Journal of Project Management*, 22(4), 273-279. <https://doi.org/10.1016/j.jiproman.2003.11.001>
- Williams, T. M., Eden, C., Ackermann, F., & Howick, S. M. (2001). The use of project post-mortems. In *Project Management Institute Annual Symposium* (pp. 1-6). Project Management Institute. <http://eprints.soton.ac.uk/36949>
- Wittgenstein, L. (1953). *Philosophical Investigations*. Blackwell Publishing, Oxford.
- Wohlin, C. (2014). Guidelines for snowballing in systematic literature studies and a replication in software engineering. In *Proceedings of the 18th international conference on evaluation and assessment in software engineering* (pp. 1-10). Association for Computing Machinery. <https://doi.org/10.1145/2601248.2601268>
- Wright, L. (1973). Rival Explanations. *Mind*, 82(328), 497-515. <https://www.jstor.org/stable/2252204>
- Yardley, D. (2002). *Successful IT Project Delivery: Learning the Lessons of Project Failure* (1st ed.). Addison Wesley.
- Yeo, K. T. (2002). Critical failure factors in information system projects. *International Journal of Project Management*, 20(3), 241-246. [https://doi.org/10.1016/S0263-7863\(01\)00075-8](https://doi.org/10.1016/S0263-7863(01)00075-8)
- Yin, R. K. (2009). *Case Study Research: Design and Methods* (4th ed.). SAGE Publications Ltd.
- Yin, R. K. (2011). *Applications of Case Study Research*. Sage Publications. <https://uk.sagepub.com/en-gb/eur/applications-of-case-study-research/book235140>
- Yin, R. K. (2018). *Case Study Research and Applications: Design and Methods* (6th ed.). Sage Publications.
- Ylikoski, P. (2012). Micro, Macro, and Mechanisms. In H. Kincaid (Ed.), *The Oxford Handbook of Philosophy of the Social Sciences* (pp. 21-45). Oxford University Press. <https://doi.org/10.1093/oxfordhb/9780195392753.013.0002>