CAN WE PREDICT SUCCESSFUL MARKET INTRODUCTION USING ON-GOING R&D EVALUATION DATA?

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ABSTRACT

This study aims to find reproducible correlations/causality between the evaluation data of ongoing R&D projects funded by NEDO and the ex-post monitoring data of actual commercialisation achievement by those projects. The understanding of the results of this study will be used for designing our R&I policies for the next era as a funding agency by, for example, promoting more effective schemes which will eventually increase our contribution to society.

The results showed positive correlations between the assessed grade for sections of the evaluation and the commercialisation status, indicating the possibility of identifying those projects that need management revision before the extended R&D activities by the companies.

INTRODUCTION

ABOUT NEDO

Following the two oil crises of the 1970s, New Energy and Industrial Technology Development Organization (NEDO) was established in 1980 to promote the development and introduction of new energy technologies. Since then, NEDO has become one of the largest public research and development management organisations in Japan, and it works with the government to implement economic and industrial policies.

In this capacity, NEDO undertakes technology development and demonstration activities to carry out the two basic missions of addressing energy and global environmental problems and enhancing industrial technology by integrating the combined efforts of industry, academia, and government.

THE EVALUATION SYSTEM IN NEDO

NEDO has established and been applying its evaluation system for two decades. Figure 1 shows the overall scheme of the present evaluation and survey scheme for a typical 5-year project. Starting from the project planning stage, we have a set of four evaluation opportunities-chances for each project plus an extended survey for selected projects.

(1) An *ex-ante assessment* is performed when it is still at the project's planning stage to see if the project is worth being carried out. The results of an ex-ante assessment are fed back for refining the project plan and requesting the final budget scheme.

(2) A *mid-term evaluation* is performed typically once for a project, and the results are directly reflected onto the management of the project for the rest of the period.

(3) A *finishing evaluation* is performed after the project is finished. The results of the finishing evaluation are often used as a reference for the planning of related new projects. An external panel of 5-10 evaluators is organised for each mid-term and finishing evaluation.

(4) After the end of the project, NEDO conducts ex-post surveys for up to six years (1, 3, 4 and 6 years after the end of the project). The NEDO evaluation department performs ex-post surveys, supervised by an external specific subcommittee, using questionnaires and interviews as the source data from the participant companies. The survey is necessary for the outcome evaluation, which assesses the post-project development by the participant companies and the resulting impact of the project on society.

(5) An *extended survey* is performed for selected projects that have produced products with economic or societal impact. We name these selected products as "NEDO inside products". As of 2020, 120 products are registered.

The outcomes and impacts of all NEDO projects are then used for accountability for taxpayers and for improving the project management system in general.

