SOME EVALUATION METHODS FOR R&D PROJECTS AND APPLICATION ORIENTATIONS

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Abstract:

Research and development (R&D) works have very high roles for sustainable development of organizations and enterprises. Therefore, R&D projects are established and implemented with diversified forms. With limited resources and prefixed development orientations, however, they should be evaluated in an adequate way. Various evaluation methods and models were proposed by scientists, each of them have its own strong points and weak ones. This report presents two methods popularly used and the combined one of them for a better integrated evaluation purpose. One of the purposes of this report is to combine qualitative indicators with variables in an optimal model. However, since the new model just passed some low scaled pilot works its weak points were not exploded. Therefore, the further steps targeted by the author are to test the methods for projects of larger scale to get a multi-aspect vision to the obtained results.

Key words*: Project; R&D; Evaluation; BSC; DEA.*

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1. Introduction

R&D is the tool for organizations/enterprises to innovate and enhance the quality of their activities, to produce new products and services, to build up competitiveness and to implement the sustainable development [6]. In practice, numerous R&D projects are established, implemented effectively and to make breakthrough moves in both science-technology and socio-economic plans. Naturally, there are projects that were submitted but not selected for implementation, and, even implemented, could not produce expected results. This shows the need to have a scientifically based method with recognized standards for evaluation of R&D projects. The model needs to provide projects in all of their stages, namely: feasibility study establishment, implementation and acceptance [11]. Based on this evaluation, manager can make decisions for selection, continued implementation, additional volumes for projects under implementation or volumes of supports for newly set-up projects. Evaluation outcomes of projects and acceptance stage help management agencies to have new findings through achievements and experiences of implemented projects and

then to be better positioned for management works during next stages. However, different from other projects in field of construction and industries, R&D projects have certain qualitative information that are unable to be predicted and quantified nature. It requires specific evaluation methods [6].

Many scientists, local and international, proposed different models for evaluation of effectiveness of R&D projects. The models usually are based on the two main methods: pre-determined score method and optimal modeling method.

The pre-determined score method has advantages to evaluate R&D projects in all their aspects, quantitatively and qualitatively. However, this method has weak points that the scores are of qualitative nature and the gained scores depend on assessment of individual examiners (views, concepts and psychological status) and it is very difficult to determine synthesizing parameters [11].

The optimal modeling is good in its exactness with possibilities to examine different options but has its weak points in necessity to follow many assumptions to get the standard based version. These assumptions, as always, reduce the generality nature which will make appear other difficulties and shortages during implementation.

In these conditions, the author will present in this report some largely used evaluation methods and combine them to get the most optimal method. Namely, the pre-determined score method is viewed through the BSC method (Balanced scorecard) [9] which is adjusted when applied for evaluation of R&D projects, and the optimal modeling method is viewed through the DEA method (Data envelopment analysis) [4] and then a combined method is proposed. The combination of these two methods is for the following targets.

1. Orienting the projects to achieve the established strategic objectives;

2. Optimizing resources to achieve effectively targets;

3. Balancing the targets to achieve.

The combined method presented in this report can be applied for evaluation of R&D projects in benefit targeting enterprises of R&D projects of non-benefit organizations (NGOs or not).

2. Contents

2.1. Balanced scorecard method (BSC)

The BSC method was developed by S. Kaplan, Norton *et al.* [9,10,11]. Substantially, the method is based on the pre-determined scores for input and output elements of the examined objects. The resulting scores allow to have a global vision about the objects and to compare them. Initially, BSC was applied largely, and actually is used widely as tools for setting up strategic plans for organizations/enterprises [11]. Recently, BSC is applied with success for evaluation and management of projects. R&D projects have their unique natures where they target the vision of long lasting development which hide potential risks. This requires to conduct a global evaluation to balance chances of success and objectives to achieve then to select the most suitable options for investment and implementation.

The selection of evaluation indicators (measuring) is one of the crucial elements which decide the success of application of the BSC method. In general, the evaluation indicators are to meet the following requirements:

- *Being clear:* evaluation indicators must be presented in a clear manner to make related people understand and have similar interpretation. In addition, the projects can be evaluated in their different stages (such as: proposal, implementation, which require the clearly defined stages of application of evaluation indicators.
- *Orienting strategic targets:* evaluation indicators need to present strategic orientations of organizations/enterprises which mean scores for strategic indicators must be higher than the ones of other indicators.
- *Being sufficient but not superfluous:* evaluation indicators must be sufficient to be able to evaluate different aspects of projects but not superfluous because otherwise, they risk to disperse development strategies.

The use of BSC for evaluation of R&D projects is not only to help the research fund managers and investment owners to select options to meet development strategies but to provide tools for effective evaluation during the whole life cycle of projects. At early stages, BSC can help not only project setting authors to clarify and orient their visions and strategies to objectives but also investors, project owners to select the most suitable projects for investment and implementation. At the stage of project establishment, BSC can be used to set up concrete targets and strategies and to deploy resources for implementation. At the stage of project implementation, BSC is used to measure effects and to evaluate the values of projects if the situation or the priority order changes,... The evaluation works in this stage include both the ones which had been achieved in the

past period and the ones which are to be achieved in the next period. And at the final stage, BSC is used as a tool to make conclusions and lessons.

