

SPECIAL ISSUE ARTICLE

Managing innovation portfolios: From project selection to portfolio design

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Abstract

As innovation is critical in driving growth and competitiveness, companies establish innovation (or new product) portfolio processes to select the “right” innovation projects that are allocated the necessary resources. These processes have attracted considerable interest from both academics and practice. However, the results of innovation portfolio management processes are widely perceived as unsatisfactory. This study provides a systematic overview of portfolio management approaches and research advances of the past decades, and it explores the root causes of innovation portfolio management challenges. We propose that the problem is a result of an overemphasis on project selection (from an assumed available list of reasonable candidates), which has led to a focus on analytical methods of portfolio evaluation that are applied generically (not customized to the specific strategy of the organization). As a result, the creation or assembly of initiatives that cover the strategic innovation goals of the organization, in other words, portfolio design as a creative process, has been neglected. The result has been sophistication but little alignment with the specific strategic aims of the organization. We propose that a focus on portfolio design, followed by portfolio evaluation and management (with iteration feedback) may at least mitigate the widely observed challenges. We illustrate with a case example how the process might work. This proposal asks for new empirical research.

KEYWORDS

innovation, innovation project portfolio, new product development, portfolio management, portfolio selection

1 | INTRODUCTION

Innovation and new product development (NPD) are key factors driving sustainable corporate growth and competitiveness (Cooper & Edgett, 2003; Cooper et al., 2004; Kavadias & Chao, 2007). As a result, significant amounts of resources are allocated to the R&D of new products on a yearly basis. According to a recent study (Brennan et al., 2020), the global R&D investment is staggering. In 2019 alone, organizations worldwide spent \$2.3 trillion on R&D, the equivalent of roughly 2% of the global GDP.

Despite the sizeable investment, sales generated from new products seem far from satisfactory (Cooper & Edgett, 2003).

A recent survey of more than 400 industry practitioners found that the three top executive concerns related to innovation were “*more money going into innovation*,” “*not getting full benefits from those investments*,” and “*continuing to miss targets*” (Melis, 2018).

1.1 | A case study of a high-technology company

Typical reasons for this perception of underperformance are illustrated by the following real-world case, which demonstrates ongoing innovation portfolio management challenges at a technology company (B Company) in China, which specializes in solar thin-film technology. This technology

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allows the production and use of lightweight, flexible, and efficient solar cells and derivative products. In 2018, B Company launched a new product strategy, under the mission of “powering everything,” which reflected an effort to embed lightweight solar thin films into various traditional products, so that these products could self-generate electricity and offer additional functionality. After 3 years of pursuing projects to execute this innovation strategy, results were unsatisfactory. The senior executive team concluded that its portfolio management process had stumbled over several recurrent issues, which were spread across different functional areas and levels of decision making. The main symptoms of problems were the following:

1. *Fewer commercialized projects* than planned caused a revenue shortfall. After spending \$300 million annually (7% of revenue) over 3 years on 70 new product development projects, which were expected to drive sustainable growth, only five projects were eventually commercialized and generated a mere 5% of total revenue. Even the most successful new project met mixed market acceptance.
2. *Too many small projects* in the portfolio limited the value generated. NPD typically starts off with small “proof of concept” projects (e.g., a prototype design with sleek appearance and small-scale desirable functionality), which justify further commitments only when successful. However, early stage successes (which were perceived but not fully proven) encouraged the executive team to consider ever more new “promising” projects (such as a “solar paper” prototype), driving an inflation of 70 projects pursued in parallel.
3. Senior executives *rarely killed projects*. The senior team succeeded only five times in the 3 years to terminate projects, and those terminations were project mergers or obvious failures. Any hint that a project might be terminated by the senior executive team usually invoked “new” information by the project leaders about bright prospects and renewed reasons for optimism. Senior management felt more comfortable believing in undiminished success chances than admitting a (sometimes) obvious loss.
4. *A few longer-term projects* utilized a large portion of resources but could not be effectively reviewed mid-course, and their resources were not even planned to be reallocated towards alternative projects in the event of failure. In this case, a solar car project and a solar aircraft project kept ongoing for more than 3 years, accounting for almost 50% of the total budget. Both projects had the potential for significant returns. The solar car project was jointly developed with a major global car company and took 2 years to design a prototype and test feasibility over a wide range of applications. The resulting product might at some point dominate the new generation of electric vehicles, but failure would cause a large investment loss. The solar aircraft project was jointly developed with a major social media platform, achieving a successful prototype, and received praise from the platform’s CEO. However, the market size was eventually proven to be small, and financial success therefore elusive.

5. *An unbalanced allocation* of strategic resources indirectly caused a substantial decline in income. Revenue interactions existed between the traditional solar panels and the new solar-based product investments—the new products consumed scarce resources, including capital, production capacity, and manpower (not only in numbers of available people but also in motivation: employees in the new product projects felt more important than those engaged in traditional solar panel manufacturing). The result was a drop-off in support of the core solar panels, which caused a significant revenue drop. While dedicating some production capacity to new products was a prerequisite for creating new revenues, the extent of emphasis on the new products ended in damaging the core business.

The example highlights the necessity and value of innovation (or new product) portfolio management with effective resource allocation and innovation strategy support (Kavadias & Chao, 2007). As we will see in the next section, the problems experienced by B Company are not unique, but rather typical for the difficult multidimensional decision challenge of allocating resources across the innovation projects of the company.

1.2 | The need for a new portfolio management framework

The goal of innovation portfolio management is to support and strengthen the business’s competitive position (and often it is also mentioned that it should maximize the financial returns of a company’s product innovation investments). Professionals and academics alike have devoted significant attention to this problem since the 1980s (Chagas Brasil & Eggers, 2019; Cooper et al., 1997a; Kavadias & Chao, 2007; Kavadias & Hutchison-Krupat, 2020; Loch & Kavadias, 2002; Meifort, 2016; Roussel et al., 1991; Wheelwright & Clark, 1992). Optimists maintain that business results are achievable when portfolio review is implemented properly and conducted on a regular basis (Loch & Kavadias, 2002). Moreover, a structured portfolio management process benefits a company by forming a common basis for discussion and strategy implementation (Loch & Kavadias, 2011). By putting discipline into the process and providing a consistent basis of comparison, people can compare projects and assess them on the same basis of information with the same criteria (Hutchison-Krupat & Kavadias, 2015, 2018). Managers also expect to obtain better focus, and alignment to strategy, as well as balance across the right mix between short- and long-term projects (Cooper et al., 2001).