Figure 1. The overall scheme of the present NEDO evaluation and survey
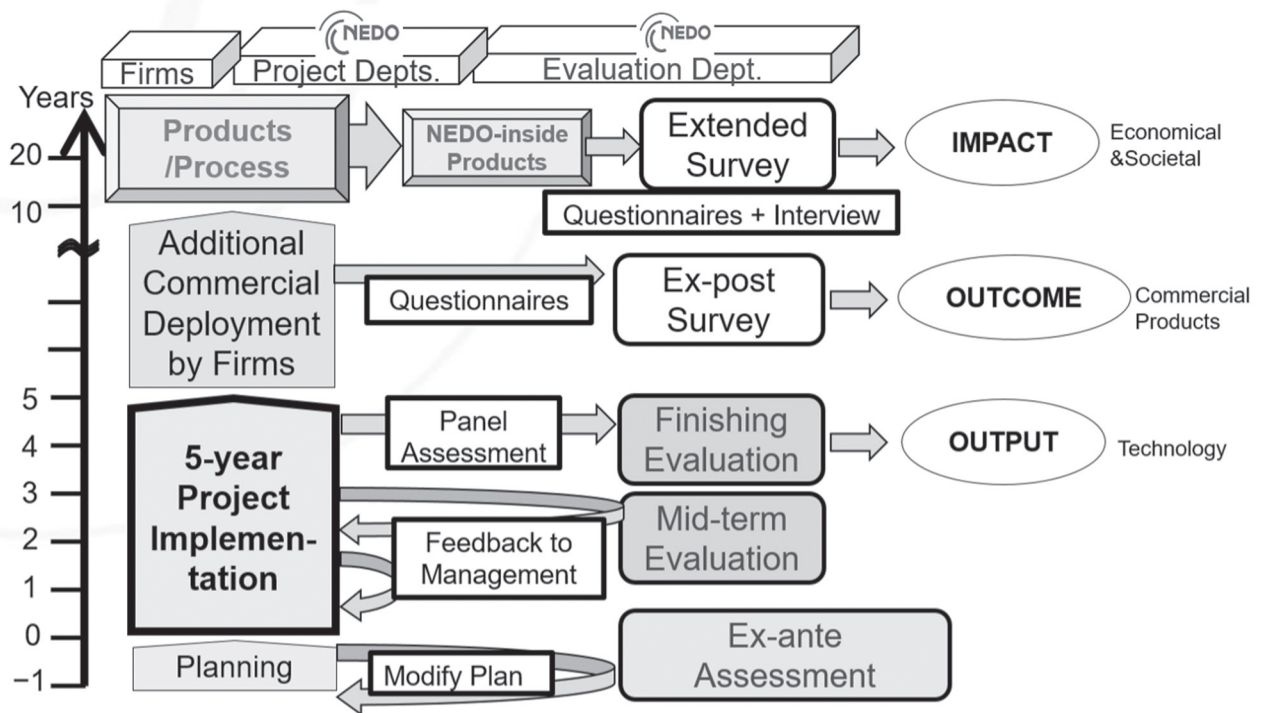
OBJECTIVES OF THIS RESEARCH

As a funding agency for accelerating innovation, NEDO's responsibility is to maximise the outcomes of national projects through the commercialisation of their development results. To realise this mission, it would be beneficial if the activities after the completion of the funded project could be controlled by referring to the evaluated score of the project to facilitate commercialization.

The evaluation department of NEDO has set up a system to evaluate each project's output and assess the project's outcome after the completion of the project (as in Figure1).

This study hypothesises a correlation between the results of the finishing evaluation and the ex-post survey of each project. If so, it is possible to predict the expected extent of commercialisation from the evaluation results during or just after the project implementation. This research contains a new way of understanding data in that it analyses and uses the results of two systems of data, output evaluation and outcome assessment.

METHODOLOGY

We used all 334 NEDO projects completed between the years 2002 and 2013 with results of finishing evaluation as the population of the analyses, 178 of which also conducted outcome surveys for up to six years after completion.

There are two categories in the nature of NEDO projects: "standard" type and "basic" type. The standard ones aim to commercialise new products mainly through applied research and development during the funded project, while the basic ones are implemented starting from more fundamental research. Of 334 projects, 167 were standard type projects, and 167 were basic type ones. Of the 178 projects that completed both finishing evaluation and ex-post survey, 99 were of standard type, and 79 were of basic type.

(1) Finishing evaluation at the end of the project

Projects were evaluated at the end of the implementation (hence the name finishing evaluation) by a panel of five to ten evaluators selected from outside the organisation for each project. For each project, detailed evaluation items were set along each of the four viewpoints. NEDO's four evaluation viewpoints

Position & Significance,
Project Management,
R&D Achievement, and
Prospects for Practical Application.

According to the pre-defined criteria, each panel member marked between 0 and 3 for each viewpoint.

In addition to the scores, the evaluators provided detailed comments on each evaluation item. This paper does not treat comments, although an interesting textual analysis is expected.

(2) Ex-post survey

In NEDO's project system, several companies participate in one project to develop related product groups. A total of 684 firms participated in the 99 standard-type projects, and 441 companies participated in the 79 basic-type projects. Electronic surveys were conducted with these companies asking them about their R&D progress since the end of the NEDO project.

