Failed R&D Project Identification

(a working paper)

by

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Executive Summary

Research and development is risky, with heavy odds against commercial success; only one in ten ideas reach the market. It is thus helpful to recognize when a foundering project has reached the point where funds spent on it would be better spent on more promising work. This paper explores studies concerning R&D decision making and identifies one of the more practical models that would be suitable for routine use by a manager. It also evaluates more nascent works that promise to produce improved R&D decision making tools in the future.

One paper describes an evaluation technique that holds promise as a practical, objective decision analysis tool that a manager can use to aid in the decision whether to terminate R&D project. The study analyzes company survey results to develop eight major factors are developed to help distinguish between successful and unsuccessful R&D projects. As part of the decision model, the R&D process is broken down into five stages interspersed with four decision points. A probability function is derived for each stage using regression analysis that measures the probability of success at that stage. The results of this study should be used cautiously until empirical evidence is gleaned.

Another project evaluation model is found that is claimed to allow a project's potential payoff to be determined in the case of premature termination in a manner that is more accurate than salvage value estimates based on net present value or internal rate of return. The model is based on the theory of optimal stopping times, the models for which have been used to evaluate uncertain investment projects.

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Introduction

Research and development is risky, with heavy odds against commercial success; only one in ten ideas reach the market.[i] It is thus helpful to recognize when a foundering project has reached the point where funds spent on it would be better spent on more promising work. The goal of the research behind this paper is to explore studies concerning R&D decision making with an aim toward identifying a practical model suitable for routine use by a manager. A secondary goal is to evaluate more nascent works that promise more valuable R&D decision making tools in the future.

As expected, there is much literature in both the academic and popular business press on how to manage R&D projects; most of this, however, pertains to the ongoing management issues of viable projects, with relatively few papers on the matter of recognizing failed R&D projects.

In reviewing the literature on recognizing failed projects, somewhat of an evolution is identified. The earliest works consist of developing common-sense general guidelines, or "rules of thumb."

Improving on this is the later application of more sophisticated survey and analysis techniques to develop better general guidelines. Most recent are sophisticated quantitative decisions models to determine the best termination point of a troubled R&D project.

General Guidelines for Project Termination

The general-guidelines works contain qualitative techniques that can be used to help decide whether to terminate an R&D project. Often, these seem too general. For example, the authors of one paper describe research of 211 companies and conclude with the following four tests that should be met in order to predict that a project will succeed:

1) a relevant business need, problem, or opportunity has been clearly identified

2) an appropriate scientific or technical approach has been matched with the need, problem, or opportunity

3) the project result can be transferred to an internal user

4) the internal user and produce, market, distribute, and sell the resulting project[ii]

If not unremarkable, these results are of limited value; they provide scant decision making help to the project manager.

More guidance is found in a paper describing a technical audit used by the 3M company that not only serves as a tool to evaluate the current status of laboratory programs, but also helps predict the ultimate success or failure of an R&D effort.[iii]

3M’s R&D programs are evaluated on technical, business, and overall factors. Technical factors include overall technology strength, personnel (number, skills) competitive factors, remaining R&D investment, manufacturing implementation, and probability of technical success. Business factors include financial potential, 3M competitive position, and probability of marketing success. Overall factors include organization/planning, staffing, program balance, and intra-firm coordination/interaction.

Numerical ratings and essay comments are developed in each of the above areas. Results are compared within and between laboratories to evaluate the merits of the individual product programs. (To shelter 3M’s promotion of embryonic efforts, such programs are exempted from the audit.) One limitation of the 3M program is that is not an ongoing monitoring process: instead, each R&D unit is evaluated once every two or three years.

Objective Stopping Rules

Objective stopping rules based on computationally-intensive statistical analysis have appeared fairly recently – within the last 10 years. This may be due to not only the greater availability of computing resources to the research community, but also to the concomitant increase in company data that is aggregated and made more readily available through modern management information systems.

A 1985 study, based on a survey of 51 companies with the data analyzed using discriminant analysis, identifies 16 factors that are said to discriminate "very well" in the decision to continue or terminate an R&D project.[iv] The authors claim that "R&D managers can immediately benefit from the analysis by considering the factors and applying them to their current project portfolios" as a decision-making aid.

