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CURRENT INDUSTRIAL PRACTICE OF MANAGING RISKS IN PRODUCT DEVELOPMENT PROJECT PORTFOLIOS

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ABSTRACT

Managing portfolios of development and engineering projects currently presents significant challenges to companies. This is even more the case in the management of portfolio risks, where both industry and academia currently lack a clear conceptual understanding of what portfolio risks are and what influences them.

The objective of this paper is two-fold: First, based on a literature review and industry focus group discussions, we introduce a new model for describing portfolio-level risks. It consists of three types of risks (escalated risks, common cause risks, and cascading risks) based on 9 types of interdependencies in PD project portfolios (Technology, Budget, Objectives and Requirements, Infrastructure and Equipment, Skillset and Human Resources, Process and Schedule, Supplier, Legal and Regulatory, and finally Market and Customer).

Second, we investigate how risk management on the portfolio level is currently executed in industry. The paper describes the results of a survey with n=43 participants, investigating the frequency and impact of portfolio risks, and the influence of the interdependencies on the portfolio risks.

Keywords: product portfolio management, risk management

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1 INTRODUCTION: RISK MANAGEMENT IN PRODUCT DEVELOPMENT PROJECT PORTFOLIOS

1.1 Context

Managing portfolios of development and engineering projects currently presents significant challenges to companies. This is even more the case in the management of portfolio risks, where both industry as well as academia have an inconsistent understanding of what portfolio risks are and what influences them. The purpose of this paper is to improve our current understanding of portfolio risk management, as well as describe the current state of practice in industry.

1.2 Use and Definition of Portfolio

The term "portfolio" is used in different situations and can hence lead to confusion. It is often associated with the modern financial portfolio theory, introduced by Harry Markowitz. According to his theory, it is possible to form a portfolio of securities that has an overall lower risk level than any individual security in the portfolio. Hence, the value of the portfolio can be maximized for a given level of risk (Markowitz 1991).

Nowadays, the term "portfolio" is used to describe a pool of entities that is managed together. This is the case for a collection of information systems (McFarlan 1981), new technologies (Ringuest and Graves 1999; Robert G. Cooper, Edgett, and Kleinschmidt 1998), products (Cardozo and Smith 1983; Devinney and Stewart 1988), suppliers (Bensaou 1999; Olsen and Ellram 1997; Gelderman and Semeijn 2006) and projects (Rajagopal, McGuin, and Waller 2007; PMI 2008a).

The focus of this paper is on project portfolios. Therefore we refer to the Project Management Institute's (PMI) definition of portfolios as "a collection of projects or programs and other work that are grouped together to facilitate effective management of that work to meet strategic business objectives". For portfolio management "an organization uses tools and techniques (…) to identify, select, prioritize, govern, monitor and report the contributions of the components to, and their relative alignment with organizational objectives" (PMI 2008a).

1.3 Risk Management on the Portfolio Level

1.3.1 Inconsistent use of the term "Portfolio Risk Management"

Only a limited number of portfolio management methods account for risk in their portfolio decisions, such as (Cardozo and Smith 1983; Devinney and Stewart 1988; Ringuest and Graves 1999; van Bekkum, Pennings, and Smit 2009; De Maio, Verganti, and Corso 1994; Petit and Hobbs 2010). But these authors see risk management as creating an overall optimal risk/return balance of the portfolio. Their understanding of "risk management" is different from the industry standards for risk management, which consist of actively identifying, analyzing, mitigating and monitoring portfolio risks (ISO 2010; AIRMIC and IRM 2002). The major differences are highlighted in Table 1.

Table 1: Differing Portfolio Risk Management Perspectives

Portfolio Management Perspective	Risk Management Perspective
• Create an overall optimal risk/return balance in the portfolio • Consider risks in project selection, resource allocation and portfolio balancing	• Integrate risk management processes (identification, analysis, mitigation, monitoring) into project portfolio management • Link project (risk) management with portfolio (risk) management

1.3.2 Integration of Project Risk Management with Project Portfolio Risk Management

Very limited research has been done in the area of integrating portfolio level risk management with project level processes. Project level risk management methods, as proposed by (PMI 2008b), are not applicable for project portfolios, as they assume projects as independent entities within a corporation and assess risk with regard to deviations from cost, schedule and performance. Portfolio risk is more than the sum of its parts: Even if all projects fulfill their planned cost, schedule and performance target, it does not guarantee the automatic achievement of strategic portfolio objectives, such as a good alignment of projects, portfolio balance or portfolio value maximization. Risks on the portfolio level are not only determined by individual project risks, but also generated by the project ensemble (Archer and Ghasemzadeh 1999; Sanchez et al. 2009).