The survey questions include whether they were still developing the product, the current TRL (Technology Readiness Level) of the product development, and what factors they think might have contributed to the success or failure of product development. In addition, relevant questions related to the status of the product's TRL, such as the sales amount and the launching date, precede the TRL question itself to minimise the inaccuracy to some extent in the case the responsible staff for the product have changed since the previous survey.

The TRLs used by NEDO are by NEDO's definition. A simplified version used for this study is shown in Figure 2. In this study, stages 3 and 4 are combined to make a category "Practically Applied", and the percentage of products (companies) that reach the Practically Applied stage for each project is called the "commercialisation rate" of the project. In addition to these four TRL stages, some projects are discontinued at some point in the six years of the ex-post survey period, and these cases are counted as "discontinued". Also, using the answer to the first ex-post survey, the percentage of projects that did not immediately stop in-house development after the end of the funded project but at least continued then is called the "immediate continuation rate".

NEDO-TRL

NEDO TRL-1
Research: fundamental/elemental research

NEDO TRL-2
Technology development: research withtaken into consideration practical application/commercialization

NEDO TRL-3
Practical application: establishment of technologies for practical application/mass production

NEDO TRL-4
Commercialization: transactions in the market

Figure 2. NEDO TRLs. TRL-3 and TRL-4 combined define the "practically applied stage" in this study

RESULTS

First, trends were analysed within each of the two datasets, the finishing evaluation and the ex-post survey. Correlations between these two datasets were then examined.

(1) Results of the finishing evaluation

The distribution of finishing evaluation scores of all projects for the four viewpoints is shown in Figure 3 and Table 1. The mean score for the first viewpoint (Position & Significance) was the highest among the four viewpoints. This is because the position of the project is assessed at the end of the project when the project has already been running for five years, which increases the number of positive evaluations. It is a challenging issue whether to include this viewpoint in the finishing items.

The mean score for the fourth viewpoint (Prospects for Practical Application) was lower than for other viewpoints. One interpretation of this is as follows. During the implementation of a project, the management side tends to prioritise the achievement of direct development objectives, and relatively less consideration is given to the actual prospects after the end of the project.

Next, a comparison is made between the standard and basic types of projects for each evaluation viewpoint. T-tests showed a significant difference at the 5% level for the second viewpoint (Project Management), with the standard type having a higher score. As NEDO's R&D is aimed initially at applying already developed technologies, the effort to manage basic type projects may have been relatively weak.

