Toward High Reliability Project Organizing in Safety-Critical Projects

ABSTRACT

High reliability organizations claim to be special organizations that have consistently demonstrated safe performance in operating environments, which are simultaneously of high technical complexity, high consequence, and high tempo. This article argues that the literature on high reliability organizing, which emerged through studying day-to-day operations in the nuclear industry, air traffic control, and U.S. navy aircraft carriers, might hold important lessons for how the project management community can approach the management of safety-critical projects—projects in which safety is of paramount importance. Its aim is to consider how high-reliability organizing might be realized in these safety-critical projects.

KEYWORDS: project management; high reliability; safety-critical, complex projects

INTRODUCTION

Imagine for a moment a safety-critical project—the building of a new nuclear power plant, the safe disposal of highly radioactive nuclear waste, or the design of a new gas-turbine aircraft engine. Safety is the overarching priority in these environments; yet, these projects are complicated, multi-million pound dollar endeavors that span several years and require the skilled efforts of many different professionals, often working across disparate organizations under the watchful gaze of a broad array of internal and external stakeholders and regulatory authorities.

This article considers whether the literature on high reliability organizing, which emerged through the study of *day-to-day operations* in the nuclear power industry, air traffic control industry, and U.S. Navy aircraft carriers (Schulmann, 1993; La Porte, 1988; Rochlin, La Porte, & Roberts, 1987, respectively) could hold valuable lessons for how the project management community can approach the management of safety-critical *projects*— projects in which safety is of paramount importance and where the hazards that must be controlled can harm either the environment, personnel, or the public (Reiman & Oedewald, 2009). To the best of the author's knowledge, there have been only four previous studies that have viewed projects through the lens of high reliability. Two of these studies concern reliability in IT projects (Sullivan & Beach, 2009; Denyer, Kutsch, Lee-Kelley, & Hall, 2011), and two are situated in the domain of construction management (Brady & Davies' [2009] review of London's Heathrow Terminal 5 project and olde Scholtenhuis & Dorée's [2013] study of urban infrastructure projects). Aside from these studies, there has been scant application of the theory of high reliability organizing to the domain of project management.

This article is structured as follows: First, the particular challenges facing safety-critical projects are explored. Second, the theory of high reliability organizing is introduced and the extant literature on high reliability organizations is synthesized into a set of defining characteristics of an 'ideal-type high reliability organization.' Third, the similarities and differences between safety-critical *projects* and *day-to-day* operations are discussed; demonstrating that the environment of the safety-critical project is sufficiently similar to that of ongoing operations to make the theories of high reliability organizing relevant and applicable to project managers engaged in safety-critical projects. Subsequent sections address lessons that project managers might take from high reliability theory and hypothesize how high reliability organizing might be realized in safety-critical projects. Finally, methods of future empirical validation are proposed.

The Challenges Inherent in Safety-Critical Projects

The nature of the safety-critical project is perhaps best understood by illustration: for example, building a new facility to house nuclear waste or the entry into service of critical aircraft components, such as brake actuation systems. The consequences of errors in the design, construction, or operation of these projects would be serious, if not catastrophic. Accidents would almost certainly involve injury and loss of life and in the case of nuclear incidents, wide-ranging and long-term environmental damage. The overarching priority afforded to safety in these projects is a differentiating factor between safety-critical and other more routine projects, in that the traditional performance objectives of time, cost, and quality are *always* secondary to safety. Conservative solutions may also be favored over technological advances (Kettunun, Reiman, & Wahlstrom, 2007) and opportunities for learning through trial and error may be limited due to the high consequences of failure (Weick, Sutcliffe, & Obstfeld, 1999). In addition, the technologies that underpin these projects are complex and often subject to externally mandated change: in the nuclear industry, in response to new regulatory requirements (La Porte & Thomas, 1995) and in civil aerospace, in response to competitive pressures from airline operators or regulatory demands imposed by the European Aviation Safety Agency or the Federal Aviation Administration (Hollnagel, Woods, & Leveson, 2006). The delivery of these projects also depends on a complex and often fragmented supply chain. There may be severe resource constraints on the project team, both internally through a lack of staff members with the capability to carry out the project and in the wider supply chain (for example, in getting subcontractors to commit to extended working in remote locations) (Saunders, Gale, & Sherry, 2015).

