Integration of Product and Technology Development Process with R&D Portfolio Management using Efficient Frontier Analysis

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Abstract- **In times of good economy as well as poor, research and development organizations are called upon to propose new innovations and justify their programme spending. This proposal and justification process in many cases requires that the researcher insure alignment with strategic business needs and direction of the company. It most often takes the form of a detailed financial analysis that demonstrates the current and future value of the program deliverables. This paper outlines a method for converging two processes, strategic product development and technology planning, thus making a more efficient and robust tool for R&D portfolio management. The framework developed in this work provides the ability to use known and practiced financial assessment tools applied to a streamlined product-technology planning process.**

In section I, we introduce the topic and section II provides the practical motivation for our work. We then discuss the background for the use of the Efficient Frontier within the context of an R&D portfolio. In section IV, we outline the complete framework; we review the required framework processes and components and provide a sample of how the framework operates. In sections V, we discuss limitations of the framework and we conclude in sections VI and VII with several ideas for future work on the subject.

I. Introduction

Human intelligence experts indicate that the human brain overestimates small risks and underestimates large risks. The general population also tends to be far more sensitive to losses than to any gain. This fact is exacerbated in times of cost-cutting and economic downturn when concern about value of expenditure is necessarily increased [12].

To add to this, the environment in which most traditional R&D organizations function is structured such that funding is often tied to the revenue of the corporation. This leaves many in the functional departments to feel like they are "taxed" in order to support R&D [13]. Given these facts, there is a clear need to be able to build and justify R&D portfolios that are:

- Strategically aligned with the corporation's business
- Demonstrate a commensurate, or at the least, a defensible forecast of return on investment for the risk incurred
- Balanced through diversification of risk [11]

The ability of R&D organizations to bear the burden of an elaborate or financially complex proposal and justification process, however, is limited. This is particularly true in periods of low economic growth. The more rigorous the financial and cost-benefit process, the less time researchers can spend on the development of products or technology, their primary charter. Additionally, although there are those financially trained and minded scientists, there are many who are specialists in other fields outside of finance. By increasing the demand for advanced financial analysis for each R&D project, the typical corporate scientist has to either acquire new financial skills or in some extreme cases, provide the necessary information without sufficient knowledge of what is provided or its accuracy.

Financial questions such as whether to use Real Option or Net Present Value (NPV) calculations to determine future value are often difficult for researchers not in the finance field to answer quickly and with confidence. NPV, for example is a method of calculating the potential future value of an investment made today. While it may be simple for many trained financial analysts to work through the NPV analysis, many in R&D would find it challenging to provide an accurate NPV for each project they propose and/or manage. Additionally, NPV requires the use and thorough understanding of the corporate discount rate [2]. This means that those managing technical projects would need to understand the current cost of money to the corporation as well as the discounted cash flow and the method of net present value. While this possible, it may not be an efficient use of research labor.

In our work, a small sampling of scientists and group leaders were asked if this financial analysis was a feasible addition to their project proposal and justification processes. While all consulted felt the math was straightforward, none felt connected enough with the financial balance sheet of the company to be confident in the results calculated. Stronger negative feelings were expressed about the complexity of such a step in an already cumbersome process. It was clear that the merit of such a process was understood but the effort to create it and its long-term utility were questionable.

II. Motivation

Innovative and cost-effective product development is one of the key enablers for a successful technology

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company. There is little debate about the benefits gained from a streamlined product development process, which is closely linked to the strategic business objectives [13]. Most of us involved in the day-to-day product development process have seen projects or programs that embody these gains.

While it is important to have such a process, the details of such are beyond the scope of this work. There are many excellent resources on the implementation of a successful product development process. The foundation for our work assumes that a company has a workable product development process in place and operating.

Given such a process is in place, corporate R&D organizations developing new products and technology traditionally spend significant time proposing and justifying the work to be done. In early phases or stages, there may be very little or no cost justification required. As the investments in time and or value increase, a greater depth of justification is required both technically and financially [3]. But it is not just the proposal and justification process, which requires effort and time, but also the effective management of the portfolio of projects operating within R&D. This leads to our primary motivating factor for the work outlined, the efficient creation and financial assessment of technology portfolios. Technology projects and the return they can provide are financial assets not unlike, in many ways, equities in the commercial market. Without simplified mechanisms for the proposal, justification and management of these assets, the defensible allocation of funds to programs can be a very cumbersome and painful process. Worse still, it may be done in isolation, outside a global view of the portfolio risk/return, and perhaps even based on some subjective evaluation.