However, despite the availability of a well-stocked toolbox, the reality of portfolio decision making suggests that senior managers are still struggling with the multidimensionality and complexity of multiple innovation projects in an innovation portfolio, which are long-lasting, uncertain, relate to different strategic priorities and possibly interact among one another. Portfolio management continues to be a challenge across small, medium, and large organizations

TABLE 1 Overview of innovation portfolio challenges

Author and Year	Method	Key findings of portfolio challenges
Adams and Boike (2004)	PDMA 2004 survey	Increased resources are allocated to minor product changes and small improvements, focusing on incremental NPD efforts.
Burleson (2021)	Case study	Symptoms of poor portfolio management: just incremental improvements; “lack of resources” cited as the reason for new product difficulties; new products not launched on time; inability to act on new opportunities.
Cooper et al. (2000)	Survey in 205 companies	Too many projects for limited resources; ineffective optimization; absence of solid information; minor projects in portfolio
Daugherty et al. (2020)	Accenture survey in 1090 executives across 11 industries	Innovation investment not allocated strategically; innovation investment not made with discipline; companies that govern innovation extensively achieve stronger revenue growth over time.
Eckert and Hüsig (2021)	Literature review	Focus too much on incremental innovation; focus too little on long-term, radical innovation; ambiguity in decision making due to lack of solid information; decision-making bias due to overconfidence in reducing cost; managers often display termination decision bias.
Goffin and Mitchell (2010)	Conceptual paper	Valuation problems: which project are worth doing is not identified; balance problem: high risk vs. low risk, incremental vs. radical; difficulty in having an open management process where all actors involved are committed to the achievement of good results.
Killen et al. (2008)	Survey in 60 Australian organizations	Lack of “central, well-communicated, formal process”; lack of “the support or buy-in for the PPM process from all relevant areas and levels of the organization.” Shortages of time and resources make it difficult to implement PPM; lacking reflection of strategy.
Markham and Lee (2013)	PDMA 2012 survey	Radical and more innovative projects are reviewed less than in 2004; more radical projects reviewed less often than incremental projects.
(Melis, 2018)	Survey in 468 industrial practitioners	Clear gap between strategy and execution; insufficient alignment with strategy; too many projects for limited resources; decisions going back and forth.
Tolonen (2014)	Interview 47 executives in 10 companies	Disconnect between company strategy and expected portfolio target; idea and role of portfolio are not thoroughly understood by management team; PPM not consistently implemented as a concept and a tool; portfolio and subportfolios are not clearly defined; the portfolio process requires more clarity; governance of portfolio management is not formally structured and implemented.
Ward et al. (2010)	Case study at HP	Multiple similar projects in portfolio result in increased demand volatility and reduced forecast accuracy.

(Eckert & Hüsig, 2021). In this article, we provide an overview of new product portfolio challenges and previously identified solutions with their shortcomings, and we propose a framework to address the portfolio challenges. Section 2 identifies the main challenges of managing portfolios from a literature review; Section 3, then, overviews the solution approaches that professionals and academics have proposed to address these challenges; Section 4, finally, discusses why previous approaches have been insufficient, and introduces a proposed framework to improve innovation portfolio management.

2 | THE CHALLENGES OF MANAGING AN INNOVATION PORTFOLIO

Reflecting the fundamental role of portfolio management for successful innovation and new product development, both practice and academia have identified similar inherent difficulties in portfolio management that challenge existing prioritization and funding methods. Table 1 provides a brief overview of innovation portfolio management challenges that

have been identified. Thereafter, we discuss them in more detail.

1. *Strategic alignment: the disconnect between company strategy and desired portfolio objectives.* Killen et al. (2008) surveyed 60 Australian organizations and observed a need for portfolios to better reflect strategy. Similarly, the Tech-Clarity survey (Melis, 2018) suggests a clear gap between strategy and portfolio execution, and a recent Accenture study (Daugherty et al., 2020) of 1090 executives across 11 industries diagnosed that companies were not allocating innovation investments strategically.
2. *Imbalanced composition: Insufficient proportion of more radical innovation projects.* A Product Development Management Association (PDMA) study found that during the period of 1994–2004, the proportion of resources allocated to small product changes and improvements increased significantly, suggesting that companies increasingly focused on incremental NPD work. At the same time, high-performing companies emphasized a diverse portfolio, including new to market initiatives as well as incremental efforts (Adams & Boike, 2004). The 2013

PDMA survey provided further evidence of this trend and showed that “more radical projects were reviewed less often than incremental projects,” as radical projects represented more risk to the company (Markham & Lee, 2013). Consistent with this finding, Burleson (2021) found that one of the four symptoms of poor innovation portfolio management was embodied in *new products representing only incremental improvements*. Jugend et al. (2016) and Eckert and Hüsig (2021) came to a similar view that firms were overly focused on incremental innovation and paid too little attention to long-term, radical innovation.

3. *Project valuation: absence of solid information.* Cooper et al. (2000) pointed to the difficulty of “go/kill” decisions due to a lack of quality information; 44% of respondents in a survey by Tech-Clarity (Melis, 2018) also admitted to suffering from “back and forth decisions.” Eckert and Hüsig (2021) highlighted the ambiguity in decision-making, which led portfolio managers to allow ideas to develop further until they understood the benefits and could make better judgments. Similarly, Goffin and Mitchell (2010) identified the valuation problem as one of the three key portfolio challenges.
4. *Portfolio Overload: too many projects for a limited resource.* In our personal finances, we are mostly aware that we cannot write cheques above our account balance. But when we add projects to the new product portfolio without knowing the available capacity, this is what we do. Thus, “lack of resources” has often been cited as the reason for the difficulty of new products (Burleson, 2021). However, lamenting a lack of resources may hide the dilemma that in the face of the inherent uncertainty about which projects will actually succeed, senior management is tempted to “overload” the portfolio, similar to how airline companies overbook seat capacity to ensure maximum revenue. Ding and Eliashberg (2002) suggested that this practice was widespread in pharmaceutical companies. Under certain circumstances, this may make sense (when projects die off at a high rate, so natural project “turnover” allows short-term reductions in capacity use), but often, this causes projects to compete for scarce capacity and hinder one another.
5. *Support and Buy-in: lacking full support and understanding.* Tolonen (2014) interviewed 47 executives from 10 companies and found that the companies did not describe and document the innovation portfolio process—management’s overall analysis and decision-making process was not thoroughly understood by all involved. Similarly, Killen et al. (2008) (echoed by Goffin & Mitchell, 2010) mentioned the need for a “central, well-communicated, formal process” and the need for “the support or buy-in for the IPM [innovation portfolio management] process” from all relevant areas and levels of the organization. Similarly, Kendall and Rollins (2003) argued that one of the great challenges of portfolio management was gaining the commitment of senior management to comply with the process (rather than overriding it based on spontaneous judgments).

6. *Portfolio governance: lacking clear portfolio ownership and formal enforcement.* Tolonen (2014) found that the definition of innovation portfolio ownership was often unclear; governance was not formally structured and implemented across the portfolio; data objectives and data specifications for portfolio management were not defined. Naturally, this led to diverging interpretations of the available information and to differing project support decisions. Daugherty et al. (2020) similarly concluded that over time, improved innovation governance was expected to result in stronger revenue growth.

The diagnoses of the innovation portfolio management challenges are not dissimilar to the problems discussed in our opening case example. The key question is, of course, how these challenges can be overcome—this has been the subject of much professional and academic effort over the last four decades. The next section offers a condensed overview of the most important solution approaches that have been proposed.

3 | INSIGHTS FROM PAST WORK AND EXPERIENCE

Over the past few decades, there has been a wealth of academic research on the innovation portfolio problem, using a variety of perspectives. We attempt to summarize the conceptual approaches as well as the main insights and limitations of the proposed solutions. Six groups are summarized in Table 2 and then further explained. The six groups emerged through an iterative process of reviewing the papers among the three authors, applying a few distinct criteria: the methodology used to analyze the problem, the discipline “of origin” (e.g., Operations vs. Organizational Behavior or Theory), and similar terms used in previous review studies (e.g., Kavadias & Chao, 2007).

