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INDIVIDUAL RESEARCH PAPER

R. Balachandra, ***"A Comparison of R&D Project Termination Factors in Four Industrial Nations"***, IEEE Transactions on Engineering Management, Vol. 43, No. 1, February 1996

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1. EXECUTIVE SUMMARY

This article identifies the factors used to terminate R&D projects in four different nations; namely US, UK, Germany and Japan. It interprets similarities and differences between these factors for these four nations. It actually adds Japanese data into the previously collected and analyzed data for other three nations. R&D activities are quite extensive in both national and foreign-owned companies of these four nations. Therefore, from an R&D management standpoint, it is important to understand the nature of R&D project termination process in different nations.

The data for each nation have been collected through questionnaires. Since questionnaires are not designed by the same individual and not employed at the same time, they are not identical. The very first study was conducted in US companies. Japanese data were the last data set collected in one central research laboratory of a very large Japanese multinational firm that is engaged in many industries. However, data in the other three nations came from different companies in different industries. Company and project characteristics for these three nations' data are illustrated in [4]

Besides, identifying the factors to terminate an R&D project for each nation through Discriminant Analysis, it also interprets reasons for similarities and differences between them. Furthermore, percentage of correct classification between successful and failing projects based on the methodology of this study is illustrated. It is really the justification and verification for using such a methodology.

2. CONCEPTS

R&D activities play a major role in today's business where technology is rapidly changing [2]. They include, but are not limited to, extensions of existing products/services, development and improvement of new products/services. R&D resources are usually scarce since it is not easy to find highly intelligent and innovative individuals to be employed in R&D departments. R&D activities are risky by nature since a very small percent of R&D projects are successfully completed [2]. An R&D project goes through such stages as idea, feasibility, development, test market and commercialization [3]. Although the decision to terminate an R&D project is likely to occur at any point along the R&D pipeline, it frequently occurs at the end of development phase [22]. R&D project termination decision have been made during the development stage in all projects on which data have been collected for this study. This stage is important in deciding to terminate as large sums of money are involved during this stage and early decisions to terminate potentially failing projects save much scarce resource [3]. As a result of this, unnecessary expenditure in a fruitless quest would be prevented and scarce resources would be released for more profitable work.

Project termination is a difficult decision to make. It is a tendency that such decisions get delayed because of this difficulty, resulting in loss of money and waste of resources. Therefore, timing of such decisions is crucial. Furthermore, project termination is considered as a failure and failure is something that individuals could not withstand easily. Besides, its psychological effect on individuals, failure potentially engenders a fear of losing prestige and confidence within the organization [2].

Project start and project termination decisions are conceptually and temporally different [22]. Project termination is made at a later stage. The initial conditions that favored the project start have not stayed constant. The changes in these conditions lead to project termination or continuation at later stages. Moreover, even though same or similar factors apply to both decisions, their goals and/or benchmarks might be different for these two decisions.

Similarities in nations of this study, such as market type, technological and industrialized nature, do not necessarily mean that decision variables and their weights in R&D project termination would be the same. It is clear that these nations are different in national culture, management and organizational philosophies. It is the objective of this study to reveal similarities and differences among these nations in regard to project termination decision and provide explanations for them by employing Discriminant Analysis methodology.

3. LITERATURE SEARCH ON R&D PROJECT TERMINATION

The author of this article, R. Balachandra has made substantial contributions to R&D project termination decision area. This section presents the most chronological work in regard to R&D project termination decision. As indicated in [2], little work has been done in the area of R&D project termination. On the other hand, project selection has been extensively studied by many researchers [7, 8, 9, 14, 18]. Buell's [6] and Holzmann's [13] studies were probably the first formal publications on R&D project termination field. They were based on personal experiences of authors, therefore lacking the empirical treatment of the subject. Project SAPPHO in England [24] studied a number of projects and listed a set of factors considered critical in the shelving decision. Myers' and Sweezy's [20] empirical study of innovations failures focused on termination at any point along the R&D pipeline. Cooper [10] identified a set of factors determining a new product's successful introduction into the market, that offered more distinct information on project termination. Rubenstein et al. [25] listed more than 20 factors deemed responsible for the success of R&D project. Ramsey [23] developed a comprehensive framework for assessing development projects that include the termination decision. However, his work focused more on the selection decision, with the termination decision wazzu involving a primary review of the former decision.