Tools like cost-benefit analysis, CBA, can often fall short of the need for a realistic assessment of a project and/or a portfolio. As we mentioned tools like NPV, and the more complex real options, and EVA require a depth of understanding and financial detail that most group leaders/scientists just don't have or want. To take a practical example, NPV makes several assumptions about the reversibility of a project, which is unrealistic in the practical sense. This method implies that R&D projects are stoppable without the realistic costs, not only the cost incurred but also the costs associated with the loss of opportunity [2]. A technology real option as expressed by several researchers corrects much of the financial issues around such mechanism in portfolio management [10]. However, this is done at the expense again of complexity for the researcher.

The goal of this research is to get reasonable financial assessment at a portfolio level, simplified proposal and justification processes, and integration with corporate strategy in one repeatable package. To do so, we propose to begin with the basics behind portfolio theory and progress through analogy to our simplified framework.

III. EFFICIENT FRONTIER AND PORTFOLIO THEORY

Fifty years or more ago, statistics revolutionized financial management. By focusing on statistical models for financial investments the complexity and proliferation of data was reduced to a manageable quantity for the investment professional.

Over the years, statistical models have evolved, yet "Modern Portfolio Theory" as originated by Professor Markowitz continues to provide a concise measure of investment while seemingly ignoring the significant data about the individual investment like the fundamental business activity and its financial statement detail [8].

We propose to use this same abstraction as a means to reduce the complexity of data concerning R&D portfolios. Before we can make our parallel to R&D however, there is one further concept to discuss, the use of the efficient frontier and the concept of efficient portfolios. In financial analysis, a portfolio is a grouping of assets or investments. Each asset has a historical or expected return within the portfolio. For each portfolio then it will have a mean value of return. The risk of each asset is the standard deviation of its historical or expected returns. For the entire portfolio, the return is then the weighted average of the mean returns of all the assets currently held, or in all the potential investments. Using these parameters, an efficient portfolio can then be calculated based on Professor Markowitz' original equations. An efficient portfolio is one that minimizes the risk of a group of assets while maximizing the potential return [6]. This expression is represented in our R&D scenario by an optimization equation as follows:

Minimize: $\sigma_p^2 = \Sigma_{I=1}\Sigma_{j=1}X_iX_j\sigma_{ij}$

Subject to: $\bar{R}_p = \Sigma_{j=1}x_j\bar{R}_j$ (1)

In Equation 1, σ_p^2 is the mean standard deviation or portfolio risk and $\bar{R}_p$ is the estimated portfolio return.

The efficient frontier is the curve representing the efficient portfolio boundary line and is a widely used tool for evaluating and composing portfolios either by acceptable risk or by potential return. For any risk level within the class of assets, the efficient frontier will indicate the highest return portfolio in that same class. The use of efficient frontier in this manner requires the following assumptions and constraints on the analysis be made and understood:

- That there exists a minimum risk of the total portfolio
- That the maximum return of a portfolio is found when it is composed of one asset
- There is a set of feasible investment called the "feasible set", no assets fall outside that set [7]

Given this brief background, we can proceed to how these tools and methods can be applied to the management of R&D portfolios.

A. Risk and Return

Asset management through the use of modern portfolio theory has the benefit of well-defined return and risk parameters. This is one area where the analogy to R&D portfolios is more difficult and will depend on an acceptable corporate finance definition.

IV. LPA Framework Approach

A. Process

The framework begins with any generic product development process. The principle requirement for this process is that it is strategically linked to corporate business.

In the product development process, there is a market plan, which addresses the customer and the market place for the company's products or services. This market plan is then broken into product lines where feature and function differentiation is outlined. Finally each product line will identify key technology areas where features and function development is necessary to achieve the market demand [1]. This represents the first key component of the framework.

The second component of the LPA framework begins with the technology project, which is usually part of a broader technology program. These programs are often then combined to form a portfolio. Depending on the size of the company and the complexity of the technology there can be a hierarchy of portfolios and in our case; it is segregated into major business areas.

The final component in the framework is the technology plan details, which is further decomposed into technology components. This is the critical component that identifies a finite number of technology focus areas that the company is willing to invest in. The figure below outlines the conceptual setup of the framework.