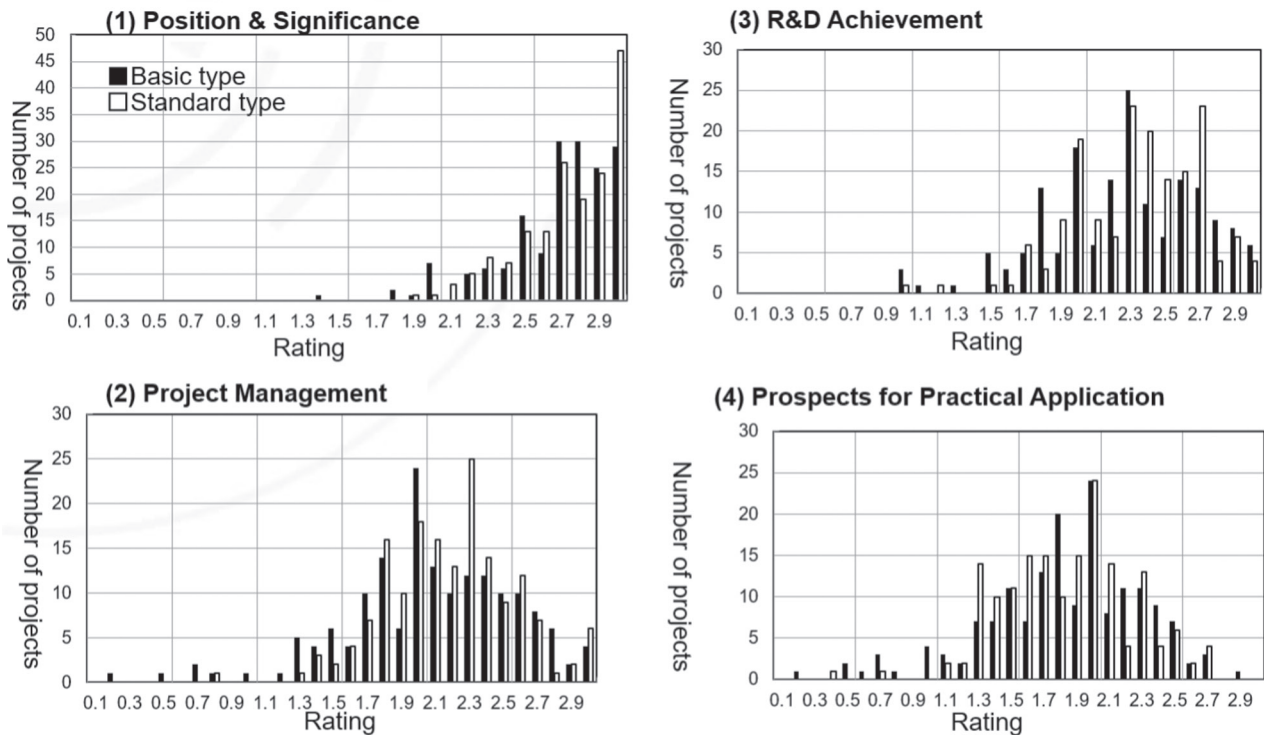**Figure 3.** Distribution of scores for four viewpoints

Table 1. Distribution of scores for four viewpoints (SD: standard deviation)

	(1) Position & Significance		(2) Project Management		(3) R&D Achievement		(4) Prospects for Practical Application	
	mean (median)	SD	mean (median)	SD	mean (median)	SD	mean (median)	SD
standard type projects (N=167)	2.73 (2.8)	0.26	2.18 (2.2)	0.38	2.34 (2.4)	0.36	1.84 (1.9)	0.40
basic type projects (N=167)	2.68 (2.8)	0.30	2.08 (2.1)	0.50	2.26 (2.3)	0.44	1.83 (1.9)	0.48

(2) Results of the ex-post survey

We examined the status of each product in the NEDO-TRL (1-4 and "discontinued") for the standard type and basic infrastructure type projects in the final surveys, which were done 6 years after the end of the project. The results are shown in Figure 4. The ratio of the commercial-ized (TRL 3 or 4) products to the total products is 29% for the standard type and 20% for the basic type. The percentage of discontinued prod-ucts was 22% and 33%, respectively, with the basic model being the larger of the two.

Figure 4. Distribution of TRLs for standard and basic projects obtained from the ex-post survey six years after the end of the projects
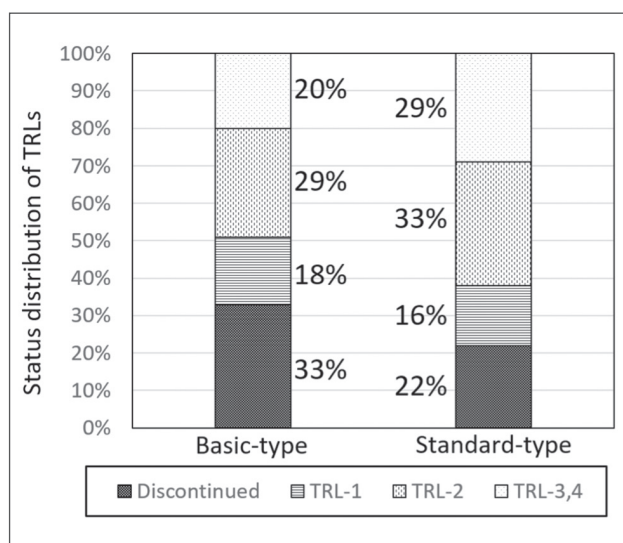
The reasons for these results may be that since it generally takes longer to commercialise basic-type projects than standard-type ones, the percentage of abandonment is relatively high for basic-type ones due to lack of judgment at the end of the project. It makes sense to discontinue the project that cannot show its future.