Raelin and Balachandra [22] identified 16 factors which discriminated very well the decision to continue or terminate a project in the development phase. The data were collected from 51 R&D projects in high-tech companies. Baker et al. [1] concluded that to terminate how likely an R&D project is to succeed requires to evaluate it to four principal sources of uncertainty, the fit between the technical and business objectives, transfer of project results to an internal user and how well that user can produce, market, distribute and sell the resulting product. This study was based data from 211 R&D projects in four lines of business: low carbon, flat rolled steel; agricultural chemicals and pesticides; packaged process foods and industrial chemical intermediates. Balachandra, in the meantime, expanded his database from 51 R&D projects to 114 projects in the US from different industries. In his book, called Early Warning Signals for R&D Projects [2], he identified 12 factors that help decision makers indicate the potential success or failure of a project.

Using Balachandra's questionnaire as a basis, Lange [17] developed a new questionnaire and collected data on German R&D projects. Rather than using two categories (successful and unsuccessful) as done in most studies, Lange classified the pool of his R&D projects into three categories: successful, deferred and unsuccessful. Having merged the deferred and unsuccessful projects into a single "unsuccessful" category. Balachandra and Brockhoff [3] made a comparison of US and German data. Besides merging, because of the differences in questionnaires used in US and German studies, they fit the two data set to the same scale and matched some factors, that were stated differently. Their analysis showed that the same factors can be used to effectively identify failing R&D projects in both the US and Germany. Some of the other studies were extensions of the US and German studies. For example, Brockhoff [5] included British data into previous data and made a comparison of R&D project termination decisions between three nations: US, Germany and UK. In this study, interpretation of contributing factors to the success of R&D project and their different discriminatory power has been made as well. Furthermore, it compared German and British data based on three groups of data as explained earlier. Data have been classified into three categories in German and British studies.

The article under analysis adds another nation's data to three other nations. A similar analysis as in [3] has been carried out. A later study by Kumar et al. [16] investigated project termination decision at various stages of R&D project life cycle, rather than development stage. The monitoring framework developed in this study through 60 projects identified discriminating factor for successful and unsuccessful project. Its main advantage is that it provides a single factor for monitoring the success at various stages, which is really a combination of all factors. Another very recent study by Balachandra et al. [4] explore the manner in which managers inform R&D staff of the decision to terminate or continue a project. They also present the project monitoring procedures of 78 large German, British and US companies. Differences in communication patterns and monitoring methods are of particular interest of this study.

4. METHODOLOGY USED IN THIS STUDY

As indicated earlier, responses from questionnaires provided data for each nation. US data contained 114 projects [2]. Japanese questionnaire was developed from US questionnaire with minor improvements on the original one. 57 projects from a central laboratory of a big Japanese multinational company formed Japanese data. German questionnaire [17] also used US questionnaire as the basis and contained usable data 112 projects. It is translated back into English and administered in UK which collected data on 43 projects [5]. Due to the fact that changes in values of certain key factors of the project would help identify the success level, questionnaires included questions for the evaluation of some factors at the beginning and the time of most recent review or termination point.

Discriminant Analysis is used to analyze the data of each country separately. This resulted in identification of the significant factors for project termination decision in each country and their discriminatory factor between successful and failing projects. The conversion of data from each nation to the same type and inclusion of the same factors were required for Discriminant Analysis. At this point, it is worthwhile to give brief information on Discriminant Analysis.

Discriminant Analysis is a powerful multivariate statistical technique to study between two or more groups of objects with respect to several variables simultaneously [15]. Data cases should be members of two or more mutually exclusive groups. These groups (sometimes called classifying variables) must be defined so that each case belong to one and only one group. The groups in this article were successful and failing projects. Characteristics used to distinguish among groups are called discriminating variables. In this case, they are the factors used in project termination decisions, such as deviations in time schedules, change in top management support and so on. They must be measured at the interval or ratio level so that their means and variances can be calculated and they can be legitimately employed in mathematical equations. In each questionnaire, variables have been measured either at their actual value or on some type of scale which differs from one questionnaire to another. The following figure illustrates well the relationship between groups and discriminating variables in Discriminant Analysis.