These projects are often played out in the public domain—witness the recent extensive media debate over the decision to allow electricity utility Électricité de FranceEDF to begin building the first new nuclear reactor in the United Kingdom in 20 years (see, for example, BBC, 2013). There may be multiple stakeholders, often holding contradictory opinions. Ignoring stakeholder groups is not a realistic and sustainable option; rather, the views of the local community, politicians, and the media must be taken into account alongside those more directly involved in the project (suppliers, contractors, project team, customers, and regulators). Finally, safety-critical projects can be large or small in scale, with many such projects concerned with ongoing maintenance and upgrades to existing facilities or products. For example, a project to replace a failed component in the hazardous environment of a nuclear power plant, where engineers can only work for 120 seconds before reaching their annual permitted dose of radiation, is a safety-critical project, even if its budget and timescale is measured in U.S. $'s thousands and weeks, rather than U.S.$'s millions and years.

Theories of High Reliability Organizing

The foundational research on high reliability organizations was carried out in three particular organizations: the U.S. air traffic control system (La Porte, 1988), electrical operations, and power generation at the Pacific Gas and Electric Company (Schulman, 1993) and flight operations aboard two U.S. navy aircraft carriers (Rochlin et al., 1987). Although the three original case studies were diverse in their activities, the researchers found similarities in that "*they all operate in an unforgiving social and political environment, an environment rich with* *the potential for error, where the scale of consequences precludes learning through experimentation, and where to avoid failures in the shifting sources of vulnerability, complex processes are used to manage complex technology"* (Weick et al., 1999, p. 32). Other common features were the high priority afforded to safety, hierarchical yet decentralized decision-making processes, evidence of redundancy (both in equipment design and operating procedures), and strong organizational cultures that fostered openness, individual accountability, and constant vigilance in anticipating and responding to potential safety threats (Roberts & Bea, 2001; Weick et al., 1999). The findings from these three seminal case studies gave rise to the term 'high reliability organizations,' although the original proponents preferred the expression 'reliability-seeking organizations' as a more dynamic descriptor of the concept (Bourrier, 2011; Rochlin 1993). The notion of a high reliability organization has more recently been extended to industry sectors beyond the original context (cf. healthcare, Gaba, 2000; Ruchlin, 2004), power generation and transmission (Roe & Schulman, 2008), oil and gas (Mannarelli, Roberts, & Bea, 1996), fire-fighting (Myers, 2005), the military (Demchak, 1996), and construction (olde Scholtenhuis & Dorée, 2013).

The evolution of research on high reliability organising has not been without controversy. Two specific areas of contention remain the ongoing debate between normal accident theory and high reliability theory as explanations of safe performance in safety-critical organizations (see, for example, Bain, 1999; Leveson, Dulac, Marais, & Carroll, 2009; Rijpma, 1997; Rosa, 2005) and the extent to which the characteristics of high reliability organizing can be translated from their original context of highly complex, socio-technological systems to a broader range of 'less exotic' organizations (Creed, Stout, & Roberts, 1993). Olde Scholtenhuis and Dorée (2014) argue that research on high reliability organising has been limited by its reductionist focus on absolute reliability and on environments that are safety-critical in nature, whereas an alternative, more pragmatic perspective would view reliability as relative, of import to all organizations in terms of improved performance and therefore applicable across a far broader range of industries. Indeed, many of the features of high reliability organizations make good practical sense and promoting a more open, just, and learning culture, decentralizing decision making and acting more mindfully is good working practice, whatever the organizational context. An additional nuance in the contemporary debate around high reliability organizing involves the use of the term "organization," which, it is argued, may limit thinking around high reliability organizing to matters of structure and procedure. In reality, "organizations" are enacted by individuals so the analysis might be better undertaken at the level of individual behaviors and cognitive processes (Creed, Stout, & Roberts, 1993).