(3) Correlation between the data sets of the finishing evaluation and the ex-post survey

The survey was conducted for 99 standard-type projects, for which both finishing evaluation and ex-post survey data were available.

The variables of the finishing evaluation selected for the correlation test were the scores given by the panel on each of the four viewpoints. For the ex-post survey, we used the number of companies in each project, the commercialisation rate, the immediate continuation rate at the end of the project and the abandonment rate after six years as the variables.

The correlation results are shown in Table 2. First, there is a positive correlation between the practical application viewpoint score of the finishing evaluation and the practical application achievement rate of the outcome survey with a 1% probability of significance. Next, there is a negative correlation between the score on every viewpoint of the finishing evaluation and the discontinuation rate of the ex-post survey at a 1% or 5% significance. Therefore, to some extent, it is possible to predict the likelihood of future commercialisation based on the finishing evaluation scores.

Table 2. Correlations between finishing evaluation and ex-post survey results of standard-type projects

(* and ** refer to 1% and 5% probability of significance, respectively)

		Finishing evaluation scores			
		(1)Position & Significance	(2)Project Management	(3)R&D Achievement	(4)Prospects for Practical Application
Ex-post survey scores	Number of companies	0.04	0.03	0.04	0.06
	Commercialisation rate	0.01	0.15	0.01	0.28**
	Continuation rate	0.14	0.00	0.15	-0.05
	Immediate discontinuation rate	-0.22*	-0.22*	-0.24*	-0.33**

DISCUSSION 1:

COMPLEMENTARITY BETWEEN FINISHING EVALUATION AND EX-POST SURVEY

There is a difference in the robustness of the approach for the results between evaluation, which assigns grades according to predetermined evaluation criteria, and ex-post survey, which is a set of self-reported answers to questionnaires. In evaluation, the project is assessed based on a causal relationship between the outputs and the implementation of the project rather than based on chance. Surveys based on self-reported data are generally considered insufficient to ensure a causal link between the implementation of the R&D project and its outcomes.

The correlations between the finishing evaluation and the ex-post survey shown in this study are not causal in themselves. However, suppose the finishing evaluation shows a causal relationship between project implementation and output expression. In that case, the correlation between extended R&D activities after the end of the funded project and outcomes found later in the ex-post survey is also assumed to have a causal element. It is unclear within the scope of this study how to quantitatively demonstrate that the correlation between finishing evaluations and outcome surveys has some causality, but if this hypothesis is correct, it would further enhance the usefulness of outcome surveys after the end of the programme. It would make the feedback efforts described below more meaningful.

DISCUSSION 2:

FEEDBACK AND REFLECTION ON CURRENT PROJECT MANAGEMENT

Based on the above concept, it is understandable that the outcome survey results could be reflected in the design of other similar projects. For example, an attempt could be made to increase the rate of future commercialisation by designing and managing projects in such a way as to raise the grade of the fourth viewpoint in the mid-term evaluation during project implementation.

NEDO has established a "Management Guideline" as a manual on project implementation for project managers. The Management Guideline focuses on some of the evaluation items in the finishing evaluation and recommends starting concrete efforts to tackle the items two years before the end of the project. For example, the company in the project should identify the department within the company that is responsible for commercialisation and set up a system for exchanging views with the project manager to clarify issues such as mass production technology and marketing. The idea is to increase the probability of successful commercialisation of the project by being aware of these items two years before the end of the project. This is evidence-based policymaking at a micro-level.