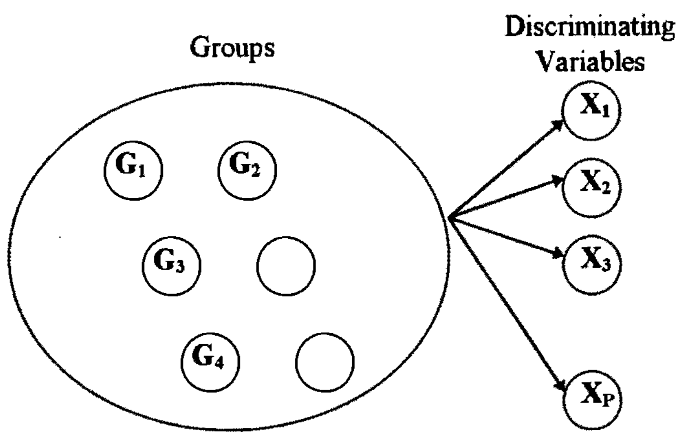

Figure 1: Relationship between groups and discriminating variables in Discriminant Analysis

Discriminant Analysis assigns weight to discriminating variables in such a way that means of scores of groups differ as much as possible. A discriminant function is obtained, which is a weighted combination of discriminating variables [12]. After estimating the values of these coefficients or weights, a project can be classified by first evaluating the discriminating variables for the project, computing its discriminant score by applying weights for the variables and examining the value of the score to which the project belongs. In this case, if a project has a positive score, it is considered a successful projects. Otherwise, it is considered a failing project.

A different type of discriminant analysis, called stepwise discriminant analysis has been employed in this study. It helps eliminate variables not needed for categorization and selects only the most useful discriminating variables. Variables are entered into the equation in order of their discriminating power. A statistical parameter, such as a partial multivariate F ratio is used to control the selection and also the removal of variables in the ultimate set of optimal discriminating factors [15].

Discriminant Analysis seems to be an appropriate methodological technique. It not only weights the discriminating variables, but also identifies whether they are making a positive or negative contribution. Accuracy of discriminant function can also be obtained based on the correct classification of the original set of cases.

5. FINDINGS OF THIS STUDY

After transforming all data for four nations into a comparable format, the authors were left with a total of 310 projects. The classifying variable was either success or failure. Even though there were different number of discriminating factors in each individual data set, there were a total of forty common factors which led the authors to start their analysis and comparison. Common factors do not necessarily mean that they were exactly defined the same in each study. Some of these variables were used to create new variables reflecting the changeover the project's duration. In other words, they represented the change in the evaluation at two point in time: one at the time of project initiation and the other at the final review or termination point. Therefore, a total of 28 variables were used, of which 27 were independent and "status of the project" (successful or unsuccessful) was the dependent variable. Data of each country have been analyzed separately using discriminant analysis as done in previous studies [2, 3, 5]. A total of 16 factors appeared in all four discriminant functions.

The values of discriminant function coefficients indicate their relative contribution for discriminating between successful and unsuccessful projects. If a discriminating factor has a positive coefficient, it is considered as a favorable factor for the project success. Otherwise, it is safe to draw a conclusion that it adversely affects the project fate, leading to failure. That factor that appeared in more than one discriminant function does not mean that it would have the same sign in the discriminant function or its coefficient value would be the same. In other words, the effect of discriminating variables on project success and their discriminatory power would differ from one nation to another even though some of them are identical. The following table shows the significant discriminating variables and their effect on the project success, such as favorable or adverse.

FACTORS	US	GERMAN	JAPAN	UK
Probability of success via technical route	F	F	F*	N/A
Deviations in time schedules	A*	A	N/A	N/A
Deviations in cost schedules	A*	N/A	N/A	N/A
Time of anticipated competition	A	F	A*	F*
Chance event	A	A	A*	N/A
Smoothness of technical route	F*	N/A	A*	A
Pressure on project leader	A	N/A	A*	N/A
Project champion	F	F	F*	F
Change in probability of commercial success	F	N/A	F*	F
Change in number of end uses	A	F*	A*	N/A
Change in support of top management	F	F	N/A	F*
Change in support of R&D management	A	A	N/A	A*
Change in commitment of project leader	F	N/A	F*	N/A
Change in availability of experts	F*	A	A	A*
Stage of life cycle	N/A	F*	N/A	N/A
Adaptability of project leader	N/A	F	F*	F

Table 1: Significant discriminating variables and their effect on the project success by nation

F* or A* appearing under a country means that the corresponding favorable or adverse factor, respectively for the project success has the highest discriminating power of all the countries under comparison.

Authors in the paper first examined the overall picture presented by the analysis. Some factors in the original factor pool, such as government regulations, alliance with other projects or corporate activities, association between commercial and technical aspects and a few related to project staff and leader interestingly did not appear in the final set of 16 factors. They have been found to have some effect in other studies. Authors stated the reason for that as remaining constant over project life cycle. Moreover, they felt confident in the quality of discriminant function for each country dote due to high canonical correlation coefficient. Finally, percentage of correct classification of each discriminant function between two different projects was really high.