The most promising model, however, with respect to feasibility of practical application and usefulness today, appears to be a recent study that analyzes company survey results using multiple logistic regression techniques.[v] Applied to a data set from 60 successful and unsuccessful projects of Canadian firms, eight major factors are developed to help distinguish between successful and unsuccessful R&D projects.

As part of the decision model, the R&D process is broken down into five stages entailing four decision points. The five project stages are: 1) Initial Screening, 2) Commercial Evaluation, 3) Development, 4) Manufacturing/Marketing Launch, and 5) Initial Commercialization. The four decision points are between the stages. This model is diagrammed in Figure 1. A probability function is derived for each stage that measures the probability of success at that stage.

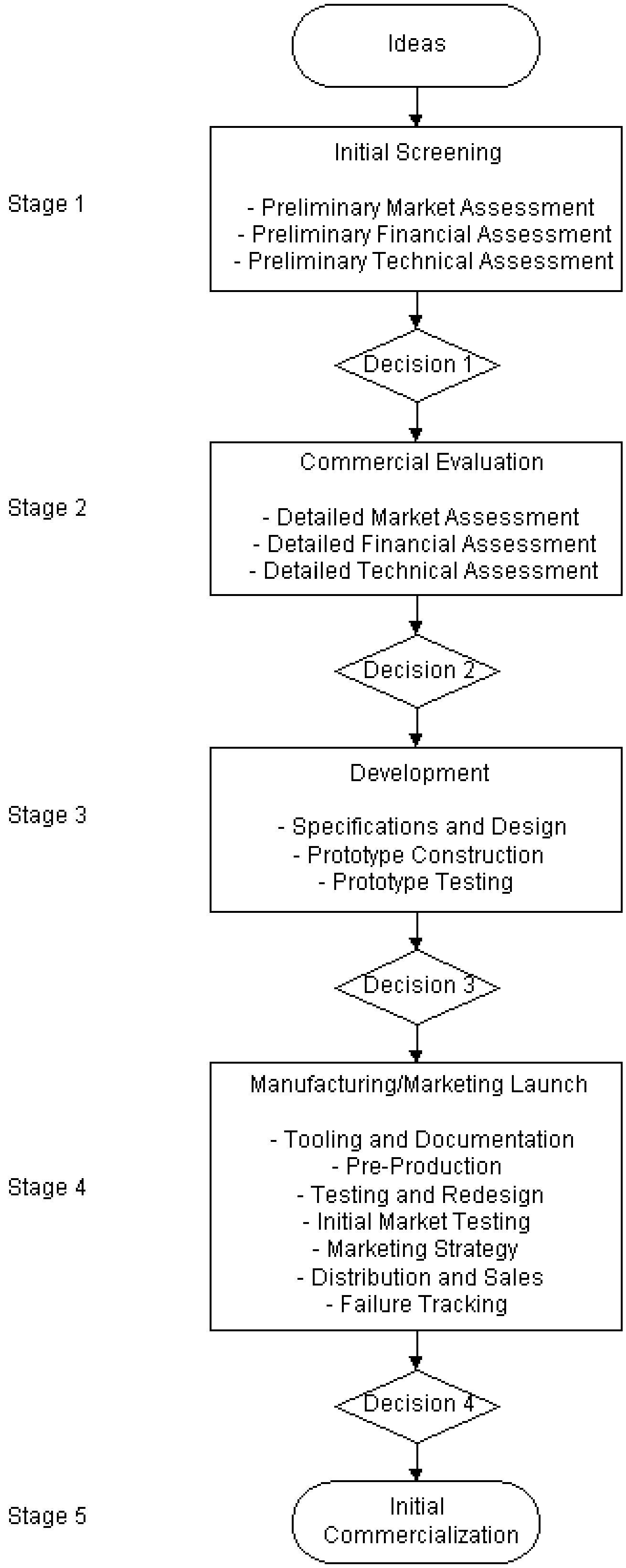

Fig. 1. Activity-decision stage model.