Having recognized this; the Project Management Institute published a risk management process, specifically designed for the project portfolios. The PMI breaks down portfolio risk management processes into identification, analysis, response development and monitoring (PMI 2008a). For each of those process steps, it suggests techniques and methods. As a baseline, a portfolio management plan containing portfolio objectives and criteria must be defined, against which risks are identified and analyzed.

1.3.3 Portfolios as Complex Systems

Another way to integrate project risk management with portfolio risk management is to look at portfolios from a system complexity management perspective. A portfolio can be seen as a system consisting of multiple projects, which are connected through a complex web of interdependencies. Risks that affect one project in the system can hence propagate to other projects on many different trails. From that point of view, project interdependencies are major factors that influence portfolio risks and the vulnerability of a portfolio. Having this in mind, Sanchez proposed a framework which takes into account resource, knowledge and strategy interdependencies for portfolio risk identification (Sanchez, Robert, and Pellerin 2008). The risk of "firefighting" in product development portfolios can be well explained from a systems perspective with interdependent projects (Repenning 2001). Resources are drawn away from well-performing projects to fix problems in underperforming projects that have the same resource requirements. This leads to a cascade of additional problems in the formerly well-performing projects as they are now understaffed. This triggers a vicious circle of resource shifts from well performing projects to formerly well performing projects.

1.4 Current consideration of "interdependencies" in portfolios

1.4.1 Importance of interdependencies:

Most project portfolio management methods have their limitations in so far, that they neglect project interdependencies and assume independent project properties (Santhanam and Kyparisis 1996). Baker and Freeland conducted a comprehensive review of project selection methods and point out an "inadequate treatment of project interrelationships with respect to both value contribution and resource utilization" (Baker and Freeland 1975). Major portfolio management literature, such as Cooper's "Portfolio Management for New Products" or PMI's "Standard for Portfolio Management" recognize the importance but do not elaborate on how to account for interdependencies in portfolio decisions (Robert Gravlin Cooper, Edgett, and Kleinschmidt 2001; PMI 2008a).

1.4.2 Current consideration of interdependencies in literature:

The only authors that partly considered interdependencies were the ones proposing mathematical programming and optimization algorithms (Santiago and Vakili 2005; De Maio, Verganti, and Corso 1994; Medaglia, Graves, and Ringuest 2007; Lee and Kim 2001; Stummer and Heidenberger 2003; Zuluaga, Sefair, and Medaglia 2007; Dickinson, Thornton, and Graves 2001). Although the authors suggest different mathematical algorithms there is one commonality: Interdependencies are accounted for by using a coupling coefficient that captures the joint probability of success of two projects.

The above mentioned authors' common classification for interdependencies are 1. "cost and resource", 2. "benefit and payoff" and 3. "outcome" interdependencies, which was first introduced by (Aaker and Tyebjee 1978).

1.4.3 Shortcomings in the classification of interdependency types:

The multiple authors citing the categorization of interdependencies by Aaker and Tyebjee had their focus on developing mathematical optimization algorithms and consider interdependencies as coupling coefficients between multiple projects. But the coupling coefficients have to be estimated a priori, before the algorithm optimizes the portfolio. No process or heuristics is available to estimate coupling coefficients that are created by interdependencies. For the purpose of having a checklist to identify all relevant interdependencies, the categorization by Aaker and Tyebjee is too abstract and incomplete. For instance, within their category types, it is not clear where to fit schedule interdependencies, objectives interdependencies, supplier interdependencies. Furthermore, different authors propose other interdependency types, such as “knowledge”, “strategy”, “commonality”, “integration”, “market interaction” (Terwiesch and Ulrich 2008; Sanchez, Robert, and Pellerin 2008; De Maio, Verganti, and Corso 1994). In order to adequately treat project interdependencies, a new comprehensive framework is needed that helps to identify interdependencies and assess their impact. This will not only facilitate the estimation of coupling coefficients for mathematical optimizations of the portfolio, but also reduces portfolio risks. In fact, De Maio et al. (1994) pointed out that the main causes for failure in new product development in insufficient management of project interdependencies to assure compatibility at portfolio level.