A final limitation of high reliability theory is that it often treats safety and reliability as interchangeable and equivalent concepts when, in reality, they are not. Leveson et al. (2009) define safety as "*freedom from unacceptable losses (accidents)*" and reliability as *"the probability that a component satisfies its specific behavioural requirements over time and under given conditions"* (Leveson et al., 2009, p. 234). In these terms, the deliverables of a safety-critical project may be safe but unreliable, or reliable but unsafe, unreliable and unsafe, or safe and reliable. This confusion in terminology is eloquently captured by Roe and Schulman (2008) who state: "*For some it [reliability] means the constancy of service; for others, the safety of core activities and processes. Increasingly it means both anticipation and resilience, the ability of organizations to plan for shocks as well as to absorb and rebound from them in order to provide services safely and continuously*." (Roe & Schulman, 2008, p. 5)

For the purposes of this article, safety is defined as a criterion or constraint in the way in which the organization or project performs its mission, rather than an outcome of the project per se. Reliability encompasses constancy of operations, anticipation, and resilience to shocks and surprises (Roe & Schulman, 2008) rather than the more constrained engineering focused perspective of Leveson et al. (2009).

Characteristics of an 'Ideal-Type' of High Reliability Organization

Several authors have sought to articulate a set of attributes, exhibited by high reliability organizations, which differentiate them from other organizations see, for example, Boin & Schulman, 2008; La Porte, 1996; Roberts & Rousseau, 1989; Weick et al., 1999; Weick & Sutcliffe, 2007). Table 1 summarizes the high reliability organization literature and synthesizes it into five core characteristics, which underpin an 'ideal-type of igh reliability organization.' These are a *strong organizational culture, clarity of organizational objectives, the presence of redundancy and slack, mindful behavior and the ability to prosper in the paradoxes*—recognizing that this differentiation is a subjective and theoretical one and that there are areas of commonality between the various characteristics.

Core High Reliability Organization Characteristic	**Underpinning Features of High Reliability Organizations**
Clarity of Objectives	A strong sense of mission (Laporte, 1996) Effective communication of the bigger picture (Rijpma, 1997; Roberts & Bea, 2001) Safety is highly prioritized and cannot be traded off against other competing objectives (Dekker, 2011; Leveson et al., 2009; Roberts & Rousseau, 1989) Safety is incentivized (Roberts & Bea, 2001) There are a number of core events that simply cannot be allowed to happen (Boin & Schulman, 2008)
Strong Organizational Culture or "ways of doing things round here"	A culture of learning—the organization rigorously seeks to know what it does not know, constantly searches for improvement, and undergoes repeated training exercises and simulations (Bierly & Spender, 1995; Dekker, 2011; La Porte & Consolini, 1998; Leveson et al., 2009; Rijpma, 1997; Roberts & Bea, 2001) A culture of reliability "*that distributes and instills the values of care and caution, respect for procedures, attentiveness, and individual responsibility for the promotion of safety among members throughout the organization*" (Boin & Schulman, 2008, pp. 1052–1053) A culture of trust, openness, and accountability, underpinned by a willingness to report errors (Reason, 1997; Weick & Sutcliffe, 2007) A strong technological/professional culture, where there is peer pressure to perform, and individuals demand a high degree of discretion and autonomy (Boin &Schulman, 2008; Laporte,1996; Rochlin, 1993) Organizational hubris and complacency are challenged (Roberts & Bea, 2001; Weick et al.,1999)
Presence of Redundancy and Slack	Redundancy in equipment design and operating procedures. Individuals are trained for multiple jobs and hold overlapping responsibilities and accountability (Dekker 2011; La Porte, 1996; Leveson et al., 2009; Rijpma, 1997; Roberts & Rousseau, 1989; Rochlin et al., 1987) Conceptual slack—different perspectives are tolerated and differing interpretations maintained (Boin & Schulman, 2008; Rijpma, 1997; Schulman, 1993; Weick et al., 1999; Weick & Sutcliffe, 2007)
Mindfulness	The importance of cognitive processes as well as organizational processes and structures (Weick et al., 1999; Weick & Sutcliffe, 2007; Vogus, Rothman, Sutcliffe, & Weick, 2014) Pre-occupation with failure—high reliabililty organizations are perfection demanding, obsessively monitoring, and constantly vigilant toward threat anticipation and response (Coutu, 2003; Rochlin, 1993; Weick & Sutcliffe, 2007) Reluctance to simplify interpretations—high reliability organizations focus on collecting and analyzing any warning signals that something is amiss and avoid making assumptions regarding underlying causes *(*Boin & Schulman, 2008; Weick et al., 1999; Weick & Sutcliffe, 2007) Sensitivity to operations—high reliability organizations monitor diverse inputs and value soft intuitive knowledge as well as hard facts. (Weick et al., 1999) They are attuned to weak indicators that something might be amiss (Coutu, 2003) Commitment to resilience—high reliability organizations are effective at