3.1 | The knapsack problem (KP)

The knapsack problem is the oldest conceptualization of the portfolio problem, as it addressed the challenge of allocating a scarce resource among claimant projects. It has been studied as early as 1896 (Mathews, 1896). It draws its name from the problem of packing the most valuable items into a knapsack with limited volume. If the items could be included fractionally, an optimal procedure would be to rank them by the index “value/volume taken up” and fill the knapsack in this order until it was full. But if items are indivisible (must be included completely or not at all), this procedure is not optimal because it may end up with left over unused capacity because the last item no longer fits—one may need to include “less valuable (per volume unit)” items to fill the capacity to the highest total value.

This ad hoc filling of capacity requires combinatorial optimization methods, and it can be shown that the problem complexity grows exponentially with the number of the items (in technical terms, it is “NP complete”) (Balas & Zemel,

TABLE 2 Comparison of Six Research Streams on Innovation Portfolio Management

Item/stream	Knapsack problem (KP)	Dynamic programming (DP)	Decision ANALYSIS (DA)	Organization and team (OT)	Psychology and behavior (PB)	Qualitative portfolios (QPA)
Perspective	Project collection	Project collection	Decision	Organization	Behavior	Practice
Purpose	Optimization by creating algorithms	Preprogrammed policies about project treatment as a function of changing project status and interactions	Assist decision makers in selecting decision by providing tools and framework	Identify successful organizational elements that can support port-folio management	People use (subconscious) heuristics to simplify complex decisions	Rather than optimization with tools that are too complicated, seek balance of strategic criteria
Coverage	0–1 knapsack problem; bounded knapsack problem (BKP); unbounded knapsack problem (UKP); NP-complete problems; Mental search bias	MAB: highest indices; Multi-class queueing: delay cost; Optimal admission rule; The stochastic and dynamic version: threshold policy	Multi-criteria decision making, e.g., through linear importance weight aggregation of criteria or via Analytic Hierarchy Process. Consideration of multiple viewpoints across involved parties.	Strategy, organization, leadership, process, incentives and coordination, risk management.	Heuristic rules; individual biases (e.g., salience, short-termism, overconfidence, loss aversion); social biases (status competition, group-think, relationships)	Bubble diagrams and other visual representation of balance across segments, product lines, countries, technologies
Key insights	Packing the most valuable items into knapsack of limited volume. With fractional items allowed, it is optimal to rank the items by “value/volume,” but when items are included 0/1, “unused” capacity needs to be taken into account: to use capacity, one may need to include lower priority items. Therefore, combinatorial optimization methods used.	As long as stages capture relevant project status, state-dependent policies can identify: project prioritization on waiting time/waiting cost, on value or quality/scarce resource demand, with threshold policies for when to progress a project. Thresholds can depend on scarcity of the resource used.	Portfolios address multiple goals of the organization; Prerequisite of KP and DP because DA provides “aggregated criteria” for optimization, inclusion or optimization. Also, DA tools should facilitate communication and collective problem structuring.	Successful day-to-day IPM requires frequent project reviews, assigned responsibility for IPM, sufficient slack capacity, stable core teams on projects and a mentality to increase resources into projects.	Individual biases may merit procedure modifications (e.g., present projects in different orders, discuss long-term effects); Group composition and decision procedures must anticipate possible status competition, cronyism or group-think in order to ensure decisions in the interest of the whole organization.	Diagrams enable discussion of “reasonableness.” Thus, the emphasis is on discussion among the decision maker team. Less dependence on complex and manipulation prone data, as the inputs to the diagrams can be “plausibility checked.”
Challenges	Narrow assumptions: items are of fixed and known capacity needs; complexity of combinatorial optimization black box (lack of transparency); valuation data often noisy; little application in practice.	Complexity has limited optimization use in practice; however, qualitative use of DP offers a language and concepts for dynamic project reviews and updates.	No insight from portfolio problem and solutions; applicable questions.	Without proposing systematic solutions or measures; too fragmented.	Modification of procedures to counterbiases is ad hoc and can create tensions. “Nudging” via procedures can be second-guessed and make people cynical.	Lacking theoretical and empirical foundation. It is not clear what diagrams to use, and “reasonableness” can also be hiding expedient political compromises.

1980; Dantzig, 1957; Karp, 1972; Martello et al., 1999; Martello & Toth, 1977).

The Knapsack problem has had limited impact on practice (Cooper et al., 1998; Loch & Kavadias, 2002; Martinsuo, 2013) for two reasons. First, the solution algorithms are complicated, representing a black box to users, and prone to degeneracies without careful calibration (Kavadias & Chao, 2007; Loch et al., 2001). Second, the Knapsack problem rests on assumptions that are too rigid to keep recommendations relevant—project values and resource needs are not deterministic but stochastic, project value has multiple dimensions beyond only financials, while project scopes (and therefore budgets) are not fixed but can be adjusted up and down; so projects can indeed be included “fractionally,” at least in one period.

3.2 | Dynamic programming and real option valuation (DP/ROV)

Dynamic programming is a method of representing, at first, individual projects, which go through “stages” (or phases) of development in a stochastic manner (for example, projects may progress well with “high quality” or less well with “lower quality”), and the status in one stage influences a project’s evolution in later stages. A key assumption is that a *state* in a stage captures all relevant information about the project, without having to go back and look at earlier stages; this assumption ensures that the progression is “memoryless” and allows decision makers to articulate a “policy” that “pre-programs” optimal decisions about the project depending on which state it is in during a given stage.¹ For example, the policy may prescribe that a project is continued if its quality is above a critical threshold, or that the project may be given more resources in a stage if its quality is high but a critical delay since the beginning of the project has accumulated.

Special cases of DP have become well known. First, the so-called multiarmed bandit (MAB) problems, corresponding to the “stop or continue” arms of a slot machine can represent stop-or-go decisions across multiple projects that share a critical and indivisible resource (e.g., expensive lab equipment). A critical number called the *Gittins index*, which depends only on each individual project’s state, indicates which project candidate is best to work on (Bertsimas & Niño-Mora, 1996; Gittins & Jones, 1974; ROSS, 1982; Whittle, 1980). The “value/resource required” policy from knapsacks, discussed earlier, can be interpreted as a simple Gittins index. However, no Gittins index policy applies when there are switching costs for changing between projects, see Banks and Sundaram (1994).

DP methods have also been able to roughly characterize what one might do when multiple projects interact. One important case consists of projects in a portfolio competing for access to scarce resources and causing waiting (queueing) delays (Kavadias & Loch, 2003). A robust simple policy prescribes giving priority to the project with the highest delay cost divided by the expected processing time (Harri-

son, 1975; Smith, 1956); this requires linear waiting costs to be optimal but represents a reasonable approximation even for convex waiting costs (Ha, 1997; Van Mieghem, 2000; Wein, 1992). Instead of prioritizing on delay costs, one may also prioritize on “value at stake” (Loch & Kavadias, 2002; Zschocke et al., 2014). In this case, more available capacity lowers the threshold for project continuation (Ketunen & Salo, 2017; Lewis et al., 1999; Stidham, 1985), while the continuation threshold increases when capacity is scarce immediately (Kleywegt & Papastavrou, 1998) or in subsequent stages. Similar priority schemes may be useable when considering the capital budgeting of competing projects and accounting for their real option values (Childs et al., 1998).²

DP applications also (like Knapsack applications) become complex quickly when multiple projects are in a portfolio, and thus they become “black boxes” that managers can no longer connect to the accuracy or distortions of the underlying data. Also, a DP/ROV approach faces limitations in the presence of unknown unknowns (ambiguity) as discussed in Pich et al. (2002), Adner and Levinthal (2004), and Klingebiel and Adner (2015). Therefore, “optimization” applications of DP have not been widely used (with some exceptions where the evolution of projects is very simple, and data are easily available). However, DP has been very powerful in building a conceptualization and an intuition of how to think about dynamic reviews over the course of project evolution (from one stage to the next), what to look for (e.g., updated value, delays, quality), and based on what criteria to change actions (e.g., kill, continue, run a test to reduce uncertainty, adjust resources, modify). Projects are not “fixed items” as in a portfolio knapsack that, once included, are committed until failure, but they evolve and their treatment is updated. Thus, DP has been influential by creating a conceptual language of how to think about project changes and respond to them.