2 TYPES OF INTERDEPENDENCIES IN PD PROJECT PORTFOLIOS

The approach to synthesize the types of interdependencies between projects in a portfolio was first to review and consolidate the available literature that treats interdependencies. Literature sources were first found in the fields of project and portfolio management, but ventures were also made into the fields of interdependencies between complex engineering systems, infrastructures and information systems (Carraway and Schmidt 1991; Czajkowski and Jones 1986; Fox, Baker, and Bryant 1984; Archer and Ghasemzadeh 1999; Zuluaga, Sefair, and Medaglia 2007; Medaglia, Graves, and Ringuest 2007; Verma and Sinha 2002; Santhanam and Kyparisis 1996; Lee and Kim 2001; Horwitch and Thietart 1987; Gear and Cowie 1980; Dickinson, Thornton, and Graves 2001; Danilovic and Sandkull 2005; Carlshamre et al. 2001; Dudenhoeffer et al. 2007; Lindemann, Maurer, and Braun 2008; Aaker and Tyebjee 1978; De Maio, Verganti, and Corso 1994; PMI 2008a; Sanchez, Robert, and Pellerin 2008; Sanchez et al. 2009; Weingartner 1966). A list of interdependency types was maintained while screening the literature. Once, new types were identified, they were added to the collection. In a second step, this list was reviewed and discussed with members of an industry focus group to evaluate on whether interdependency types had been omitted. The results of this iterative process are summarized in *Table 2*. We distinguish between interdependencies that are internal to the company and external to the company. Internal interdependencies come from technology, budget, requirements, skills, infrastructure and processes. External interdependencies come from the environment, such as suppliers, customers and regulatory environment.
For each of the interdependency types, real life industry examples from an aerospace company are given in *Table 2* to illustrate how two projects are linked with each other. Industry partners confirmed the comprehensiveness and conciseness of the types as adequate.

Table 2: Industrial Examples for Interdependency Types

Interdepenency Type	Industrial Example
Internal	
Technology Interdependencies	Technology developed by one projects is needed by multiple other projects
Budget Interdependencies	Funding decisions for one projects can change the funding of other projects
Objectives and Requirements Interdependencies	Requirements in a design project influences requirements in a production project
Infrastructure and Equipment Interdependencies	Shared equipment by multiple projects
Skillset and Human Resources Interdependencies	Project needs the skills and knowledge gained by another project
Process and Schedule Interdependencies	A project is prescribed to wait for another project before it can continue
External	
Supplier Interdependencies	Projects share the same supplier
Legal and Regulatory Interdependencies	Projects operate under the same legal and regulatory environments
Market and Customer Interdependencies	Projects share the same target market or customer

3 TYPES OF PRODUCT DEVELOPMENT PORTFOLIO RISKS

3.1 Current Definitions of Risk Types

The generic ISO 31000 Risk Management Standard still holds for the portfolio level, and portfolio risks are seen as "effects of uncertainty on objectives" (ISO 2010). However, portfolio risks types cannot use the same terminology as project risk types since "cost risk", "schedule risk" and "performance risk" are merely a categorization with regard to project objectives. Other categorizations, such as "technical", "schedule", "budget" and "market" (Unger 2003) do not represent the special characteristics of portfolios. Since interdependencies are at work, portfolio risks can arise through the portfolio composition and do not add up linearly as the sum of individual project risks.

To account for the characteristics of portfolios, the PMI distinguishes between component risk, structural risk and overall risks (PMI 2008b).

- Component risks are "risks from the individual components (here: projects) that have been escalated from the component manager for information or action at the portfolio level".
- Structural risks are "associated with the way in which the portfolio is composed, and the potential interactions among the components".
- Overall risks are "more than just the sum of the portfolio component risks. The interactions between component risks can lead to the emergence of one or more overall risks".

Although this definition is specifically tailored to portfolio risks, the term "overall risks" is very broad and less tangible. In discussions with our industry partners, they experienced difficulties to distinguish "structural risk" with "overall risk". A definition is needed, that ideally distinguishes portfolio risks in a way that each risk type can be identified, analyzed, mitigated and monitored in different ways.