	improvisation; at anticipating and responding to surprises. (Weick et al., 1999; Weick & Sutcliffe, 2007) Under-specification of structures—highly ordered systems can actually propagate errors more quickly, and so in moments of crisis a form of *"organized anarchy may be more appropriate. Routines, designs and decision making authority become less rigid with decisions migrating around these organizations in search of a person who has specific knowledge of the event"* (Weick et al., 1999, p. 49; Mannarelli et al., 1996; Rijpma, 1997).
Ability to Prosper in the Paradoxes	The organization is able to preserve and prosper within paradoxes, such as: • How can decision making be both centralized and decentralized? • How can organizations have well documented processes but abandon them in moments of crisis? • How can organizations and individuals cognitively process multiple interpretations of operational events and yet not become paralyzed by analysis? (Boin & Schulman, 2008; Mannarelli et al., 1996; Rochlin, 1993; Roe & Schulman, 2008; Weick et al., 1999; Weick & Sutcliffe, 2007)

Table 1: Synthesis of the high reliability organization literature into five key characteristics of an "ideal-type" of high reliability organization

The characteristics in Table 1 can be crudely bifurcated into those that emphasize structural and cultural factors (*strong organizational culture, clarity of organizational objectives, the presence of redundancy and slack)* and those that p focus on cognitive processes (mindfulness and the ability to prosper in the paradoxes), acknowledging that the split is an artificial one and that many cultural factors are cognitive in origin. The real explanatory power of the five characteristics, however, lies in its origin as a synthesis of the extant literature and its potential to proffer an analytical lens through which to view safety-critical projects. With this in mind, our attention is turned now to consider the differences between operations and projects in the safety-critical environment and the relevance of *high reliability project organizing* to safety-critical projects.

Similarities and Differences between Ongoing Operations and Projects

High reliability organizations purport to be a special set of organizations that have demonstrated consistently reliable and safe performance in an operating environment that is simultaneously of high technical complexity, high consequence, and high tempo (Boin & Schulman 2008; Perrow, 1984; Roberts & Rousseau, 1989; Rochlin, 1993). Small fluctuations or errors in one part of the system can rapidly escalate through the tightly coupled system with potentially disastrous consequences; however *projects* that are undertaken in these complex socio-technological ecosystems are also of high complexity, high consequence, and under enormous pressure to deliver safe and reliable outcomes. The question addressed in this section is whether there are sufficient similarities between the project environment and those of on-going operations to render the theories of high reliability organizing relevant to the management of safety-critical projects. Tables 2 and 3 provide the framework for this discussion. Table 2 summarizes the key similarities, and Table 3 highlights the main differences between safety-critical operational environments and projects.