3.3 | Decision analysis (DA)

The first two streams discussed in Sections 3.1 and 3.2 aim (at least in principle) at optimization, that is, they seek to determine “what” the portfolio composition should be. In contrast, the third stream, Decision Analysis (DA), provides tools and frameworks from a decision theory perspective to assist decision makers: it tries to address the “how to” of project portfolio selection processes. The key contribution of DA to new product portfolio management is the introduction of Multiple-Criteria Decision Making (Henriksen & Traynor, 1999)³: KP and DP start with the assumption that there is one agreed-upon value maximization criterion (e.g., “value” or “total return”), where in reality, a portfolio has multiple purposes (financial return, as well as segment coverage, as well as robustness, etc.). Moreover, multiple stakeholders in the organization maybe looking at different relevant criteria. Multi-criteria valuation builds upon the classical, and simple, “pros and cons” table, listing the strengths and weaknesses

of each project on each relevant criterion. It may also assign importance weights to the criteria. Through these (importance) weights, the multiple criteria values can be aggregated into a composite “overarching” project value. More sophisticated aggregation methods than linear combination with importance weights also exist, such as the analytic hierarchy process (Hammond et al., 1998; Saaty, 1994). DA may be seen as the “prerequisite” to applying DP (or other methods of making portfolio inclusion and prioritization decisions), as DA provides the agreed upon value dimension to base its project decisions on.

Multicriteria decision tables are not sufficient to make portfolio decisions because they fundamentally consider project values in isolation: the aggregated values (obtained from weighted averages of all relevant criteria) are obtained from individual project data alone, as if each project existed in isolation. Therefore, they can at most achieve combinatorial comparisons across individual project values. However, by their very nature, portfolios are collections of projects that must “act” together to support and achieve the strategic priorities of the organization. Metaphorically, even if one likes oak trees the best, a forest that consists only of oak trees will likely not fulfill the objectives of the forest master who tries to achieve various goals (for animal populations, soil support etc.).

Other proponents of DA emphasize that it must support information exchange and consensus regarding selection criteria (Brenner, 1994); DA tools should facilitate communication, the interpretation of different individual visions, and collective problem structuring (Lawson et al., 2006; Montagna, 2011). This element of DA already points to the next stream of methods, organizational, and stakeholder interactions.

3.4 | Organization and team (OT)

The fourth stream (OT) highlights the insight that innovation portfolio management is not only an optimization and decision-making challenge, but in its core a multi-level organizational problem. Therefore, effective portfolio management needs to achieve consensus toward a common goal, which requires organizational processes (rather than ad hoc decisions): (1) strategy (firm’s strategic orientation and aspirations); (2) organization (organizational characteristics, cultural aspects, organizational learning); (3) leadership (leadership style, leadership involvement, competence of different management levels); (4) process (formalized project management and project reviews at specified intervals); (5) risk management; (6) incentives and coordination (incentive structure, coordination, and control roles). Successful portfolio management requires frequent project reviews, assigned responsibility, sufficient slack capacity, and stable core teams on projects (McDonough III & Spital, 2003). Innovation portfolio decision-making effectiveness (portfolio mindset, focus, and agility) is positively related to innovation portfolio success (Kester et al., 2014).

OT elements allow constructively influencing the relationships between the actors in the organization and portfolio outcomes. Since the early work of (Bower, 1972), researchers have considered different relationship dimensions to understand portfolio outcomes. The diversity of perspectives among the stakeholders that may approve portfolio projects (Criscuolo et al., 2017; Oraopoulos & Kavadias, 2020), the delegation of decision rights (Hutchison-Krupat & Kavadias, 2015, 2018), the establishment of shared incentive schemes beyond individual project bonuses (Crama et al., 2019; Schlapp et al., 2015), as well as the specificity and breadth of the communicated strategic objectives (Chao & Kavadias, 2008; Hutchison-Krupat, 2018; Klingebiel & Rammer, 2014) shape which projects are included in the portfolio. Different configurations of OT can support innovation portfolio management, and which “rules” the organization applies should be contingent on high level portfolio strategic objectives (e.g., how many radical innovations are desired, or how many per market segment). Much more research is necessary to be able to characterize the “normative” OT support of innovation portfolio management.

3.5 | Psychology and behavior (PB)

Most formal models of operational and decision analysis assume that the people involved in operating the systems are perfectly rational, or at least can be induced to behave rationally. Indeed, the very purpose of decision systems is to support the rationality of decisions, meaning the inclusion of considerations that the organization recognizes, values, and feels it can defend against internal or external questioning. However, uncertain and complex decisions such as those shaping innovation portfolios are *never* fully represented by the available formal criteria. *Intuition* is always involved, or implicit unconscious shortcuts that allow people to process information that is too complex to be fully considered in real time (Hogarth, 2001). This holds certainly for applying decision criteria, and it holds even more for collecting and judging the noisy, unreliable, and complex data that underlie the decision procedures.

Intuition is powerful and important because it allows people to come to conclusions quickly when required, and to implicitly aggregate information that they have access to, formally or privately, in their own heads. However, intuition is also well known to be prone to biases and distortions. Some biases result from the heuristic shortcuts people use when faced with complex decisions (Benartzi & Thaler, 2007; Chao & Kavadias, 2008; Gigerenzer & Gaissmaier, 2011; Gino & Pisano, 2008; Kester et al., 2011; Keyes, 1972; Loch, 2017). Examples are salience, such as the position of a project in a list, where early placement increases the selection probability (Muthulingam et al., 2013; Schiffels et al., 2018) or the way individuals fill the available resource budget (Pape et al., 2020). Other relevant biases are short termism (paying less attention to consequences far in the future), overconfidence (the underestimation of ignorance about outcomes), or loss

aversion (e.g., spending more effort to avoid a small failure than to ensure a large upside). These are individual decision biases. They can be sufficiently important to warrant changes in discussion protocols, for example, presenting projects in varying order over the day, or explicitly discussing long-term effects to make sure they are not implicitly (and unspokenly) discounted (Crisuolo et al., 2021).

Beyond individual biases, there are also social preference biases, or unconscious social needs in groups. In particular, *status competition* may compel people to engage in a discussion to win the argument rather than to achieve the best outcome for the organization; *group identity* may discourage participants from rocking the boat and “soiling the nest” by pointing out weaknesses or being critical of the overall position (this is related to group think), and *relationships* may cause camps to arise, the members of which are beholden to one another and will maintain a position to not negatively affect their camp peers, rather than, again, looking for the best outcome for the organization (Loch & Wu, 2007, 2008; Wu et al., 2011). For example, a portfolio decision maker may be more concerned with appropriateness rather than best decisions (Christiansen & Varnes, 2008). These social biases may fundamentally distort the portfolio decisions, and careful organizational processes (choice of committee members as well as decision rules) may be necessary to keep social biases and “group politics” within limits.

