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Aligning the R&D Portfolio with Strategy Using a Method Based on Expected Business Impact

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***Abstract*— R&D project portfolios are commonly constructed by applying multiple criteria and weighted scoring methods not widely understood beyond R&D practitioners. This complicates justifying investments in R&D to the CEO and Board. The limitations of valuing R&D projects in purely financial terms point to a need for expressing R&D project value in alternative terms relatable to business strategy. The proposed method aligns R&D investments directly with various intended contributions to business success called Business Impacts. This judgment-based method crucially includes a technique for directly comparing different types of Business Impacts, thereby creating a non-financial, but common, scale for project valuation that all projects can be ranked on. Agreeing with the CEO and other key stakeholders on the composition of a desired Target Portfolio in terms of Business Impact and Time Horizon prior to R&D proposal solicitation and selection will cascade strategy and improve the quality of R&D proposals. The process is flexible and can be augmented by Technology Strategy elements such as Technology Roadmaps and other criteria. The resulting R&D Portfolio is readily communicable at the Board level and facilitates strategic rebalancing as the need arises.**

Keywords*— *R&D, portfolio management, project selection, strategy, valuation, business impact, multi-criteria model

I. Introduction

The scale of R&D investment at both a corporate and national level underscores the importance of sound R&D portfolio management. Together, OECD member countries spent approximately $1.9 trillion, or 2.7% of their GDP, on R&D in 2023. U.S. business R&D spending alone was $729 billion, with China closely behind [1]. An established body of research points to usually positive, though heterogenous, firm-level returns to R&D spend [2], [3]. Studies find market value to be positively associated with R&D spending, but with substantial variation across firms and industries [4]. A plausible explanation for this heterogeneity of outcomes is that R&D spending effectiveness varies substantially due to management factors, such as alignment with an organization's strategy.

The R&D portfolio is the CTO's responsibility while corporate strategy is the responsibility of the CEO acting in concert with the Board. The goal of R&D portfolio management is ensuring that limited financial and human resources are deployed in service of the corporate strategy. Assembling and managing an R&D portfolio is challenging as the stakes are high, but so are the uncertainty levels. Portfolio management entails strategic choices above the individual project level requiring a higher-level perspective. Using strategic buckets facilitates R&D resource allocation across strategic categories rather than only ranking individual R&D projects [5].

The method expounded in this paper builds on these concepts by employing strategic buckets representing high-level business outcomes called *Business Impacts*, rather than using monetary or synthetic valuation variables. It includes a technique for directly comparing different types of Business Impacts, enabling the valuation and comparison of different in-kind projects, benefits of which may be measured in qualitative and/or qualitative terms. The paper starts with a brief background on R&D portfolio-management methods, followed by a detailed description of the proposed technique for strategically aligning R&D portfolios. Implications of the technique are discussed, followed by the conclusion.

II. Background: R&D Portfolio Management Methods

The basic principles for effective R&D portfolio management are active involvement of decisionmakers, proper evaluation of projects, and portfolio balancing. The latter is done across important attributes such as time horizon, basic research, applied research and development, or whether an innovation is incremental or radical [6]. Portfolio management is at the highest layer of R&D management where it must align all R&D investments overseen by the CTO with strategic goals set by corporate leadership [7].

The *knapsack problem* – the challenge of packing the most valuable combination of items into a knapsack with limited volume – is an old visual metaphor for the constraints encountered when assembling a portfolio [8]. It points to the need for combinatorial optimization methods to deal with the complexities of portfolio selection and management. Portfolio construction is a nontrivial exercise entailing the selection of an optimal set of projects of different organizational value and technical uncertainty, their relative timing, and allotted share of scarce resources. Complexity analysis shows that even simple portfolio optimization problems are NP-hard problems, i.e. the number of possible portfolio combinations grows so rapidly that finding the mathematically optimal solution becomes computationally impractical as the number of choices increases [9]. This phenomenon can also be referred to as *combinatorial explosion*. Organizations deal with this inherent complexity by adopting various rules of thumb intelligible to human participants, or by employing sophisticated mathematical models. The uncertainties of technical outcomes, market conditions, and other external factors necessitate human judgment in portfolio decision making.