3.2 New Definition of Portfolio Risk Types

The solution comes from the fields of risk management in infrastructure systems, such as telecommunication networks, electricity grids or nuclear facilities. In infrastructures, risks are categorized by their failure modes (Rinaldi, Peerenboom, and Kelly 2001). In a nuclear facility, for examples, the failure of a component can be local and have little effect on the system as a whole. A component failure can also cause the common failure of multiple other components. A cascading failure is the most dangerous scenario, in which one failure cascades through the system, causing a breakdown that was experienced in the Fukushima disaster (Strickland 2011). With some adaptation, the analogy from the risk definition for infrastructure systems can be applied on project portfolio risks. The different portfolio risk types are:

- Escalated Risk: A single isolated project risk is escalated, as the severity of the risk is also significant on the portfolio level. E.g.: A critical technology causes a project disruption and the associated losses are also relevant on the portfolio level.
- Common Cause Risk: One common source of risks simultaneously and directly affects multiple projects. E.g.: The failure of one supplier disrupts all projects that are dependent on parts and services delivered by that supplier.
- Cascading Risk: A portfolio risk created by dynamics of project interdependencies within the portfolio. One failure in a project causes cascading failures in related projects through a complex cause-and-effect network. E.g.: "Firefighting" in an organization is a cascading risk, which leads to a cascade of additional problems in the formerly well-performing projects, as they are understaffed. To fix these problems, another shift of resources takes place and triggers a vicious circle.

3.3 Benefits and Limitations of New Portfolio Risk Type Definition

The advantage of this categorization is that each portfolio risk type is identified, analyzed, mitigated and monitored differently in each of the risk management process steps. Table 3 outlines the main differences in each risk management process steps for each risk type. When a company describes their portfolio risk management process, with the help of Table 3 one can already assume how well a certain risk type is handled. If a risk type is not well handled and the same company assesses its relevance (frequency of occurrence and impact) as high, this table provides starting points on how to complement their current risk management process to better manage all relevant portfolio risk types.

After knowing the advantages of the new definition of portfolio risk types, the limitations must also be considered. An escalated risk can also have a common cause or cascading effect on the portfolio level.

It is hard to determine how far a failure scenario will go. A risk manager in a company would have to know all project interdependencies very well, in order to determine how risks will spread in his portfolio.

Table 3: Risk Management Process vs. Portfolio Risk Types

Process Step	Escalated Risk (No/little interdependency)	Common Cause Risk (Interdependency + pooled coupling)	Cascading Risk (Interdependency + sequential coupling)
Identification	Wait until risk is escalated to portfolio risk register	Screen database for risks that can affect multiple projects	Model project interdependencies and search where cascades can potentially occur
Analysis	Evaluate the effect of risk based on portfolio success criteria	Evaluate the combined impact that this risk has on multiple projects.	Model and simulate the potential impact
Mitigation	Mitigation mainly takes place at the project that escalated risk.	Change portfolio composition by eliminating the common cause.	Change portfolio composition. Create buffers between critical interdependencies.
Monitoring	Monitor project risk	Monitor common cause	Monitor risk model

4 CURRENT PORTFOLIO RISK MANAGEMENT PRACTICE IN INDUSTRY

4.1 Sample Description

To get an overview of the industry sectors represented in the survey, Figure 1 shows a breakdown of respondents. Out of a sample of 43 responses 34% account for the Defense sector and 18% for the Aerospace sector. Together, the Defense and Aerospace industry represents over 50% of the sample. The other half consists of Energy, Manufacturing (excluding Defense and Aerospace), Information Technology & Telecommunications, and various “other” industries. The respondents represent companies with large annual budgets, as shown in Figure 2. The majority (60%) had annual budgets over $1 billion. Only 18% possessed budgets lower than $100 million. The large budgets are due to the usually large Defense and Aerospace companies. But another reason is that smaller companies are less diversified and do not possess portfolios with different projects. Even less are they likely to perform formal risk management on the portfolio level, if only a small number of projects exist in the company.