3.6 | Qualitative portfolio analysis (QPA)

The last stream (QPA) is motivated by the observation that many formal methods have not had a large impact on practice because they are too complicated and require data input that is either hard to obtain or manipulable (such as underlying financial analyses, scoring models or DPs). This stream proposes the use of qualitative portfolio diagrams (“bubble charts” or other visual representations), instead of optimization models, to represent the key strategic trade-offs that the organization needs to resolve (Cooper et al., 1997b; Roussel et al., 1991; Wheelwright & Clark, 1992). Rather than the optimization of some type of composite value index, the explicit purpose of QPA is to achieve a *balanced* portfolio. “Balance” here refers to the need to address multiple strategic needs (that are hard to quantify in a target number), such as supporting multiple segments, multiple product lines, to maintain multiple technology competencies, or to have a balance between core-supporting and new business creating initiatives. The bubble diagrams enable an effective discussion by (i) dimensionalizing the complexity of the task at hand, and (ii) creating a common reference scheme (the visual representation) so as to make the discussion of project comparisons among the decision makers more robust (the approximate position of a project in a bubble diagram is harder to subtly manipulate than financial number estimates). This way, decision makers may converge to some consensus on whether the multiple trade-offs are addressed “reasonably” (rather than “optimally”, which can be seen as

an ambition that is often elusive and a hindrance rather than helpful).

In addition to these tools, Cooper et al. (1997a) propose a “strategic bucket” model, which in its simplest form states that “we should have 90% incremental projects that support the current business, and 10% of radical projects that create new business.” The 10% here would reflect, of course, the high risk of radical projects, but what the right bucket categories are, and what the right target percentages, is hard to “prove” (and therefore prone to manipulation). Chao and Kavadias (2008) examine the business environment conditions under which the strategic bucket approach can be productively applied (environmental complexity and instability affect the applicability of strategic buckets), whereas Hutchison-Krupat and Kavadias (2015) show that strategic buckets can mitigate information asymmetry challenges in hierarchical organizations and ensure that project leaders align team efforts with the overall strategic objectives.

4 | WHAT SHOULD INNOVATION PORTFOLIO MANAGEMENT LOOK LIKE?

Our discussion in Section 3 suggests a peculiar situation. Amidst a general awareness of the importance of the innovation portfolio, a significant number of conceptual frameworks and organizational procedures have been put forth over the last few decades, each capturing pieces of portfolio management and addressing parts of the problem (e.g., how to address biases with decision procedures). Yet, management methods have not managed to arrive at an overarching “professional” procedure that would give us hope to overcome the challenges identified in Sections 1 and 2. In other words, well-justified methods are available, but they appear as fragmented answers to the overall challenge, and this way are insufficient and have failed to win wide acceptance by practicing managers.

4.1 | Recent discussions of “Integrated” portfolio management

There is some evidence that we need to, in some way, combine different approaches to get good results: Cooper et al. (1998) found that leading companies used a *hybrid* approach that combined different existing methods; these companies relied much less on financial methods but had an explicit and established approach to innovation portfolio management with organizational buy-in. Cooper et al. (2000) summarized solutions for managing portfolios from industry practice, including implementing a stage gate process with strict “go/kill” decision points, establishing resource capability analysis, developing product and technology strategies, and incorporating a desired portfolio balance into the gate process.

Another recent proposal builds on “agile development” (Thomke & Reinertsen, 1998) concepts. Cooper and

Sommer (2016, 2018, 2020) propose an agile-stage-gate hybrid approach that enables decision makers to get better information earlier through repeated iterations and validation demos. These proposals come at a highly aggregate level, and they do not specify whether they suggest more early testing, so more solid information is available for planning the stage gate process (which would be merely an extension of the stage gate philosophy similar to Cooper, 1994), or whether they actually suggest that more testing and information updating should be incorporated in projects (which would be consistent not only with DP thinking but also with recent approaches to the management of innovative projects including pivoting and parallel trials, see Lenfle, 2022). Certainly, intensified reviews of individual projects would enable projects to “pivot” and allow the portfolio itself to possibly change its composition more frequently rather than sticking to large projects over many years. This would be consistent with a general trend in project management over the last decade toward more flexibility and adjustment (Davies et al., 2022; Loch et al., 2006). However, the call for frequent reviews and evolving the innovation portfolio (even if this is not “programmed” by a DP planning) is not by itself a fundamental deviation from previously discussed portfolio management principles.

4.2 | A different interpretation of the observed innovation portfolio challenges

The discussion so far suggests the possibility that the professional and scientific innovation management community perhaps have actually produced sufficient methods—solving the portfolio management challenges may not require new additional methods, but it may be sufficient to apply the existing methods in a different order and spirit. Figure 1 summarizes the known innovation portfolio methodologies with a characterization of their emphasis.

The innovation portfolio needs to first and foremost (1) support the organization’s business strategy (embodying its market-offering-related change over time). In order to accomplish this, (2) a collection of *feasible* innovation projects needs to be created, or parts of it possibly assembled from various corners of the organization as well as from key high level strategic initiatives that senior management aims to pursue. (3) The candidate project proposals then need to be (i) valued on the dimensions that best reflect the company strategy, and (ii) monitored with respect to their goal compliance. (4) The valuation cannot be frozen at the outset but needs to allow possible changes, while accounting for decisions that will be contingent on intermediate results over time. (5) For these portfolio analytic steps to happen, the organization must be informed so it can align itself behind this, and (6) the stakeholder coalition (internal and external) that supports the strategy must be convinced and kept informed and supportive as changes occur.

Within our discussed collection of methods, knapsack, decision analysis, and qualitative portfolio methods can be

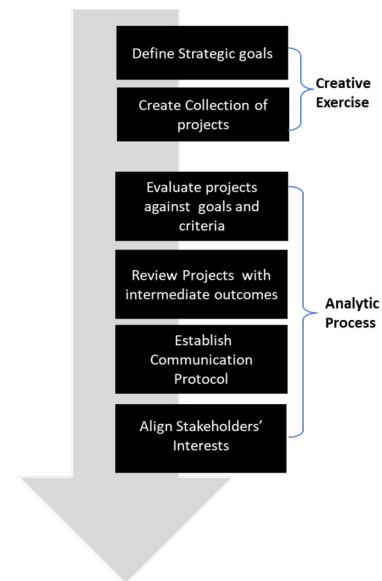


FIGURE 1 A “process” of innovation portfolio management [Color figure can be viewed at wileyonlinelibrary.com]

connected to Step 3i, DP and agile methods can be connected to Steps 3ii and 4, and OT and PB methods can to Steps 5 and 6. While we may see Step 1 as outside the scope of portfolio management (one cannot at every turn question the strategy), we cannot but notice that Step 2 has simply not been addressed. Implicitly, it has been taken as given that a reasonable candidate list exists from which one can select—the projects have been seen as “falling from the sky in sufficient number and fully formed” (perhaps being produced by some other organizational process that we do not need to concern ourselves with). Therefore financial or multicriteria decision making have been taken for granted as the right methods to select the “best ones.” Moreover, we seem to be assuming that the other mysterious process has produced an already “good” list, which can be relied upon to already address our strategy, which allows us the luxury to use *generic* criteria: NPV, or ROI, or time to break-even, or positions in generic bubble diagrams representing standard tradeoffs such as “return versus risk” or “market growth potential versus risk.”⁴

As a result, the usual method discussions miss an important qualitative difference in the phases of the portfolio management “process”: the creation of the portfolio (based on strategic priorities) remains at its core a *creative activity*. Just like the articulation of a strategy, portfolio creation cannot be the outcome of the application of an optimization algorithm to a known set of “right ballpark” project candidates that have fallen from the sky. Instead, it should reflect the (partially intuitive) perception of opportunities, and the creation of a set of initiatives that together produce an appeal. It is a creative act that produces a collection of initiatives that have supportive links to strategic priorities (Jonasson & Ingason, 2018; Lin & Luh, 2009). Specifically, the decision makers must articulate what they want to achieve and ask for initiatives that accomplish just these goals, either proposing their own ideas

or demanding from their respective staff (in their areas of responsibility) projects that address the desired issues. Many of the initiative ideas come from staff (easily 50%, see Sting et al., 2015), but the staff will not propose initiatives that go in the right direction unless asked and directed (the idea directions that staff may produce spontaneously are nearly infinite and on average only weakly related to the strategic goals management wants to set for the future). Thus, selection (among ideas proposed) is certainly present, but the ideas must be created and solicited. And the key element of a “good” portfolio is whether it reasonably addresses the desired targets, not whether each project is “brilliant” in itself by some generic measure.