A. *Three-Class Typology*

A wide range of R&D portfolio management methods exist. For simplification, we discern three main classes:

- *Class I: Evaluation- and Governance-Driven Portfolio Methods* include all methods relying on evaluative judgments, typically based on multiple criteria and weighted scoring implemented in a decision-making process. These include checklists, scorecards, stage-gate criteria, weighted scoring models, standard Multi-Criteria Decision Making (MCDA) [10], Saaty's more sophisticated Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) [11], and Portfolio Decision Analysis (PDA) [12]. Typical scoring models simplify the merit calculation for each proposal by using a small number of standard criteria to which point scores are allocated and totaled, often using different weights per criterion [13]. For all Class 1 methods, evaluation precedes optimization and management judgment remains central.
- *Class II: Financial and Option-Based Valuation Methods* comprise methods that value projects primarily in monetary terms sometimes adjusted to incorporate uncertainty or risk. These include Net Present Value (NPV), Internal Rate of Return (IRR), and payback calculations, real options [14], and decision trees. Real-option analysis extends option-pricing techniques developed in the financial industry and attempts to maximize the monetary value of an R&D portfolio. It is considered useful for analyzing multiple time-staggered R&D investments and deciding the timing of R&D projects [15].
- *Class III: Optimization-Centric Portfolio Construction Methods* construct portfolios algorithmically by selecting projects and allocating resources to maximize value subject to constraints [16]. These include integer/mixed-integer programming, multi-objective optimization, stochastic/fuzzy optimization, dependency-aware and roadmap-based models, as well as heuristics and metaheuristics.

B. *Implications for Practice*

According to a recent review, practitioners mostly use Class I and II methods, with formal optimization methods (Class III) playing only a limited role in actual R&D portfolio settings [17]. This is consistent with our industry experience with R&D portfolio-decision processes where we often encounter some variation of Class I criteria-based scoring models, sometimes combined with Class II financial methods. This class dichotomy can lead to organizational tension as CFOs tend to prefer financial valuations while CTOs maintain that these cannot always be feasibly calculated for R&D projects, especially those at earlier stages far removed from their potential application and deployment where monetization would occur. An organizational preference for financial metrics may thus bias the portfolio towards later-stage R&D, which may or may not be desirable depending on the strategic context.

C. *Aligning R&D Portfolios to Corporate Strategy*

Cooper, Edgett and Kleinschmidt [5] found that strategy methods of portfolio alignment outperform financial methods. Research from as far back as the 1980s agree that R&D projects are more likely to succeed when coupled to a clearly identified business need, problem, or opportunity [18]. A process – whether implicit or explicit – is needed to align the R&D portfolio strategy with the higher-level business strategy. The strategic fit of a portfolio can be defined as the extent to which the portfolio reflects the business strategy [19].

As a design goal, dimensions for linking R&D portfolios to strategy must be recognized at the corporate-strategy level while being relatable to the R&D level. This ensures that proposals may be classified or bucketed in strategic terms. For example, Santiago and Soares [20] propose a bucketing framework with technology, market, capabilities, and organization processes as the main dimensions supplemented by the external environment.

Another design decision concerns the ranking or scoring system to use for assessing the relative merits of R&D project proposals. For example, Henriksen and Traynor [21] propose a scoring tool that respectively rate technical, programmatic, and business return (if successful) using a 5-point Likert scale from 'very high' to 'very low'. Other scoring dimensions using the same scale are relevance, risk, and reasonableness (likelihood of success).

Descriptions used in any scoring rubric must be rigorous and unambiguous to minimize 'gaming the system', the tendency of proponents to find ways to justify inflating the scores of their favored projects. Process integrity also requires minimizing decision-making biases. For example, with a fixed number of strategic buckets a common bias of allocating equal numbers of projects to each type of bucket can occur. Known as *naïve diversification*, this tendency has been observed in multiple settings with different selection processes [22].