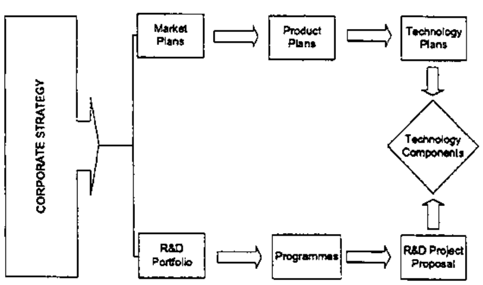

Fig. 1. LPA Framework Foundation

The operational discipline required for this framework to produce a balanced portfolio is then:

1. Each project must have a "primary" technology component associated with it
2. Each project proposed must have an estimate of return and risk which is consistently define and applied
3. Projects must be uniquely identified and monitored as they progress through the normal R&D "funnel" –
   a. *Concept ->Feasibility -> Development -> Commercialization->Launch*
4. Each project must be a part of a portfolio under a technology plan

Once established, this structure will allow the R&D organization to create test scenarios of balanced portfolios composed of different projects at the time they are proposed.

Practically, each technology project will be proposed using a standard assessment of risk and return. As mentioned above, this will be unique to the corporation and will evolve as historical data is maintained about each project.

One constraint of the framework is that the accuracy of portfolio balance calculated is proportional to the sample size of the historic return and risk. This is anticipated due to the foundation of the method in modern portfolio theory. But unlike financial assets, project performance data is often not collected leaving a void in the ability to statistically forecast success. Regardless of the fact that future success is not necessarily predicated on historic performance, historic performance does give some "guidance" for planning purposes and provides input to a more comprehensive decision-making process.

To make this framework and its subsequent analysis straightforward, we have utilized project-planning templates in conjunction with the product development templates. The R&D project leaders are responsible for developing innovative proposals, assessing the potential risk and return of these proposals by using simple spreadsheets and insuring that the proposals are provided to the appropriate technology plan leaders.

B. Methods

The framework was evaluated on a subset of projects and artificial portfolios were created to determine how well the method worked. We created a template for each part of the project proposal process. We established a prototype set of calculations including a standardized calculation for return and risk for the purpose of testing the method. The validity of these calculations was not assessed formally as they were used to get a reasonable set of data for the testing. We are not suggesting that these calculations be used in a true operational settings.

For the return variable, we established a convenient and defensible composite measure. In practice at most stages of research, a researcher can gain access to market size data of those markets in which the technology or product in question may appear. Using this generalized market size estimate; we can suggest an annualized revenue estimate of the first year of launch. This is, however. not an accurate reflection over the life of the product, so we assume an adoption curve equal to that of the ideal substitution curve for technology. We then limit that adoption to an estimate of the useful life of the technology itself. The return variable, RE_T then represents an initial revenue estimate, RE_I based on a market size plus that revenue estimate over the useful life, T_L, of the technology adjusted for market adoption using the Fisher-Pry calculation [2]. In practice, we created the following equation in a spreadsheet that hides much of the complexity:

$$RE_I + (RE_I * (FP(T_L))) = R_T \tag{2}$$

In practice, the annualized revenue estimate will require some research on the part of the project proposer [2]. This will introduce a measure of subjectivity to the return but this can be mitigated by assistance from a standard market research source that provides data on total market size.

For risk estimation, we used a standard technology-based matrix, which rates technical project risk in several categories and provide a calculated risk metric [4]. A spreadsheet was utilized for this task.

Regardless of the details of the risk and return assessment methods, the framework will provide a mechanism for a balanced portfolio as long as the assessment methods are uniformly applied across the entire portfolio. Calibration of the risk and return assessment methods is a necessary step for longer-term accuracy of the method, however.

C. Sample Results

A fictitious company, called Farm Implement Manufacturer or FIM, is involved in the manufacture of farm equipment. The company has a newly established strategy on how to grow their business in various ways through the use of integrated product development. They have several product lines or families within the company e.g. tractors, furrows, etc. Each product line team has created a plan for their products that includes features to be introduced over time. These features represent the "new technology", both breakthrough and incremental, in the product plan. The integrated R&D organization has analyzed the product platforms for the appropriate technology focus areas. These are the business derived focus areas. An additional and critical component of the technology plans are those elements derived from strategic, technical and competitive research into the innovations required by the company. These are the termed "innovation" technology areas. Rationalization and careful selection of these areas form the basis for the R&D technology focus. It is further established with the development of a technology strategy or plan. This step has tied the corporate technology into the product lines directly via these new technology areas [1].

The R&D technology plan is built from technology areas represented in the product line plans. However, the technology plan goes one level deeper to isolate specific technology components within those areas, which are deemed essential to new innovation for the company. For our sample company, we have created a data structure view in Fig 2 detailing how the framework links the product development with the R&D portfolio. More importantly, it also indicates a high level structure for a system that can automate the process. It is clear that from a data structure perspective the processes join at the technology component level.