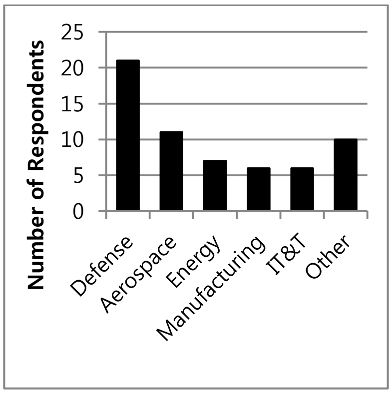

Figure 1: Industry Sectors of Companies Responding to the Survey (n=43)

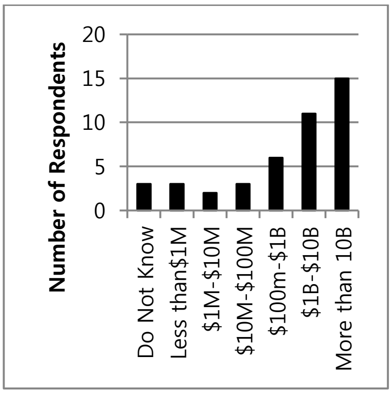

Figure 2: Annual Budget of Company (n=43)

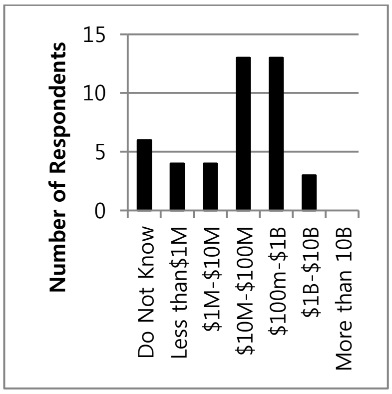

Figure 3: Typical Budget of PD Portfolio (n=43)

When contrasting the typical portfolio budget with the company’s annual budget, the importance of portfolios becomes apparent (Figure 3). 7% possessed portfolio budgets larger than $1 billion. About 30% of the surveyed companies stated their typical portfolio size as between $100 million to $1

billion. Although the logarithmic scale is approximate, one can draw the conclusion that portfolios make up large portions of the annual company's budget. For smaller companies, one portfolio will already consume the majority of its annual budget. But even for large companies, the size of a portfolio budget is substantial.
During previous case study interviews, one observation was that portfolios were not managed by distinct portfolio managers, as in the case with programs or projects, but by functional or divisional leader. An explanation for this might be the large portion of the annual budget a portfolio consumes. The budget might be so significant, that it falls under the responsibility of the functional or divisional leader.

4.2 Portfolio Risk Types in Comparison

With regard to the three different portfolio risk types introduced above, the survey asked for the frequency and impact of each of the risk types.
The ratings for the frequency were:

- "1" for "Very Rarely: Less than once every 10 years"
- "3" for "Occasionally: About once per year"
- "5" for "Very Frequently: About 10 times per year or once per month"

The ratings for the impact were:

- "1" for "Very Low: The relative deviation from portfolio plans was around 1%"
- "3" for "Moderate: The relative deviation from portfolio plans was around 10%"
- "5" for "Very High: The relative deviation from portfolio plans was around 100%"

The frequencies and impacts of all three portfolio risk types were plotted in Figure 4 and Figure 5. Since a logarithmic scale was used, it is not possible to accurately assess the mean frequency and impact for all risk types. But judging their frequency of occurrence and impact on portfolio goals, one can say that all risk types are relevant and must be actively managed. This result has implication in so far that common cause risks and cascading risks are interdependency-related risks are not sufficiently accounted for in current portfolio risk management processes.