III. A Practical Technique for Aligning R&D Portfolios

A. *Overview of the Technique*

While the desire to know the value of an R&D project prior to investing in it is understandable, insisting on quantifying value in monetary terms can lead to suboptimal outcomes. Our technique reframes that conversation to focus on the R&D project's eventual intended impact on key business outcomes recognized at the Board level. This approach facilitates more productive discussions between the CTO, the CEO and rest of the C-Suite, as well as the Board. Thus, a focus on Business Impact creates a built-in mechanism for aligning the R&D portfolio with corporate strategy, and for adjusting the R&D portfolio when the corporate strategy changes.

All R&D projects are classified according to at least these three dimensions:

1. the type or area of *Business Impact;*

2. the *relative magnitude* of the expected Business Impact;
3. and the approximate *Time Horizon* over which this impact is expected.

A sound R&D portfolio-management process requires rigorous definitions of these dimensions and logical process flows for adding or removing projects from the portfolio. Typically, there will need to be a cyclical process such as the annual budget cycle, and an exception-based process for when portfolio adjustments must be made inflight.

The next section provides guidance on choosing suitable Business Impacts and calibrating a common range scale that allows value comparisons for projects in different impact buckets. Some guidance on setting up a supportive portfolio management processes is provided, but this cannot be exhaustive as complete processes will always be organization specific. The ancillary challenges of meeting non-financial resource constraints and appropriate project timing are not covered, as these can be addressed via complimentary processes using well-established best practices and tools.

B. Step-by-Step Procedure

1) Choosing the Set of Business Impact Areas

A particular Business Impact must be more specific than 'increasing revenue' or 'lowering costs' or 'making operations more sustainable.' Instead, it is the highest-level answer as to how specifically R&D can contribute to such top-level corporate goals. Each Business Impact is thus a vital link between desired R&D outcomes and corporate strategic goals. Business Impact areas can be divided into three categories: *revenue-related, cost-related*, and *other areas* such as sustainability, reputation, safety, or regulatory. The complete set of Business Impacts chosen should always represent all three categories.

While Business Impacts are at a high level, they still require specificity. Look to typical industry metrics or key performance indicators (KPIs) for inspiration: For example, a retail store chain may have the revenue goal to increase sales per square foot rather than simply to increase total revenue. An automotive OEM may have the cost-related goal of reducing warranty cost per vehicle. A chemicals manufacturer may have a KPI related to regulatory or environmental compliance, specified in terms of minimizing the number of regulatory violations.

Each industry has such KPIs with which all managers will be familiar. Table 1 contains some examples for typical industries but is far from exhaustive. We recommend selecting no more than five Business Impact areas for classifying your company's R&D projects. If these have already been spelled out in a clear Board directive, they may be used directly. Otherwise, choose an uncontroversial and obvious set of Business Impacts that R&D can impact once the technology has come to fruition.

The advantage of classifying each R&D project by its intended Business Impact contribution is that it enables responses to Board queries such as "How much of our current \$50 million R&D spending supports greenhouse gas (GHG) reduction?" In this example, if GHG reduction were one of the defined Business Impact areas, the subtotal of R&D spending on that Business Impact would be readily available to share with the Board. This approach also facilitates dynamic portfolio adjustments when the corporate strategy changes in response to external circumstances such as economic headwinds, leading to a focus shift from revenue to cost containment. The R&D portfolio response to a strategy shift will be a corresponding adjustment of the allocation between such Business Impacts.

TABLE I. INDUSTRY KPI EXAMPLES

Industry	KPI Examples
Automotive	*Revenue*: Market share *Cost*: Warranty cost *Other*: Platform communality
Chemicals	*Revenue*: Plant utilization *Cost*: Energy usage per production unit *Other*: Regulatory violations
Manufacturing	*Revenue*: Capacity utilization *Cost*: Scrap rate Other: Backorder rate
Metals & Mining	*Revenue*: Production volume *Cost*: Cost per ton *Other*: Worker exposure hours
Oil & Gas	*Revenue*: Break-even oil price *Cost*: Lifting costs *Other*: Carbon intensity
Pharmaceuticals	*Revenue*: Percent revenue from blockbuster drugs *Cost*: Cost per new drug development *Other*: Number of clinical trial failures
Retail	*Revenue*: Sales per square foot *Cost*: Shrinkage *Other*: Customer satisfaction score
Technology	*Revenue*: License/subscription renewal rate *Cost*: Cost per line of code *Other*: Platform uptime