Similarities between Safety-Critical Operational Environments and Projects
Both are highly complex socio-technological systems (Laporte & Rochlin, 1994; Perin, 2005) • Tightly coupled • Highly interdependent
Consequences of failure are high (Rochlin, 1993) • Accidents lead to large scale injury/loss of life and /or wide-ranging environmental damage
Demanding political and social environment (Laporte & Thomas, 1995; Rochlin, 1993; Weick et al., 1999) • Multiple stakeholders with potentially divergent opinions • Projects/operations both played out in the public domain
Safety is the overarching priority (Saunders, Gale, & Sherry, 2015) • Project objectives of time, cost, and quality are secondary to safety • Operational priority is always safety
Uncertainties are many and often non-trivial (e.g., fast response required to a warning signal when the cause of the fault may not be immediately apparent or the necessity of carrying out probabilistic safety assessments, before critical elements of the design have been fixed). • Decisions taken in the absence of complete information • Reliance on judgment, heuristics, and experience • Bounded rationality and cognitive biases are prevalent (March & Simon, 1958; Tversky & Kahneman, 1982)
Both utilize resources (people, equipment, materials) to deliver products or services that are demanded by a set of customers and stakeholders (Horner Reich et al., 2013)
Both are underpinned by key processes (Hatch & Cunliffe, 2006) • Written operating procedures, project processes, and in nuclear, site license conditions and safety cases
Both are centred on action • Decisions made, meetings held and tasks fulfilled are all forms of action (Lundin & Söderholm, 1995)

Table 2: Illustration of the similarities between safety-critical operational and project environments.

Differences between Safety-Critical Operational Environments and Projects	
Operations	**Projects**
Permanent and continuous (Horner Reich et al., 2013; Turner & Muller, 2003) • Processes are stable and routine • Focus is on continuous operations • Key goal of the organization is to endure • Tendency to be organized in functions	Transient and temporary (Lundin & Söderholm, 1995; Söderlund & Tell, 2011; Turner & Muller, 2003) • Projects have a beginning and an end • Projects are temporary endeavors • Organization may be a “matrix” one with temporary “dotted” reporting lines
Tried and tested technology (Kettunun et al., 2007) • Conservative technical solutions preferred • Limited implementation of technological advances and good industry practices developed elsewhere	Uniqueness or novelty of product (Turner & Muller, 2003) • In terms of processes and outcome of the project • Manifests itself in the non-routine nature of much of project work • No two projects utilize exactly the same approach
High tempo • Many operational activities are time-urgent (Roberts & Rousseau, 1989; Rochlin, 1993) • Requirement to operate at high tempo over a sustained time period until immediate danger or hazard has passed (Klein, Bigley, & Roberts, 1995).	Measured tempo • Projects are time constrained and must be completed under a certain amount of urgency (Turner & Muller, 2003; Williams, 2009) • Differing rhythms of project and operation: in projects, the reporting is activity based, whereas in operations it is calendar based (Horner Reich et al., 2013).
Focus is on operational stability • Change is incremental and based on improvements to the status quo (Horner Reich et al., 2013).	Focus is on implementation of change • Projects are mechanisms to bring about change (Williams, 2009) • Change is central to the project mandate (Horner Reich et al., 2013).
Environment of lower uncertainty	Environment of higher uncertainty • Turner and Muller (2003) argue that uncertainty is higher in projects than operations due to the inherent novelty, and lack of guarantee that plans will deliver required outcomes

Table 3: Illustration of the differences between safety-critical operational and project environments.

Safety-critical projects, particular those that are technically complex, large in scale, and undertaken in environments such as nuclear power plants or in civil aerospace, manifestly share many similarities with on-going operations. For example, safety-critical projects are complex, of high consequence, and are undertaken in a demanding social and political environment. For example, a project to decommission 50-year-old radioactive ponds and relocate their highly unstable and contaminated contents safely is without doubt a highly complex and tightly coupled system that is allowed to proceed only under the watchful eye of the regulator; likewise, a project to design the next generation composite aircraft frame. Other similarities between safety-critical projects and operations include the presence of uncertainty, the all-pervading imperative of safety, and the requirement to mobilize teams of highly expert and often constrained resources, enact the appropriate project or operational processes and engage in diverse activities with the aim of successfully delivering the required objectives. In addition, many organizations simultaneously pursue operational and project activities, which render the distinction between projects and operations more blurred; with each often utilizing the same people, processes, and similar ways of working.