The eight variables used are shown in Table I below:

TABLE I

SUMMARY OF PROJECT TERMINATION DECISION VARIABLES

Stage	Variable
1 Initial Screening	*CORPFIT* Fit of project with corporate goals.
2 Commercial Evaluation	*SCITEK* Availability of related science and technology. *REACTION* Support for project from others in firm. *USES* Applications for innovation not previously available using similar or substitute technology. *TEKCAPAB* The adequacy of a firm's technical capability to support the project's complexity.
3 Development	*DEVPROC* Efficiency of development process. *COMTEKFT* Association between project's commercial and technological aspects, such as the extent to which the end product matches the user's requirements, and the extent to which the firm can sell the product within acceptable markup levels.
4 Manufacturing / Marketing Launch	*TEKCAPAB* (see above) *MKTEFORT* Level of effort invested in promotion/selling activities.

These variables are assigned a value on a scale of 1-5 by personnel familiar with the R&D project.

The probability of success, π_{new} , is derived using the likelihood function

$$\pi_{new} = 1/(1+e^{Y}_{new})$$

where e^{Y}_{new} is the exponent of the probability function $Y = \beta_0 + \beta_1 x_1 + \cdots + \beta_n x_n$ for each stage.

The probability functions for the four decision points, determined from the regression analysis, are:

Stage 1 $Y = 12.12 - 2.60(x)$, where *x* = the value of the variable CORPFIT

Stage 2 $Y = 12.12 + 2.60(x_1) - 3.65(x_2) - 3.37(x_3) - 3.94(x_4)$, where x_1 = SCITEK, x_2 = USES, x_3 = REACTION, and x_4 =TEKCAPAB

Stage 3 $Y = 20.18 - 3.80(x_1) - 2.65(x_2)$, where x_1 = DEVPROC and x_2 = MKTEFORT

Stage 4 $Y = 8.25 - 4.23(x_1) - 1.95(x_2)$, where x_1 = TEKCAPAB and x_2 = MKTEFORT

The probability of success for the new project, π_{new} , is compared to a predetermined threshold probability set by management, π_c . If $\pi_{new} > \pi_c$, the project is likely to be successful, and the project should be continued. If not, the project should be terminated.

As an example of how these formulas are used, assume that at the completion of Stage 1 (at decision point 1) the value of CORPFIT is 4 (on a scale of 1 to 5), the probability function *Y* is 9.61, resulting in a likelihood function π_{new} of 0.0942. This indicates about a 10 percent likelihood of success, and the project should be abandoned. If, on the other hand, CORPFIT was 5, the likelihood function would be 0.70, and the project should proceed to Stage 2. (This particular result is consistent with indications the authors found of the strong correlation between the fit of a project within a corporation and the project's chances of success.) A similar analysis is made at the other three decision points as the project proceeds.

A key to implementing this technique, in addition to the evaluation of the eight independent variables, is the determination of the threshold probability π_c . Generally, π_c will reflect the risk tolerance of management. A concern noted by the authors is that, at early stages of a project, there may be a tendency to assess project variables in a more optimistic fashion due to initial enthusiasm. Thus, management may want to set early thresholds at relatively low values.

Consideration of Salvage Value

Practically none of the papers reviewed take into direct account the salvage value of a project. The literature contains works that consider project net present value (NPV) or internal rate of return (IRR), but these are apparently subject to large biases when the value of the project is under the influence of changing factors.[vi]

A new project evaluation model is claimed to allow a project's potential payoff to be determined more accurately than by use NPV or IRR methods.[vii] The model is based on the theory of optimal stopping times, the models for which have been used to evaluate uncertain investment projects that take time to build and provide no payoff if stopped before reaching a well-defined point of completion.[viii] The buildup of value can vary, with 1) a linear relationship with time, 2) a fast build-up in value early (decelerating build-up), or 3) most of the build-up in value late in the project (accelerating build-up). A project developing new technology, for example, would have an accelerated build-up – most of the value is generated at the end because potential benefits from most of the solutions found in the early stages may not be fully realizable until other project problems are solved. Since this type of project has a low salvage value early on, it is subject to high downside risk.