2) Defining The Range Scale for Each Business Impact

This step facilitates the ranking of R&D proposals associated with different Business Impact areas. Not using a single metric such as NPV to compare R&D projects by value may seem like comparing apples to oranges. While using multiple Business Impacts is not as hard as it may seem, it requires a mindset shift:

The common scale of comparison for all Business Impacts should be an ordinal scale with three to four intuitive impact descriptions on it, such as Low, Moderate, High, and Very High. The design work is in carefully defining what each impact description means for its Business Impact area. For example, if the Business Impact is reflected by a KPI that can typically only be moved in single-digit percentages, it would resemble Business Impact KPI_1 in illustrative Table 2, where a 'high' impact is classified as a 5 to 10 percent increase. Business Impact KPI_2 is usually easier to inflect and may need to be improved by 20 to 30 percent for it to be considered a 'high' impact. Historical case examples for the company or industry can help anchor these ranges and prevent range inflation. Very High should be reserved for exceptional impacts that may have only been achieved once in the last decade or two, and perhaps not even by your company but by an industry competitor.

Completing such a table for each Business Impact area versus the ordinal scale for the Impact (from low to very high) will result in an impact rubric which can be used to compare the potential relative benefit or value-add for R&D projects that are entirely different in kind, for example, an increase in market share versus fuel efficiency for an automobile OEM. If a project has more than one Business Impact, these scores may be combined into a weighted total Business Impact score that overweighs the primary and underweighs the secondary Impact.

TABLE II. ILLUSTRATIVE RUBRIC COMPARING BUSINESS IMPACT

Scale point	Business Impact KPI_1	Business Impact KPI_2
Low	< 1%	< 10%
Moderate	1 to 5%	10 to 20%
High	5 to 10%	20 to 30%
Very high	> 10%	> 30%

Before launching the new rubric, the CTO's team must carefully calibrate the scales with the involvement of the entire R&D leadership group and key stakeholders in other departments such as product lines. That will foster trust and discourage anyone from later gaming the system to advance their favored projects. Fairness should also be maintained by using peer review to validate the Business Impact KPI for each case under consideration. This is best done in an open R&D budget decision meeting with all major stakeholders present.

3) Defining the Time Horizons to Use

A multi-year classification framework will indicate the approximate timeframe in which an R&D project's Business Impact is expected to be achieved. The simplest and most intuitive framework is the common *Three Horizons*, where Horizon 1 (H1) is the short term, Horizon 2 (H2) is the medium term, and Horizon 3 (H3) is the long term. For illustrative purposes, H1 is typically 12 to 18 months, H2 is 18 months to 4 years, and H3 is farther out. These durations will vary by industry. Time horizons should fit the industry and be applied consistently. The time horizon could also be a proxy for technology risk or uncertainty, with H3 corresponding to high uncertainty and technology exploration and H1 to low uncertainty and the exploitation of mature technologies.

Bucketing by time horizon also facilitates the cross-referencing of the R&D portfolio with the organization's Technology Strategy. For example, where the strategy is to use mature technologies in a particular technology domain, that may result in only selecting R&D projects in that domain that fall within H1. On the other hand, to be an industry technology leader in a particular domain will require funding R&D projects well into H3. NASA's Technology Readiness Level (TRL) [23] is a widely used technology-maturity scale. It assesses maturity on 1 a scale of 1 to 9: TRL 1 – 3 are various levels of basic and feasibility research; TRL 4 – 6 are various levels of technology development; TRL 7 – 9 are prototyping, systems demonstration and deployment. Generally, R&D projects in H1 should have high TRLs, while low TRLs should be assigned to H3 and mid-level TRLs to H2.

4) Setting the Target Portfolio

The chosen Business Impacts along with the Time Horizons form a two-dimensional matrix expressible in table format to depict the allocation of the whole R&D portfolio in dollar or percentage terms. For example, R&D investments in GHG reduction in H2 may be 10% of the portfolio, while R&D investments in Cost Reduction in H2 may be 15% of the portfolio. The table provides a top-level R&D budget breakdown for the CTO that is shareable with the CEO and the Board.