Table 3, however, also highlights several key differences between operations and projects, most notably, the non-routine, temporary nature of project work, the measured tempo of the project, and the strong change mandate that drives many projects. This class of projects does not proceed at such high-tempo, and are not as highly dynamic as an active operational context such as the take-off and landing of aircraft on a U.S. navy carrier, or the real-time operating environment of a nuclear power plant. Certainly there is schedule pressure in any project, and the highly interconnected nature of complex projects means that errors in one constituent part can rapidly propagate throughout the project structure, but the timescales for this propagation are more likely to be in the order of days and weeks, rather than minutes and hours, as in the case of archetypal high reliability organizations. Despite this, Tables 2 and 3 do provide sufficient evidence to argue that the environment of the project is sufficiently similar to the operational context to apply the theories of high reliability organizing to the management of safety-critical projects.

Realizing High Reliability in Safety-Critical Projects

Much will be demanded of the individuals tasked with delivering the next generation of nuclear power plants or safely decommissioning aging nuclear reactors and securing the long- term safe storage of the nuclear waste they have produced. What lessons can these individuals take from high reliability theory? And, how might high reliability organizing be realized in safety-critical projects? Table 4 begins to address these questions and uses the five characteristics of an 'ideal-type of high reliability organization' (from Table 1) to hypothesize which adaptations in behaviors, organizational structures, and *ways of doing things* might be observed in high reliability project organizing. These hypotheses have yet to be empirically tested, but a number of them are exemplified in the recent project management literature on nuclear projects and in other extreme project environments such as military and polar expeditions.

Core High Reliability Organization Characteristic	Features of a typical High Reliability Organization (from Table 1)	Hypotheses about Observable Practices in "High Reliability Project Organizing"
Clarity of Objectives	Sense of mission Effective communications Safety is a number one priority (there are core events that must not happen) Safety is incentivized	High reliability projects might: • Accelerate the formation of a dedicated project organization with capable project leadership, develop and articulate a strong sense of mission in the team, and build regular communication into project routines. • Make project objectives explicit, articulate them clearly, and ensure that the trade-offs are understood (for example the relative priority of project cost versus schedule when safety-impacting project decisions are required). • Communicate the core events that must be precluded (e.g., failure to produce a safety-case in a timely fashion, failure to respond to requests from the regulator). • Acknowledge high levels of uncertainty early on—accept that work may start on the project with only minimum agreed-on high-level objectives and many untested assumptions. Counter this by putting in place clear high-level decision-making rules (to enable the project team to make progress in the midst of uncertainty). • Ensure that project documentation, communications plans, and project team incentives are consistent with the declared project objectives.
Strong Organizational Culture	Learning culture Reliability culture Trusting culture Techno/professional culture Organizational hubris and complacency are challenged	High reliability projects might: • Build on prior safety-critical project approaches—it may not be necessary to reinvent the wheel. Encourage learning in the project team by making time to share individuals' stories, lessons learned, and past project experiences. Understand what is new about the project and what is similar to the last project. • Foster interconnections and relationships that span the project hierarchies and from which communities of practice may start to emerge. Strive to strengthen "dotted line" relationships in a matrix organization. • Signal what is valued in the project. Take visible actions that reward openness, knowledge sharing, multi-disciplinary problem solving, and allow mistakes to be made and openly reported. • Afford areas of ignorance in the project the same importance as areas of certainty— discuss and debate them rather than closing them down and allowing a culture of "doubt and discovery" to gradually assert itself within the project organization. • Delegate decision making (within pre-agreed decision-making rules), trust project team