DISCUSSION 3:

USE IN ORGANISATIONAL EVALUATION

The results of finishing evaluations and ex-post surveys directly assess the project and the participant company but are not limited to these. The complete and accumulated results of the combined evaluations and surveys can serve as key performance indicators (KPIs) for the programmes and the organisation itself, which encompass the projects. It is also a reaffirmation of the robustness of the organisation's evaluation system.

Currently, NEDO has two indicators and corresponding targets for R&D performance among its organisational goals:

(1) The average commercialisation rate of projects that reach the fifth year after the completion between 2018 and 2022 should be at least 25%.

(2) 50% or more of the projects completed during the period mentioned above should achieve a score of 2.0 or higher on the 0-to-3-scale for "Prospects for Practical Application " at the finishing evaluation.

Although there is a five-year difference in the period covered, the above two indicators should be highly consistent, as this study has shown the robustness of the evaluation system. Let's consider the correlation between the distribution of scores on the Prospects for Practical Application viewpoint of the finishing evaluation and the distribution of achievement of practical application after six years in the ex-post survey. The two target values are expected to correspond roughly.

Looking at the past performance of these target values, out of 1,125 companies (standard type and basic type) in 178 projects for which finishing evaluation and ex-post surveys were completed, 284 (25.2%) achieved commercialisation. The mean value of the "commercialisation prospects" of the 334 projects for which a finishing evaluation was completed was 1.84. Both were close to the target value.

DISCUSSION 4:

MID-TERM EVALUATION

NEDO also conducts a mid-term evaluation during the implementation of long-term projects. However, the correlation between the mid-term evaluation and the outcome survey is not as straightforward as in the case of the finishing evaluation. One reason for this may be the distance between the evaluation and survey periods.

DISCUSSION 5:

FUTURE ISSUES

In addition to the 4-level scoring, detailed comments by the evaluators are collected in the finishing evaluation. The evaluators classify the comments according to the corresponding evaluation viewpoint and the positive/negative nature of the sentence. With this dataset of comments, statistical processing can be carried out to analyse the tendency of the comment on the above classification. In recent years, text mining analysis methods have been partly established in the Japanese language, and micro-analysis of the comments could be considered.

Our mid-term evaluation aims not only to assess projects, such as scoring and ranking, but also to adjust the project's orientation. Accordingly, NEDO has established a procedure to reflect evaluator remarks from the mid-term evaluation, and the relationship between the correction procedure and commercialisation is to be investigated.

Presently the survey also collects data on the amount of product sales as quantitative output data. However, a more appropriate quantitative criterion for the outcome is the value added by the project, to which sales figures are only a rough guide. To measure added values, it is necessary to establish a baseline before the project starts or apply equivalent counterfactual analyses.

The results of finishing evaluations and ex-post surveys such as those analysed in this study are likely to vary depending on the technical field of the project and the size of the companies involved. These will be analysed separately.

The details of the methodology in the finishing evaluation and the ex-post survey vary somewhat from year to year, particularly regarding the evaluation indicators. Because of the relatively significant changes in NEDO's evaluation policy in 2013, we have analysed projects for which finishing evaluations were carried out before 2013 in this study. It will be necessary to track later situation in the same way to examine changes over time.

CONCLUSIONS

We analysed NEDO's finishing evaluation results for output assessment and ex-post surveys for outcome assessment.

The finishing evaluation showed differences in the averaged evaluation score by the viewpoints of the evaluation and the characteristic of the project. Similarly, the ex-post survey revealed differences in the distribution of the TRL levels at the end of the survey by the characteristic of the project.

The analysis comparing the finishing evaluation results and ex-post survey results showed correlations between a particular viewpoint axis in the evaluation and indicators derived from the ex-post survey.

The results imply the possibility of utilising the result of the finishing evaluation for the management companies' R&D activity after the end of the project.

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