The best way to have a portfolio of R&D projects tied to Business Impacts is by creating it that way. Therefore, the desired Target Portfolio should accompany the annual call for proposals. It must be compiled prior to proposal invitation by the CTO's team in consultation with key business partners and with due reference to Board priorities. This guidance increases the efficiency of the R&D proposal process by focusing attention on what is desired and reducing time wasted on undesirable proposals. It also avoids latter-stage manipulation to compensate for insufficiently balanced submissions. Most importantly, the guidance ensures that corporate strategic goals are cascaded down to high-level R&D goals.

5) Proposal Evaluation

All received proposals should be subjected to an initial cutoff of minimum desired Business Impact Score. Proposals beneath this cutoff are discarded. If an insufficient number of proposals survive in any bucket, a second call for proposals may be needed for that bucket. After ranking each set of proposals within their Business Impact bucket, a second cutoff representing budget constraints (as per the Target Portfolio) will establish how many high-impact proposals can be funded. This could prompt a petition for additional funding.

A consolidated ranking of all proposals by total Business Impact Score is then compiled. All projects above the minimum desired Business Impact score are funded, with the remainder receiving funding in descending order of Business Impact depending on the availability of remaining funds within their buckets. The resulting draft portfolio should be rebalanced and phased based on additional considerations as explained in Step 6, and ancillary considerations such as human resource and facility constraints not covered here.

6) Including Technology Strategy and Other Dimensions

Using a type of *Balanced Scorecard* can integrate Business Impact (by Time Horizon) defined in Steps 2 and 3 with some other key governing dimensions of Technology Strategy:

A major method of articulating the Technology Strategy is through *Technology Roadmaps*. Roadmapping is a detailed technology-management process that plans technology development over years [24]. It includes technology scanning, options selection, needs-based assessments, and prioritization [25]. Incorporating such a second dimension by rewarding R&D project proposals points for compliance with a Roadmap ensures a portfolio consistent with a corporate aspiration and vision as well as future technologies already identified as strategic.

A third scorecard dimension could represent the *Company Readiness Level (CRL),* i.e. the maturity level of the organization to successfully adopt and apply the relevant technology in its operations. The draft portfolio should also be rebalanced as needed in the light of this analysis. For example, low CRL projects may be best deferred to H2 or H3.

A fourth scorecard dimension could reward points for the broadness or *reach of the technology application* (e.g. number of platforms, product lines, geographies or operating sites).

C. Project Interdependencies

Projects with essential one-to-one interdependencies – implying that it would not make sense to proceed with one and not the other – should simply be combined and evaluated as a single project proposal. The case of one-to-many interdependencies, for example where each of projects A, B, and C relies separately on the completion of another project D usually suggests the presence of an enabling technology (contributed by project D). This may be handled by separately evaluating proposals A, B, and C on their own merits assuming D will proceed, and then allocating the cost of D to those that made the cut, say 50% to A and 50% C. It should then be checked whether the burdened projects A and C would still make the cut. If neither A, B, or C passes on their own merit, then D should not proceed either, unless it earns points in its own right for being part of pre-approved Technology Roadmap.

D. Themes and Missions

Employing the Business-Impact model does not require omitting other strategic considerations often employed in R&D portfolio creation. In fact, this approach can coexist with and seamlessly accommodate additional organizing dimensions such as missions, systems, or technology families. The concept of integrating such additional dimensions into a Balanced Scorecard was introduced in Step B.6 above. A proposed R&D project proposal's contribution to Mission Outcomes or particular Systems can similarly be added as a Balanced Scorecard Dimension for which separate points are awarded.

Additionally, the organization may choose to organize its R&D portfolio around major R&D investment themes, such as automation and sustainability. Each of these will have relevant Business Impacts to be assessed. For example, automation may improve revenue by increasing capacity utilization, but it also could increase safety by reducing worker exposure. Sustainability could reduce cost by both lowering energy consumption and regulatory violations through less emissions.