In contrast, the methods that professional and academic experts have proposed are *analytical* because of the assumed plentifulness of ballpark portfolio candidates: they start with given projects and select (formally or through qualitative organizational procedures) the “optimal” ones. However, while a rigorous application of analytical methods can *support* the selection of a differentiating portfolio, by scrutinizing the value of creative proposals, it cannot *create* a collection of projects that address the organization’s strategic goals.

4.3 | A proposal to create rather than merely select portfolios

Our discussion above suggests the conclusion that the core portfolio challenges diagnosed in Sections 1 and 2 of this paper have been treated with the wrong “recipe,” with practicing encouraged by the advice of academics and professional experts. This recipe has *focused the contributions of these methods on only a part of the portfolio process*, taking the availability of already reasonable targeted projects as given, and therefore focusing on “optimal” selection with standardized criteria. Indeed, even the proponents of qualitative portfolio diagrams (Cooper et al., 1997a) start out with the statement that the “portfolio maximizes returns to the company,” which implies a primacy of financial optimization. Putting analytical methods in the driver’s seat has undermined the necessary creative part of the portfolio process; as return goals are too narrow for innovative and novel projects (Christensen et al., 2008; Kirsner, 2022), this has impoverished the creative search for innovative portfolios that strengthen the strategic positioning, and therefore, this development has backfired.

Thus, we propose that instead of trying to invent more (and newer) methods to address the widely lamented innovation portfolio problem, we may benefit from correcting the logical order of steps (see the extension of Figure 1 in Figure 2): in a strategic discussion, the deciding body agrees on the strategic innovation goals. Then, the decision makers need to *design* a “draft” project portfolio: the reader may picture in his/her mind literally a design workshop where the goals are put on a board, everyone writes proposals on paper scraps that are added to the board, then there is critique, modification and of

ideas until a reasonable first cut has been reached that covers the goals and satisfies the group’s judgment that it is of sufficient innovativeness and quality. (Typically, many of these ideas will come from requesting proposals from staff based on pre-discussions, so there is an element of selection, but the combination and discussion of collective coverage still has the character of a design process.)

Then analytic methods come in: do the projects fulfil minimum financial requirements? Are there excessive risks involved? Are there important negative (or positive!) interactions among some projects? Are the resource requirements too far outside of the acceptable capacity (in budgets or person-years)? The formal methods support the design process by ensuring its soundness, by pointing out holes and weaknesses. Typically, the first draft will not work, and one or two more rounds are required, where profitability is improved or budgets cut, or a project added. Sometimes, feasibility (e.g., resource constraints) can mandate that some target fulfilment must be renegotiated. Thus, Figure 2 has an arrow going back from the portfolio analysis to the strategic goals: although we stated earlier that strategy should not be questioned every time around, it may happen that the portfolio design uncovers a constraint that must change the strategic goals (and sometimes it does indeed happen that the portfolio uncovers an opportunity that may even improve the strategic goals!).

After a portfolio has been created as well as evaluated (steps 2–3), discipline can then be built into the further *management* of the portfolio, by monitoring progress, intermediate outcomes and prescribing modifications when changes occur (step 4). Finally, formal efforts can be made to inform and bring on board the operating levels of the organization, and to maintain the coalitions of stakeholders that has enabled the projects to go ahead (steps 5–6). The methods discussed in Section 3 of this paper can accomplish all these accompanying evaluative activities. The core of this proposal is that portfolio management needs to be seen as first a *Design Activity Step* and second an *Evaluation and Management* step.

Proponents of the qualitative portfolio approaches (discussed in Section 3) have long emphasized that portfolio diagrams need to stimulate an active strategic discussion by the decision makers. However, we have pointed out earlier that the way this has tended to be applied has been via standardized diagrams (e.g., “return over risk,” or “process change over product change,” or “technical novelty over market novelty”). The use of standardized portfolio diagrams has prevented a true discussion of the strategic goals of *this specific* organization, rather shoehorning everyone into risk–return balances that are generically prescribed.

Indeed, review articles have repeatedly called for extending innovation portfolio management from isolated decisions of the R&D funnel to a holistic process (Kavadias, 2014; Kavadias & Chao, 2007), for viewing innovation portfolios as a multilevel organizational problem (Meifort, 2016), and for integrating across levels of analysis with a macro lens and a micro lens (Chagas Brasil & Eggers, 2019).

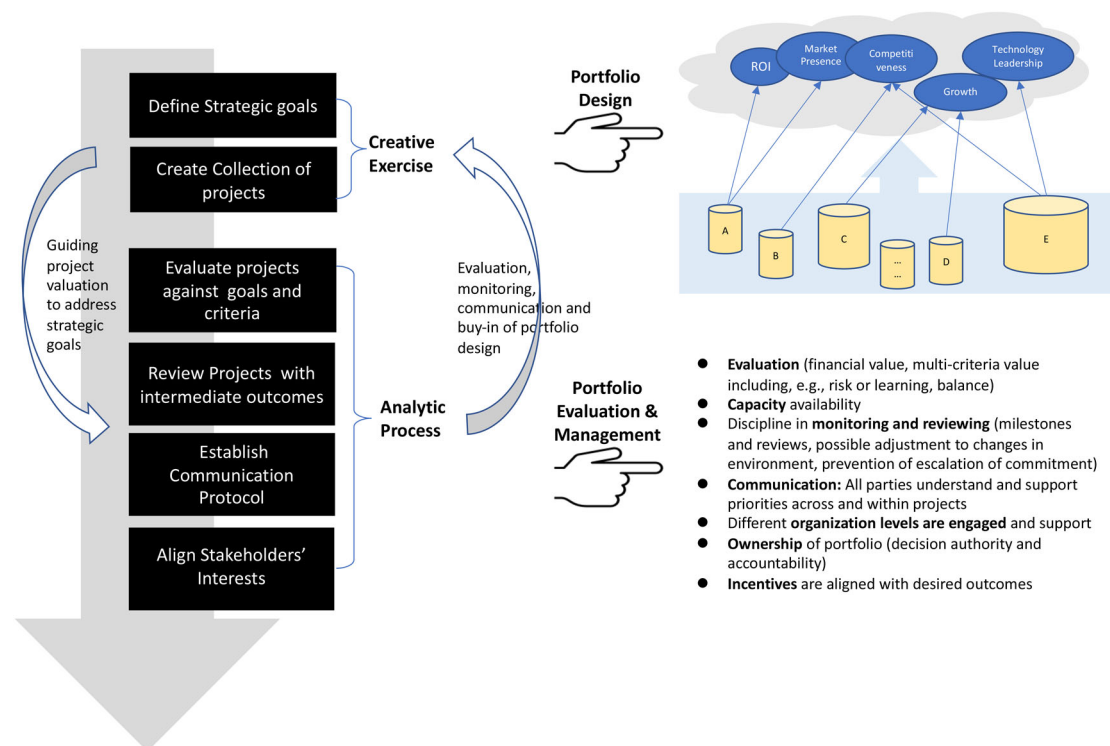


FIGURE 2 Design and Evaluation & Management support each other [Color figure can be viewed at wileyonlinelibrary.com]