The general approach to finding a solution to the optimal stopping time is to search for a optimal profit function that satisfies several optimality conditions. These conditions involve the solution of several second-order linear differential equations, and the description of that process is beyond the scope of the paper. It suffices here to say that the model is quite complex, immature, and not nearly as well suited to everyday use as the other models discussed herein.

The results indicate that the optimal termination policy is quite sensitive to how the terminal payoff evolves in a project's development process, pointing both to the importance of carefully accounting for its impact in determining the control policy for a project. The authors note the need for further empirical investigation. Though the model can be ambiguous if there is significant uncertainty about component function form or model parameter value, the authors state it should still be able to provide better project termination decision results than sensitivity analysis based on typical models such as net present value or irregular rate of return. Overall, the authors present a novel approach that indicates ongoing creative work in this area which bears following.

Country Dependencies

The data used in the models discussed above cover companies in as few as one country per study. A question is, Do these models translate well across different countries? Several related studies suggest yes. One study found common R&D termination factors in at least four diverse countries – the United States, Germany, Japan, and the United Kingdom.[ix] That study found "a remarkable consistency" in the set of factors used to determine success or failure in R&D projects among the four countries. This points to the possibility of an international manager using a common suite of tests for R&D effectiveness, regardless of country. Further research is required on some discrepancies, however. For example, in the discriminant analysis factor "Time of Anticipated Completion" the signs of the US and Japan factors are positive, which could be interpreted as meaning that the longer a project takes to complete in those two countries, the better the chance for completion. In the corresponding German and United Kingdom factors, however, the signs are negative, implying that the shorter the project time there, the better the chance for success.

A more recent work tries to identify links between five dimensions of national culture (individualism, power distance, masculinity, uncertainty avoidance and Confucian dynamic) on the one hand and the initiation and implementation stages of new product development on the other.[x] The authors make no definitive conclusion, but the paper identifies a potential new research area and presents a general framework for its study.

Qualifications and Limitations

Several cautions are to be noted with all of the studies reviewed. The sample of projects used in the analyses do not appear to be a representative sample of the universe of projects. The researchers depend greatly on the companies that choose to respond to requests for cooperation, and on the suite of projects the companies choose to put forth for study.

In terms of other cautions, one paper is outstanding in the extent of its disclaimers. It notes that while projects have some similarities in factors that can determine success or failure, failures can and do occur in important and differing ways among projects.[xi] The authors note that project success or failure can be “in the eye of the beholder;” what constitutes project failure for one organization may be viewed as success in another. An example is a firm intent on implementing a project to fulfill a need expressed by an important customer; it would make little sense to judge the success or failure of that project solely in terms of internal efficiency measures such as meeting a budget. Of greater importance would be client satisfaction.

A study focusing on the identification and comparison of characteristics of high performance firms in the telecommunications industry points to the importance of being aware of different paths to the same success.[xii] The findings indicate that the new product development strategies, structures, and processes of high performance firms vary depending on the performance measure. This study found that firms with high new product impact are risk-takers. They have a strong technological orientation and tend to aim their new products at new markets. At the same time, however, they develop new products that have synergy with the firms' existing products. By contrast, high goal performing firms are more conservative and more market oriented than firms with high new product impact. They focus on customer needs while simultaneously striving to develop products with a significant competitive advantage. In both cases, these high performance firms were able to develop patterns of behavior that were compatible with their performance objectives, but they would likely score differently on the project viability tests discussed above.

Areas under Further Study

Some areas under further study include:

1. *Analysis of errors in models due to sampling and non-sampling errors.*

2. *Implications of concurrent engineering on R&D termination decisions.* Concurrent engineering entails the overlap of many steps in the manufacturing process. How should the above models be modified, or how can new models developed, to accommodate concurrent engineering processes?

3. *Human resource management and the project termination decision.* Most project managers (85%) and their staff (80%), remain employed on other R&D projects within the same unit if their project is terminated.[xiii] This results in planning and motivational problems. A team is likely to be dissolved as their skills are not needed in the same combination as before. A challenge is that the new project meet the potential of the specialists. Underqualification and overqualification can both result in demotivation.