Following the overall analysis, individual factors for each country have been investigated. When identical variables occurred in more than one country, they were expected to exhibit the same sign. As can be inferred from Table 1, this statement held true for the factors bolded on Table 1. However, as expected, they did not necessarily have the same coefficient value or discriminatory power.

The author also interpreted why each factor appeared in each country's discriminant function and it had a particular sign for that country. Furthermore, reasons for having different discriminating power for a certain factor that exhibit the same or different sign for these countries have been explored. Some hypothesis that explain similarities and differences in the factors and their sign have been constructed. For example, longer times for anticipated competition were found adversely affect the project success in UK and Germany while they contributed to project success in US and Japan. It has been hypothesized that in Europe, project staff is demotivated due to lack of competition or longer time-to-market from competitor's side. Some differences between the factors have been observed because of cultural differences. For example, adaptability of project leader has a positive effect in Germany, Japan and UK, while it does not appear in the US function. It is hypothesized that freer environment of US organizations does not require greater degree of adaptability from project leader while hierarchical nature of organizations in other three countries does.

Some differences were thought to have come about due to perceptions and interpretations of questions in different context or conversions used to make data comparable. For example, change in the probability of commercial success was missing in the German function. It was expected that it have a positive effect in a country of free market economy, like Germany.

Not all interpretations of the author have been mentioned in this section. Main reasons for similarities and differences have been presented with an example. Basically, using Table 1, one can easily recognize these differences and similarities between four different nations and interpret them by referring to the main reason categories as explained above.

6. STRENGTHS & WEAKNESSES OF THIS STUDY

6.1) Strengths

After identifying discriminating variables for project termination decisions in four different nations, this study made a through analysis and comparison of these decisions between these nations. Similarities and differences were explained by taking each nation's culture into account. It is also shown that mathematical results are in accordance with expectations and intuitions. Besides presenting the universal factors for project termination decisions, their discriminating power and importance rate for each country were revealed. This kind of analysis would definitely help facilitate the decision making process for R&D executives involved in deciding whether to continue or terminate a project. Firms that have R&D activities overseas would benefit a lot from such an international comparison [26] since some factors for project termination decision and their importance were proven to differ from one country to another. The outcome of a quantitative method, like discriminant analysis, can not be solely used since there are a lot of subjective or qualitative factors involved in decision making process. However, the decision maker can develop (devise) his/her own methodology by incorporating the results of this study into it or justify his/her qualitative judgments about the decision by referring to this study. All these aforementioned things constitute the major strengths of this study.

6.2) Weaknesses

The following section explores the weaknesses of this study. Some of them are inevitable due to the nature of the data collection method and methodology used in this study.

- Each country data had a different sample size. Therefore, some samples are not representative of the R&D activities in this country, such as British sample. It may not be safe to draw conclusions based on small sample size. Japanese data have been collected from one large central R&D fab of a big Japanese firm. Even though this company engages in different lines of business, there are many other companies in Japan that have R&D activities. Furthermore, even though there were some common industries, from which data came in each country, different industries participated in some countries and they have not been represented in the data of the rest of the countries. The fact that R&D decisions vary from one industry type to another might have also affected the results of this analysis.
- Questionnaires used in each country were not the same since studies were not conducted by the same researchers. As a result of that, questions and their perceived meanings to respondents were different. When comparing data of four nations, the researcher matched questions from each questionnaire based on the similarity and perception, and merged them under a single category (factor).
- Even though each study used a questionnaire as a way of collecting data, study approaches were not the same. In survey studies, a great deal of attention should be given to have the respondent interpret the question the way the researcher meant. For example, to clarify the objective of the study and interpretations of each question, respondents have been personally met in some studies.