Honest strategic debates about the innovation portfolio may represent a challenge for some management teams, whose very senior members have too much status and political capital at stake to risk ever being contradicted or even outvoted. On the other hand, a shared view of the innovation initiatives and their priorities, which stems from an honest discussion in the interest of the organization, makes the portfolio more robust as well as makes it easier for the management team to explain it consistently to the organization and stakeholders. Table 3 lists the arguments why our proposal addresses the challenges from Section 2.

The arguments so far are conceptual, based on an assessment of results from previous practices and studies. The next question is then what the application of our proposal, distinguishing innovation portfolio design versus evaluation and management, may look like in practice. We now present an illustrative case study, and then discuss that our proposal needs to be tested with additional research.

5 | AN ILLUSTRATIVE CASE EXAMPLE

Table 4 compares three companies in the solar energy market (the names and numbers are disguised for confidentiality reasons). Company A is the market leader with a revenue of \$8.1B and the highest profit. Company B is the oldest and smallest of the three, but with the highest net profit margin. Company C is the youngest and least profitable (but profits are growing fast).

The companies have distinct strategies: A grew out of physics and has strategy of being the technology leader with the highest quality and solar energy conversion efficiency. B comes out of mechanical engineering and wants to lead with thin-film applications across markets (three of which have already been developed, construction, transport, and solar paper backpacks). C's founder came from financial services, and the company is the cost leader.

Not surprisingly, the three strategies lead to different strategic new product and R&D goals (Figure 3). Company A emphasizes growth and technology leadership; B emphasizes growth and presence in target markets, and C emphasizes growth, lean management, manufacturing excellence and cost reduction. These different goals require different kinds of projects in their R&D (product innovation) portfolios (Figure 3 lists not individual projects, but aggregated programs of multiple projects with common themes).

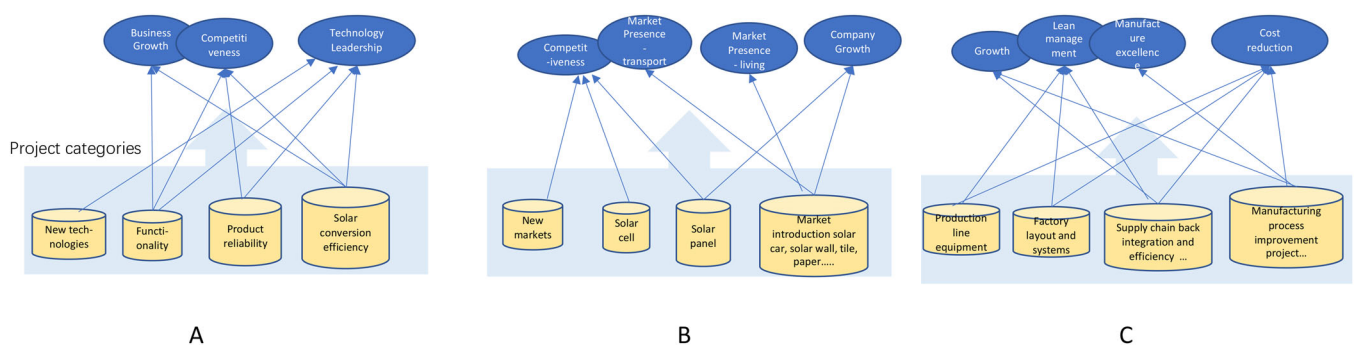
Company A has programs on new technologies, and programs for enhancements of functionality, reliability, and energy conversion efficiency. Company B has two types of programs: solar cell and panel technologies that support their base products (which still account for slightly over half of sales), plus exploration of new markets and product adaptations for the various verticals. Company C focuses on programs that are entirely focused on cost efficiency: production equipment, factory layout and systems, supply chain efficiency, and manufacturing process development and improvements. Although these three companies compete with one another, their R&D and product portfolios

TABLE 3 Why our proposal may improve the shortcomings of innovation portfolio management

IPM challenges	Main causes	How the proposal addresses the challenge	Support from previous literature
Strategic alignment	- Lack of holistic perspective leads to mismatch between strategic goals and evaluation criteria - Overreliance on analytics leads to focus on technical and financial criteria over strategic goals	- By defining strategic goals of the portfolio, any project is entered with a discussion of what it contributes. - Design of a portfolio aims explicitly to meet strategic goals.	- Cooper et al. (1999); Killen et al. (2008); Szwajkowski et al. (2006): Empirical results confirm that firms that have moved from purely financial to strategic IPM tools are more successful at innovation. - Creativity and discipline: Stevens et al. (1999).
Unbalanced composition, insufficient proportion of more radical initiatives	- Lack of creative discussion - Emphasis on “provable” outputs encourage risk aversion - Disconnect from strategy - Too weak in project review against goals and criteria	- The design of a portfolio that covers the goals leads to a balance by definition. Which balance may be contested, but this is a productive strategic negotiation. - E.g., if innovativeness is a goal, innovative projects must be in a competent design.	- Pisano (2019); Sinfield et al. (2014): Creativity without discipline is messy, discipline without creativity represents “auto = pilot.” - Stevens et al. (1999): Preselect innovative, creative people for the early stages of NPD, and then teach this group the business discipline required in stage-gate NPD processes.
Project valuation: absence of solid information	- Overemphasis on the goal of maximizing portfolio value rather than aligning the strategic goal. - The emergent uncertain nature of innovation projects leads to unreliability of information. - Multiple organizational levels and information sources lead to information ambiguity, inconsistency, and asymmetries.	- The design of a portfolio that covers the goals is negotiated holistically, which makes valuation more robust, as no one group of uncertain valuations can dominate the conclusion. - The use of intermediate results in reviewing projects reduces uncertainty through portfolio updates. - Communication protocols with uniform coding reduce information ambiguity.	- Cooper and Sommer (2016) proposed the agile-stage-gate method. It increased the frequency of assessment and obtained more up-to-date and more precise data from the projects. - Ezekoye and Luu (2020): taking an iterative, or agile, approach to portfolio reviews can increase transparency among these business leaders, mitigate organizational inertia and internal biases, and make conversations more inclusive
Portfolio overload: too many projects for limited resources	- Lack of execution discipline - Resources not released timely (upon completion or termination) - Lack of staged or milestone investments - Managers do not like to kill projects with high investment to date	- If capacity is a strict constraint in the portfolio design, “overbooking” can be limited (e.g., any project can enter only if another one finishes or stops). - Strict intermediate reviews need to “have sufficient teeth” to kill projects with low prospects and thus free up capacity.	- Cooper et al. (2000) summarized a range of solutions for managing portfolios from best industry practice, including implementing a staged gate process with strict “go/kill” decision points. - On innovation capacity, see Loch et al. (1996); Reinertsen (1997).
Support and buy-in: lacking full support and understanding	- Lack of senior executive involvement - Portfolio creation without participating of relevant departments - The absence of a common language leads to mutual misunderstanding and distrust.	- The decision group that designs the portfolio owns the portfolio and is accountable. - Incorporating stakeholder interests can be made part of the design criteria (for internal and external stakeholders). - The implementation of stakeholder interests can be undertaken with known types of processes.	- Roussel et al. (1991): corporate, business and R&D management must act as one to integrate corporate, business and R&D plans into a single action plan. - De Maio et al. (1994): effective IPM requires organization-wide information sharing and buy-in to avoid strong political and psychological pressures. - Hutchison-Krupat and Kavadas (2015): formal buckets enable alignment of bottom-up initiatives with top-down strategic goals and facilitate organizational input
Portfolio governance: lacking clear portfolio ownership and enforcement	- Strategic importance of portfolio is overlooked - Lack of ownership and accountability - This results in crisis management (when problems have festered)		- Butler (2018): Ensure that processes are in place to define, align, authorize, and control the portfolio and guide governance decision-making activities. - Loch et al. (2017): steering committee must be engaged to maintain alignment through changes