4. *The management of the R&D process itself.* One paper suggests bringing a process management approach to product development.[xiv] A major finding of this work is that investment to relieve development bottlenecks yield disproportionately-large time-to-market benefits. This would appear to be an important consideration in the problem of determining the salvage value of

projects.

5. *Project termination in the collaborative R&D environment.* In the 1980s, a new form of collaborative R&D emerged in Europe, the United States, and Japan. In this new form, companies that compete against one another join together for the purpose of developing new technology in specified areas. The technology developed by these companies is eventually used in a common manner. The impact of this environment on R&D termination decisions should be considered where appropriate.

Conclusion

The 1996 Kumar paper referenced above (associated with Table I and Figure 1) seems the most promising with regard to realizing a practical, objective decision analysis tool a manager can use to aid in the decision whether to terminate or not an R&D project. The results should initially be used cautiously, however, until empirical evidence is gleaned.

Kumar is sufficiently detailed in his methodology that a qualified manager could replicate a similar decision model construction within his or her industry or company – one that is tailored to those spheres.

Lastly, the emphasis seen on more sophisticated decision models for R&D project termination brings to mind work done in the area of statistical analysis which says that better results are to be had by using a fixed amount of decision making resources to generate two or more models and average those results, rather than expend the entire sum developing one grand model.[xv] Intuitively, the same concept should apply here. Moreover, it is advisable to use these decision modeling tools as all decision models tools should be used, as a aid to making better decisions, and not as a final determinant; that does not reduce the desirability, however, of developing models with clearer output to make them easier and better for practical use by the manager.

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[i] J. Raelin and R. Balachandra, "R&D Project Termination in High Tech Industries," *IEEE Transactions on Engineering Management*, vol. EM-32, no. 1, pp. 16-23, 1985.

[ii] N. Baker, S. Green, and A. Bean, "Why R&D projects succeed or fail," *Research Management*, November-December 1986, pp. 29-34.

[iii] L. Krogh, J. Prager, D. Sorensen, and J. Tomlinson, "How 3M evaluates its R&D programs," *Research Technology Management*, November-December 1988, pp. 10-14.

[iv] "R&D project termination"

[v] V. Kumar, A. Persaud, and U. Kumar, "To terminate or not an ongoing R&D project: a managerial dilemma," *IEEE Transactions on Engineering Management*, vol. 43 no. 3, pp. 273-284, 1996.

[vi] E. J. Ingersol, Jr. and S. A. Ross. “Waiting to invest: investment and uncertainty,” *J. Business*, vol. 64 pp. 1-30, 1992.

[vii] T. Chi, J. Liu, and H. Chen, “Optimal stopping rule for a project with uncertain completion time and partial salvageability,” *IEEE Transactions on Engineering Management*, vol. 44 no. 1, pp. 54-66, 1997.

[viii] R. S. Pindyck, “Investments of uncertain cost,” *Journal of Financial Economics*, vol. 34, pp. 53-76, 1993.

[ix] R. Balachandra, “A comparison of R&D project termination factors in four industrial nations,” *IEEE Transactions on Engineering Management*, vol. 43 no. 1, pp. 88-96, 1996.

[x] C. Nakata, and K. Sivakumar, “National culture and new product development: an integrative review,” *Journal of Marketing*, vol. 60 no. 1, pp. 61-73, 1996

[xi] J. Pinto and A. Mantel, “The causes of project failure,” *IEEE Transactions on Engineering Management*, vol. 37 no. 4, pp. 269-276, 1990.

[xii] G. Barczak, “Gaining superior performance of new products in the telecommunications industry,” Journal of Business & Industrial Marketing, vol. 9 no. 4, pp.19-32, 1994.

[xiii] R. Balachandra, K. Brockhoff, and A. Pearson, “R&D project termination decisions: processes, communication, and personnel changes,” *Journal of Product Innovation Management*, vol. 13 pp. 245-256, 1996.

[xiv] P. Adler, A. Mandelbaum, V. Nguyen, and E. Schwerer, “Getting the most out of your product development process,” *Harvard Business Review*, vol. 74 no. 2, 1996.

[xv] S. Makridakis and R. Winkler, “Averages of forecasts: some empirical results,” *Management Science*, vol. 29 no. 9, 1983.