		members and allow the sometimes quiet voice of the expert to be privileged above management orthodoxy. • Promote, incentivize, and reward project management capability and culture equally to the technological/professional one.
Presence of redundancy and slack	Redundancy in design, operating equipment and procedures. Conceptual Slack	High reliability projects might: • Understand the underlying tempo and rhythm of the project—when do key decisions need to be made, and what is the real level of urgency? • Allow flexible and staged conformance to project processes. Trust the judgments of professional project management practitioners and permit certain project processes to be cast-off in emergency or urgent project situations. • Encourage the team (both internally and in the supply chain) to discuss and negotiate their way to a plan of action that is appropriate to the specific project situation with which they are confronted. • Separate responsibility for technical delivery with schedule/cost delivery—Hold the two in constructive tension to promote discussion, challenge, and negotiated solutions. • Make every effort to develop reflective project management practitioners who can think on their feet and not simply turn the handle of the project processes. Nurture a tolerance for different perspectives, foster skepticism, and doubt and don't quash dissent. • Advocate career progression that depends not only on delivery of project milestones but on demonstration of the "right" behaviors.
Mindfulness	Preoccupation with failure Reluctance to simplify interpretations Sensitivity to operations Commitment to resilience Under-specification of structures	High reliability projects might: • Avoid complacency. Engage continuously in "what if?" questions, worry constantly about "what could go wrong here in the project?" and "what is my Plan B?" • Be attuned to small changes in projects that may be the precursors to bigger issues. • Avoid the tendency to jump to conclusions and make assumptions about the underlying causes of project problems; instead, allow discourse and discussion to proffer new perspectives on the issue at hand. • Maintain thorough knowledge of the project status, leading project indicators, and talk to the experts on the ground. Treat intuition as importantly as hard project data. • Avoid over-rigid processes, routines, and decision making and create space in the project for reflection, robust debate, and even elements of anarchy.

Ability to prosper in the paradoxes	Decision making that is both centralized and decentralized? Processes that are abandoned in urgent situations? Processing multiple interpretations of events and yet not paralysed by analysis?	High reliability projects might: • Sanction more flexible decision-making structures—think ‘markers in the sand’ as opposed to fully specified milestones. Fight to retain flexibility in the proposed project solution even when this may increase project complexity in the short term. • Involve a more diverse coalition of project actors in project decision making even if this challenges the existing project consensus. • Acknowledge and articulate the paradoxes inherent in a high reliability project. For example, how is more freedom allowed in the project, while ensuring predictable delivery? • Learn that uncertainties in safety-critical projects cannot be eliminated; instead, project managers must be able to dwell comfortably among this ambiguity when there may be no ‘right’ answer.

Table 4: Hypotheses about observable practices in “high reliability project organizing.”

For example, Table 4 hypothesizes that high reliability projects might "accelerate the formation of a dedicated project organization with capable project leadership, develop and articulate a strong sense of mission in the team, and build in regular communication routines." Garel and Lièvre's (2010) study of a polar kayaking expedition evidences this accelerated team formation through training weekends and effective and early discussion of the project goals. Table 4 also asserts that high reliability projects "afford areas of ignorance in the project the same importance of areas of certainty." Musca et al.'s (2014) observations of a mountaineering expedition in Patagonia showed that the project team robustly discussed uncertainties in weather forecasts and their ability to navigate the boat safely to the expedition start point, which ultimately resulted in significant rewording and reframing of the overall project goals. Godé-Sanchez (2010) draws on the experiences of French armed forces on operations in Afghanistan to show that individuals rapidly switch between routines and unpredictable mechanisms, methods, and tools of coordination. This provides some evidence that high reliability projects might allow flexible and staged conformance to project processes, allowing certain project processes to be cast off on emergency project situations. In contrast, Ruuska et al.'s (2011) study of project governance on two troubled new nuclear build projects at Olkiluoto and Flamanville exposed an insufficient focus on maintaining a thorough knowledge of the project status, leading project indicators and talking to the experts on the ground as hypothesized in Table 4 as an observable feature of high reliability project organizing. Last, Aubry and Lièvre (2010) provide exemplification of one of the key paradoxes in high reliability projects—the need to balance freedom in the project with the assurance of predictable delivery. They discuss the tensions between the planning and rationalization modes of action of project managers and the need to adapt and learn from the in-situ project conditions on polar expeditions in both the Arctic and Antarctic.