TABLE 4 Three solar energy companies

	Company A	Company B	Company C
Established (year)	2000	1994	2006
Founders' background	Physics and engineering	Mechanical engineering	Trading
Revenue 2020	\$8.1b	\$4b	\$5b
Profit 2020	\$1.3b	\$0.9b	\$0.15b
Growth 2018–2020			
• Revenue	57%	63%	18%
• Profit	85%	73%	93%
Main products	Monocrystalline solar panels and cells	Thin film product applications and thin film turnkey production lines	Polycrystalline solar panels and cells
Mission	Being the world's leading solar technology company	"Power anything": multimarket and multiapplication	Produce green electricity that people can afford

**FIGURE 3** Strategic goals and program portfolios of the three companies [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

are entirely different—as they should be, as the companies have very different logics of value proposition and market position.

The three very different innovation portfolios cannot be explained with financial evaluation methods or standard bubble diagrams. Each portfolio must have been produced (even if implicitly) by a translation of the company's specific innovation goals into a project collection: A's portfolio tries to achieve functional superiority, B's portfolio a balance across (core and new) markets (so, here the standard bubble diagram of market versus technology newness would actually apply), and C pursues supply chain and process excellence. This is most simply shown with the arrows in Figure 3; a more sophisticated representation could put qualifiers on the arrows of strength, or value, or (ir)replaceability. The "balance" of the projects' strategic contributions is entirely specific to the strategy of *this specific* company.

This is consistent with our proposal: only a design step can capture these portfolio priorities, no standard set of criteria, no matter how elaborate, can achieve this. Analytical methods are important in helping to make sure that the new technology projects included in the portfolio of company are sound, but analytical methods fundamentally cannot identify that new technology projects are needed.

This interpretation of the portfolios at the three companies is supported by a failure that company B diagnosed within itself: as selection criteria to the projects, even the new-market projects, it used to a large degree technical quality and conversion efficiency. This was adequate for the cell and panel programs, but it violated its own strategic logic in its new markets and market introduction programs: customers (both consumers and industry clients) did not value the subtleties of technical performance (and were indeed not bothered by slight *reductions* in efficiency) but valued ease of use, durability, customization, and pliability/formability of the thin film that influenced their user experience.

Thus, the project inclusion criteria did not match the stated objectives in the design process (winning customers in new markets). This mismatch of selection criteria (at the detailed project level) with the strategy caused the products to be less attractive, as well as too expensive, which compromised company B's market share, growth, and profitability. This kind of failure cannot be avoided by increasing the sophistication of analytical methods; it requires a clear consciousness of the strategic priorities, shared down to the project level, so people at the operating level can propose and select consistently and make consistent design decisions.

6 | CONCLUSION

This article has diagnosed a widespread impression that innovation (or new product, or R&D) project portfolio management in companies does not seem to be working to general satisfaction. Significant dysfunctionalities seem to persist, from politics and data manipulation over just wrong and short-sighted decisions to a failure to follow-up and evolve portfolios over time, which we illustrated in an example and from surveys. We have then overviewed available methods that have been proposed in academia and professional circles over the last 60 years. These methods look (collectively) competent and relevant, but have apparently not gained sufficient application across industries, or they do not address the problem correctly.

We have then argued that the failure perhaps stems not from a nonapplication of the methods, but from an application in the wrong order and with the wrong logic: the creation of a collection of initiatives that actively support and further the business strategy goals is just a *design process*, which needs to be performed by a senior management team that, with this creative activity, creates or assembles a collection of initiatives that, by design, “cover” the strategic goals. We do not by any means want to belittle that this is complicated and fraught, and will require difficult negotiations. However, without an explicit design for goal coverage, achieving the innovation goals simply cannot be accomplished well, as all the existing evidence confirms.

As a second step, *Portfolio Evaluation and Management* should productively employ the sophisticated analytical methods that are available, such as financial return, risk, capacity criteria, multi-dimensional criteria, and the “balanced portfolio bubble diagrams,” such as return over risk, product change over process change, or market newness over technology newness, which can be used once the management team that owns the portfolio has decided that a certain trade-off is indeed a strategic core issue.

Analytical methods can support the creative activity of portfolio construction (by insisting on the appropriateness of the projects included) but cannot drive portfolio construction. But portfolio management in practice has often tried to construct portfolios with formal criteria (rather than as a collective design act, which then becomes a “how to explain this” afterthought).

Although already Roussel et al. (1991) proposed that senior management teams must agree on the portfolios as strategic instruments, our proposal turns widely used practice on its head, placing the demand on senior managers to regularly engage in a design (or re-design) process that requires subtle and difficult strategic negotiations. But who else than the senior team that owns the innovation portfolio can undertake these negotiations, which must happen somewhere in the organization?

We demonstrate with a case example, comparing three solar energy companies, that the “innovation portfolio design” as separate from portfolio evaluation and management approach may offer better outcomes. We are the first

to concede that our proposal is, so far, based on a new view of previous work rather than on empirical evidence. Empirical research is needed in order to (a) show what the portfolio design process might look like (although design processes for managerial actions are well known in related areas, a transfer will have to be accomplished), and (b) to build evidence that this approach indeed benefits the organizations who apply it. We see this as important work for the near future.

ENDNOTES

¹ This DP-based formulation of project evolution has found application in individual project valuation across different literatures, for example, new product development, see Huchzermeier and Loch (2001), and real options in project valuation, see Trigeorgis (1996), or strategic management, see Trigeorgis and Reuer (2017).

² Important work that has connected queueing theory to project portfolios (such as Adler et al., 1995, 1996) is not discussed here because it has focused on the capacity need of a portfolios (and the necessity to have capacity buffers), rather than on the choice of which projects should be prioritized to join the portfolio.

³ Another widely named tool in DA is the decision tree. The decision tree, however, is equivalent to (a version of) DP. This observation highlights that the method streams discussed here overlap in various ways and are not so neatly separate as we picture in our overview for reasons of exposition.

⁴ For example, Nagji and Tuff (2012) say that the company needs to decide what it wants, but a key part of what they propose is their “innovation ambition matrix” that has as its two dimensions (axes) market novelty and product novelty, a well-known standard categorization of innovations. This may be the right way to distinguish the innovation emphasis for some organizations but not for others. It does not address the need of companies to clearly articulate what it is they want to achieve.

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