E. Technical Risk or Uncertainty

Technical risk – we prefer the terms *uncertainty* or *radical uncertainty* [7] – is implicitly accounted for by two elements included in the Step-by-Step Procedure above, TRL and the Three Horizons. Both are well defined, industry proven, and intuitive. By its very nature, R&D is accompanied by various technical uncertainties. Overinvesting in upfront assessments of these is a distraction that may bias project selection. More constructively, the scope of each project proposal should include clear milestones for the outcomes of predefined tests or experiments to resolve specific unknowns and uncertainties.

F. Introduction and Application of the Process

The portfolio design process should be driven by the CTO's office in collaboration with other stakeholders. At the start of the process, the desired Target Portfolio must be agreed between the CTO and CEO. Detailed criteria definitions, project selection, and final portfolio balancing should be the domain of a CTO-led Steering Committee, comprised mainly of direct reports to the CTO and ex-officio members from Finance and other stakeholder departments. The CEO should sign off on the final R&D Portfolio and any major changes made during the year.

The new method should ideally be employed during the start of each annual R&D budget cycle. The distribution (in percentage) as well as the dollar amounts available for each segment of the Target Portfolio should be shared with all potential R&D project proposers along with the usual thematic and technological guidelines. The rubric by which proposals will be scored should also be shared. This will elicit a more focused set of proposals.

The frameworks and process described above could also be applied retroactively to an existing R&D portfolio, first to reclassify all current R&D projects and second, to reprioritize them. The latter may be necessary in case of a mid-cycle event such as receiving a new strategic directive from the Board or CEO that necessitates a rebalancing of the R&D portfolio. Having an R&D portfolio classified by Business Impact will facilitate inflight portfolio changes as needed, and minimize the likelihood of mistakenly cutting or starting projects.

As approved R&D projects proceed, they must be evaluated for goal achievement at predetermined milestones using criteria preferably based on experimental outcomes. An early-stage technology R&D project may have a feasibility gate set around a laboratory experiment, while a late-stage R&D project may require a field test. Failing such milestone tests should trigger prompt management intervention ranging from redirecting the project to terminating it and reallocating its budget.

IV. Discussion and Implications

The technique expounded here is a new type of Multi-Criteria Decision Model that has Business Impact as its main criterion and Time Horizon of impact as its second. Additional criteria representing Technology Strategy, Missions, or Themes can be easily added in a type of Balanced Scorecard. The method entails non-monetary valuation of different types of Business Impacts that facilitates comparisons between different-in-kind R&D project outcomes, both quantitative and qualitative. While the methodology as described here does not consider project interdependencies such as resource or facility usage, these are organization-specific considerations that can be easily added as additional process steps.

The technique is an evolution of the strategic-buckets method, using as its buckets the expected impacts across various business outcomes desired at the Board level. These comprise core revenue and cost related outcomes, as well as others such as sustainability or safety.

Tying the R&D portfolio to Business Impacts and Time Horizons has several benefits:

- It establishes a common frame of reference between the R&D department, the C-suite and the Board;
- It focuses the R&D department on the needs of the business;
- It justifies R&D investment by directly linking it to intended business outcomes;
- It promotes R&D portfolio balance across time horizons and diverse business needs; and

- It protects the R&D portfolio from capricious budgets cuts and facilitates the orderly reallocation of R&D resources as priorities change.

The latter point is particularly relevant during uncertain times when the R&D portfolio is most vulnerable to budget cuts.

V. Conclusion

This paper introduces an R&D portfolio decision-making method directly tied to desirable business outcomes, termed Business Impacts. It results in a portfolio composition balanced across Business Impacts and Time Horizons that is easily understood at the R&D level as well as by the C-suite and Board. An ordinal scale to directly compare and trade off different types of Business Impacts obviates the need for overly precise financial metrics such as NPV. The step-by-step process includes the communication of a Target Portfolio when inviting R&D proposals, thereby increasing proposal quality and relevance, which enables the creation of a close-to-ideal R&D portfolio from the outset. Tying each R&D project to a Business Impact makes R&D investments easier to justify to the Board and provides a rational framework for changing the portfolio as and when business needs change. The method can be extended to incorporate additional criteria representing Technology Strategy, Themes or Missions, and company readiness.

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