Empirical Validation

The ideas presented in this article have not yet been empirically examined, although some evidence of their importance to other challenging project environments, including the military and extreme expeditions, has been illustrated. Further work is now necessary to test the hypotheses in Table 4 on a set of case study projects in safety-critical industries to understand the extent to which the behaviors, organizational structures, and cultures associated with high reliability organizing can be evidenced in the *ways of doing things* of project management practitioners tasked with delivering safety-critical projects. Initially, this would comprise the selection of a representative and accessible sample of safety-critical projects from one or more safety-critical industries. In-depth qualitative interviews with individuals involved in a project management capacity on these case study projects would be undertaken to test the extent to which the projects' *ways of doing things* align with the ideas on high reliability project organizing presented here and to facilitate their further refinement This work might focus on a specific industry sector or take the form of a comparative analysis of a number of distinct industry sectors, including non-safety critical sectors.

Conclusions

This article argues that there are sufficient similarities between challenging operational environments and projects to enable lessons from theories of high reliability organizing to be applied to safety-critical projects. Safety-critical projects do face particular challenges, and although it is acknowledged that they are not unique and that many other business-critical and important infrastructure projects must also be delivered safely, the overarching priority afforded to safety in these projects and the costly consequences of failure are of a higher order than other less extreme projects.

To succeed, project management practitioners will need to train themselves to maintain an attitude of mindfulness and conscious deliberation; to be flexible, maintaining focus on project goals, while challenging senior management to allow them to articulate uncertainty and ambiguity, questions, and assumptions rather than answers and knowledge. Projects may benefit from being structured as high reliability project organizations—drawing on the lessons from high reliability theory to pursue safety as the highest priority, while retaining a focus on the other project performance objectives of time and cost. The trade-offs and tensions at play across these three performance objectives cannot be ignored (Reiman & Rollenhagen, 2012) , the project team will require a degree of flexibility in conforming to established project processes and the authorization to go 'off script' when necessary, with the importance of continuous learning embedded throughout the project team.

The contribution made by this study to the challenge of safety-critical projects is twofold: First the nature of the safety-critical project has been explored and the similarities and differences between safety-critical projects and day-to-day operations examined. Second, the characteristics of an "ideal-type high reliability organization" have been synthesized from the literature and used to hypothesize how the concept of *high reliability project organizing* might look and be adopted by project management practitioners tasked with delivering safety-critical projects. This exploratory discussion of high reliability project organizing is not intended to be prescriptive or exhaustive, rather to serve as an opening discussion of what lessons high reliability thinking might have for project management practitioners operating in safety-critical environments.

Limitations

Many of the ideas presented here under the banner of *high reliability project organizing*, could be viewed as good project management practice across all projects, and not limited to the narrow context of safety-critical projects. However, as argued earlier the stakes are often higher in safety-critical projects, making some of the additional costs associated with *high reliability project organizing*—such as encouraging redundancy and conceptual slack, practicing mindfulness, and maintaining safety as a priority over other performance objectives—a price worth paying.

Additionally, there are dangers in presenting the literature on high reliability organizing as a panacea for all the challenges inherent in the management of safety-critical projects. There is a risk that high reliability organizations are viewed as the 'holy grail' of organizational theory: constituting structures and cultures that underpin effective cognitive processes, enabling high reliability organizations to outperform less specialized organizations. For all the research into high reliability organizations, and the plethora of defining characteristics and features for such organizations, the characteristics of high reliability still lack large-scale validation and have yet to be linked objectively to improved organizational or safety performance, if indeed it is theoretically possible to determine such a relationship (Lekka, 2011; Rochlin, 1993). Despite this, this article concludes, as Sullivan and Beach have argued previously, that the application of a contingency view of organizational theory enables projects to be "*considered as particular kinds of organizations*" (Sullivan & Beach, 2009, p. 765) and that the discipline of project management might usefully learn from an enriched understanding of high reliability organizations.

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