- The researchers did not have any control over the choice of projects included in the sample. Probably, results would have been more reliable if they had defined what project features would make a project eligible to be included in the sample.
- An inevitable drawback of survey studies is subjectivity. There is no mention in the paper how biasedness of respondents has been prevented.
- Respondents are likely not to recall all details of a project in regard to project evaluation. To overcome this "memory of respondent" problem, all questionnaires should have considered the recently terminated projects. Therefore, it is very difficult to measure the reliability of responses unless documented responses are used.
- Scales used in each questionnaire were not the same. In this study, each factor was converted to the same scale for the four countries. However, this conversion ruined the genuine nature of raw data and possibly generated some unexpected results from this study. The author testifies that some differences among the four nations have resulted from the conversion process.
- Certain conditions (assumptions) need to be satisfied before a multivariate statistical technique is used. For discriminant analysis, population covariance matrices should be equal for each group and each group should be drawn from a population which has a multivariate normal distribution. It is not clear from the paper whether these conditions were checked or not. As indicated in [15], if data for a particular problem do not meet these requirements, the statistical results will not be a precision reflection of reality.
- Discriminant analysis computes the individual relative contribution of each individual factor. However, joint effect of more than one factor might be different from the sum of individual effects of those factors. In other words, discriminant analysis does not consider the joint (synergistic) effect of these factors. For example, in this study, probability of technological success and change in support of top management have been found to have a certain effect on project success if they are considered independently. Their joint effect definitely contribute more to the project success.
- Data for each country data set were not collected at the same time. In a rapidly changing world, decisions are highly dependent on time. Some factors, that seemed to be important at the time the survey was conducted, might have turned out to be unimportant by the time for respondents. This situation decreases the credibility of results presented by this study.

7. CONCLUSIONS AND RECOMMENDATIONS

This study identified the discriminating factors for the success of R&D projects in four different industrialized, technological advanced countries. These factors are not numerous. All factors do not have the same effect for each country. There is a certain level of commonality of these factors. Even though some factors are common, their relative importance is different in some cases. Similarities and differences are mostly due to cultural/organizational aspects or project-specific features.

In a world where the internalization of R&D practices is growing, it would be highly valuable for decision maker to know the differences and similarities in R&D project termination decision in different nations. Discriminant analysis for a particular country may not be valid for each company in this country.

Even though some factors are common, they may have to be estimated for different industries or even companies in the same industry. Some large companies have already begun to collect such data although they do not apply multivariate methods in their analysis, but this holds promises for improved project decisions [5]. It must not be forgotten that even if a multivariate technique is used, the results of the current analysis would not stay the same over time and there is a need to make continuous revisions in the methodology.

Several recommendations would be applicable to companies that have R&D activities and therefore, face the challenge of R&D project termination decisions:

- Start collecting data on the factors that are identified by this study and thought to be important for this purpose at different phases of this study.
- Devise a company-specific methodology that uses such data in R&D project continuation or termination decision making process. For example, the weight of each factor can be determined and changes in certain factors over time can be incorporated into a company-specific function. The methodology should not necessarily be discriminant analysis. Analytical Hierarchy Process, Scoring Methods or Multiple Regression Techniques are alternatives for that. As another example, a company can keep track of the factors that have significantly changed over time and make a decision when the number of such factors reaches a certain number.
- Formalize the monitoring process for R&D projects [11]. Monitoring process can be done through the use of an expert system. Such a system has been proposed by [2]. Decision support systems will be very beneficial in both eliminating uncertainties in the R&D environment and providing input for decision makers in such decision processes, as project termination [14]. [2] proposes a framework for monitoring R&D projects and present a sample of difficult questions to be answered during R&D project reviews. Pillai and Rao [21] has developed a simple model for integrated project performance evaluation and a graphic for visualization of progress, cost and time. In another study by Matheson et al. [19], 45 best decision making practices that for a blueprint for building and monitoring an effective R&D program are identified.

8. FUTURE WORK

Hypotheses have been constructed by the author to interpret the similarities and differences in factors among different countries. For example, support of both R&D management and top management did not show up in Japanese discriminant function. It can be hypothesized that Japanese management do not show their support explicitly. Further studies can be performed to verify such hypotheses.

Very few studies have focused on R&D project termination processes [5]. This process includes communication methods of project status to R&D staff, decision makers involved in this process, psychological and motivational effects of such decisions on the fate of R&D organization and so forth. In general, human resource management of such decisions seems to be a fruitful potential area for further work.

The use of another multivariate technique can also be beneficial by using the same data set to justify the generalizations drawn from the results of a Discriminant Analysis study. Further research is also necessary in monitoring of R&D projects. A particular drawback at this time is the lack of normative standards against which the actual management of R&D projects and processes of decision making might be evaluated.

A similar study can be conducted by collecting data from Pacific Rim countries that started to play a major role in the high-tech industries. Furthermore, a potential research area lies in identification of discriminating factors for R&D project in environments different from those of four nations, such as protected economies, less industrialized and a lower technological level even though R&D practices in such environments are as intense and important as those in industrialized, technologically advanced countries with free market economies.

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