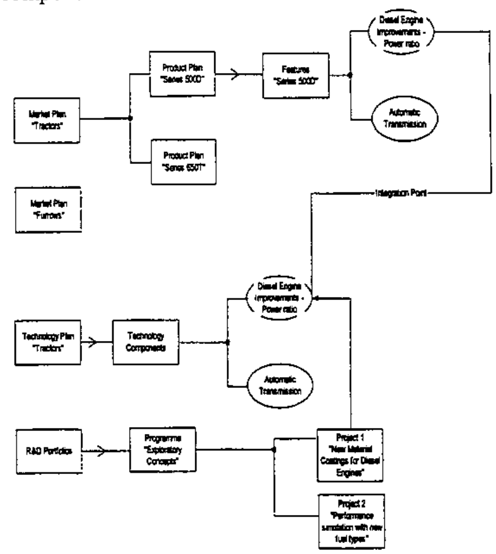

Fig. 2. Conceptual Data Structure for FIM

At this point, we are now able to utilize the project templates for return and risk for each project. Once done, the formulation of the portfolio "efficient frontier" is then possible. In our case, the portfolio team reviews the submitted proposals and data is entered across all projects within a given portfolio. These data are then used to calculate the efficient frontier from formula outlined in equation (1). The data and the curve representing the resulting efficient frontier are then plotted on the spreadsheet. We substitute asset identifiers normally found in financial portfolio management with project identifiers. The resulting graph appears as below:

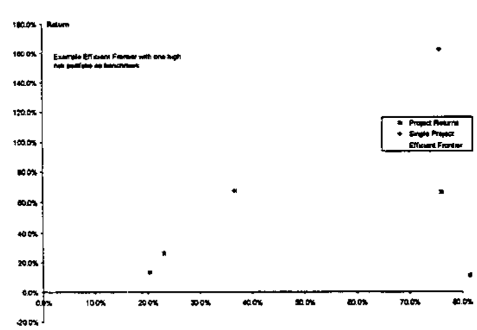

Fig. 3. Hypothetical R&D Portfolio Efficient Frontier

The curve of the efficient frontier in our case is along the line from the portfolio in the group with the lowest variance or least risk, to the portfolio with the maximum return. The interpretation of the analysis is that those portfolios closest to the curve of the efficient frontier provide the maximum return for the stated risk level [6].

The portfolio team can then vary the project mix either by risk or return, or by the risk and return by phase of project to reach an acceptable balance in the overall portfolio. The efficient frontier of the portfolio will, of course, change as the project mix changes. The portfolio team will then be evaluating the potential of the mixture of projects rather than each project in isolation. Returning to the corporation to report the results of the portfolio management process can be a case of presenting the most efficient portfolio for each major technology area, instead of discussing the merits of each individual project.

V. Limitations

The principle limitations of this method are its dependence on historic or forecasting methods of return. Return in R&D projects is notoriously difficult to determine particularly in early phase projects. Additionally, the structured project management process and full life cycle project data collection can be difficult to implement and maintain.

VI. Summary

The need for a concise means to plan R&D investments is critical. Decisions can often be made on isolated projects or programs without a view to the effect across the overall portfolio. We have proposed a conceptual analogy to the financial portfolio analysis for R&D. Additionally, we have included a simplistic means to integrate these project portfolios with a generic product development process. By combining the two principles, we have demonstrated one mechanism to create integrated and balanced technology portfolios for an R&D organization.

Through the modification of the equations for efficient portfolio analysis, the statistical methods for reduction of data complexity can be applied to R&D. With a clear understanding of the limitations of this statistical treatment, we can evaluate potential scenarios of project-based portfolios to guide decision-making.

VII. Future Work

Validation and testing of framework is the most pressing future effort to be undertaken. Due to the timeframes involved in R&D portfolio planning and management, we expect this to be a long-term activity. In addition to the validation of the methods, a detailed analysis and further development of practical methods for return estimation in an R&D setting is also of significant interest. We believe that increasing the accuracy of the framework while identifying areas to reduce calculation complexity will provide more time for scientists and engineers to work on the actual content of projects instead of the financial justification of it.

We are also investigating possible interest in the automation of the framework into a computerized system which will greatly simplify the collection of data, the formulation of proposals, and the planning of balanced portfolios. This will be an important next step in this work and will enable the further refinement of the method. Additionally, we believe it would also be a pre-requisite to examining the continuing role of such a system in increasing the overall R&D portfolio management productivity.

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