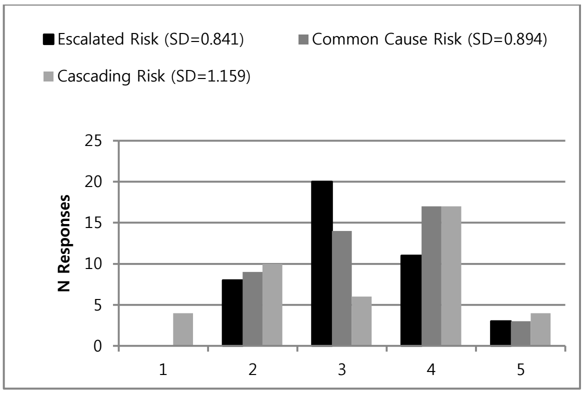

Figure 4: Frequency of Risk Types

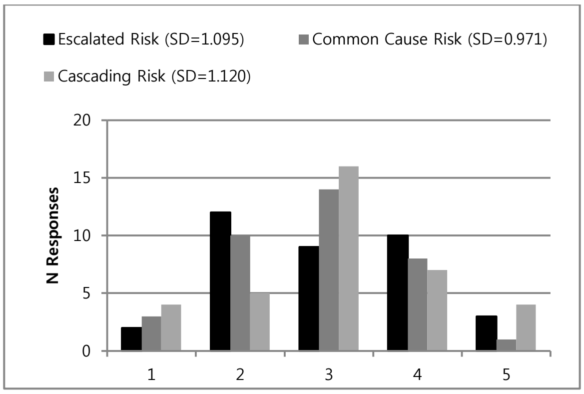

Figure 5: Impact of Risk Types

4.3 Influence of Interdependencies on Portfolio Risk Behavior

In the survey, the participants were asked to rate the influence of each interdependency carrier type on portfolio risk behavior. The results are in Figure 6. If an interdependency type can be neglected without noticeable consequences, it is rated as 1. The scale shows "3" if the interdependency changes portfolio risk behavior noticeably, but neglecting it does not have severe consequences. A rating of 5 means that the interdependency type significantly changes portfolio risk behavior and cannot be neglected without severe consequences. The most dominant interdependency type is "skillset and human resources", which reflects the problem with risk propagation in the popular example of "firefighting".

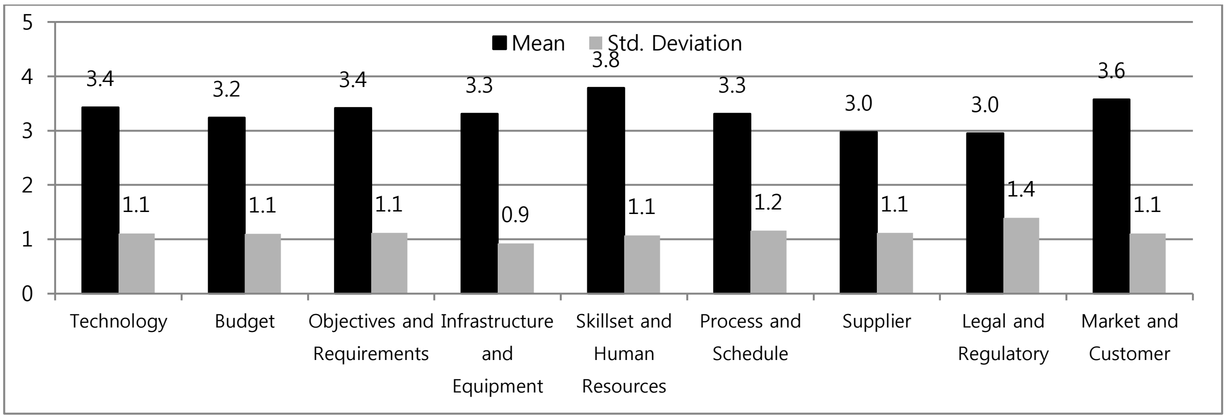

Figure 6: Influence of Interdependencies

5 CONCLUSION AND LIMITATIONS

With this paper, we aim to make a contribution at improving the current body of knowledge on risk management in product development project portfolios.

To allow for a more meaningful discussion between academia and industry, this paper introduces 3 types of portfolio-level risks that can be based on 9 types of interdependencies between portfolio projects. While this taxonomy proved helpful in our limited sample of aerospace & defense companies, it remains open whether this categorization is truly mutually exclusive and cumulatively exhaustive.

The survey results reported in this paper allow a first glance at the difference between the risk types and interdependency types. It highlights the particular importance of common cause and cascading risks, which are currently difficult to manage in practice. Escalated risks are relatively well covered in current risk management practices, which may be an underlying cause for their relatively low importance. The comparative importance of the interdependencies is reasonably uniform around a medium value of 3. Skillset & HR, as well as market and customer dependency between projects shows a somewhat higher importance for portfolio-level risks. Future work must include a more careful analysis of the data to understand the exploratory analysis reported here. The generalizability of the preliminary findings for other sectors than aerospace and defense must also be further evaluated.

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