In practice, there exist numerous BSC versions with published different evaluation indicators [11]. The initial standard version classify evaluation indicators in the four main indicators, namely: finance, clients, internal activities, learning and development. Since R&D projects usually hide potential risks, then for determination of technical and commercial success chances, it is necessary to add evaluation indicators for risk management.

If BSC is used as an individual tool, the most element is to build up benchmarks for measured results. We cannot make evaluation without standards and benchmarks. The latter may come from consideration of passed successful cases or organizations/enterprises used as referenced sources. Once standards established the evaluation works will be improved on basis of comparison of standards and the strategic objectives of organizations/enterprises.

Another fact of evaluation works impacting to the successful issue of projects and the importance of each measure's aspect is the concrete context. However, we need to generalize them for R&D projects and the BSC presented under here can be seen as a format to build up the evaluation model for R&D projects [10].

2.1.1. Financial indicator - noted as O_1

The financial indicator evaluates the global monetary contribution of projects. It reflects earned benefits, cash flows, real expenditures and etc. The financial indicator is the center target and the basis for evaluation of other indicators included in the scoreboard. Therefore, when the other indicators are established they should be classified as components in causal relations to improve the financial indicator.

Critics come from many researchers for exaggerated attentions for short term financial records which might lead to big investment for purpose of immediate benefits projects. This trend would lead to low investment for projects to create long-term values such as intangible assets and IP assets which can be created usually in R&D projects. To cover this shortage, BSC introduces yet four indicators to balance evaluation works.

2.1.2. Client indicator - noted as O_2

This indicator evaluates the satisfaction from clients. The BSC version for R&D projects evaluates the possible market value of projects as well as the satisfaction of users of R&D results and other related elements. The

satisfaction of clients is evaluated on basis of liabilities, committed time, services and quality the projects can bring in. In this aspect, data used for measurements are usually collected through surveys conducted for clients, consideration of targets, assessment of claims from clients, statistic data of transfer of products and etc. The question in this part is usually "How do you think the project has succeeded?" Concrete, necessary parameters for project evaluation include the time to transfer products, quality of products, the way clients are treated and get their expectations satisfied.

2.1.3. Internal activity indicator - noted as O_3

This indicator evaluates the contribution of projects to core competition strategies of enterprises or credibility and main tasks of organizations. Here we need to have an assumption that the highest leaders had made decisions or understood strategic orientations (political tasks). The connection to global strategies of organizations is seen through the various rates or they can be used for concrete evaluation works. When there exist a lot of options to select and every chance gives different results for evaluation the question here would be usually "The organization should focus efforts on completing well which aspects?". If organizations/enterprises want to extend or diversify capacities, the indicators have to be extended also to cover these moves. When the connection is found very low, the project should be removed or re-designed. Inversely, these parameters should be incorporated in this indicator to reflect the attracting level of the project.

2.1.4. Learning and development indicator - noted as O_4

In the actual situation of global competition, organizations/enterprises look regularly for solutions to improve activities then to keep competitive advantages. The targets of this indicator are usually the provision of necessary infrastructure for the above three indicators to get their own targets. When the evaluation is focused on short-term financial targets, it might reduce investments to improve capacities for other aspects such as human resources, systems and processes. Therefore, this indicator looks at long-term impacts of projects for development. The evaluation here includes the check of favorable conditions project create for development and the assessment of sustainability level of positive impacts from projects.

2.1.5. Risk management indicator - noted as O_5

The management of risks includes the evaluation of chances of success for techniques, technologies and commercialization which are key parameters for evaluation of R&D projects. These indicators are adjusted directly by 0-

1 measuring scale or indirectly through related parameters of operation and market figures. The probability of success for techniques and technologies includes the assessment for "shortages" of techniques, complexity level of technologies, technological skills, availability of human resources and equipment. The probability of success for commercialization includes parameters for market need assessment, maturity of markets, competition level, commercial assumptions and impacts from institutional adjustment from promulgated laws, the Government, financial institutions, banks and etc.

2.1.6. Form sheets of BSC

BSC can be changed to fit actual requirements in different fields. However, the starting point of establishment of BSC includes the success deciding core factors which appear in scientific documents, and standards and internal regulations of organizations/enterprises.

The evaluation of R&D projects, as presented above, contains some points different from the initial BSC version since the R&D projects are oriented to longer-term targets than other kinds of projects. On basis of successful evaluation models and management particularities of R&D projects, this report lists out the parameters which take in account the above particular features of R&D projects (Table 1). The model includes two levels, Level 1 includes five indicators and Level 2 includes 23 indicators for evaluation of input and outputs. In the model, the measuring units are defined also for each indicator. The units include currency values, other parameters and probability values. It is also a point to take attention for when using the model. For comparison of projects, the evaluation panel needs to fix importance rates of each indicator on basis of strategic orientations of organizations/enterprises and project realization capacities. For improvement of the quality of evaluation, particularly for importance rates of each indicator, many combined models were published… The next part of this report presents the DEA method and BSC-DEA combined method with targets to recover some weal points of the BSC method.

Table 1: Balanced scorecard for R&D projects

No.	Codes	Aspects	Indicators	Measurement units
1	O_1	Finance	Cash flow	5 years cumulated flow (VND)
			Income value	VND
2	O_2	Client	Feedback of target client groups	1. Low demand 4. Medium demand 7. Considerable demand 10. High demand
			Satisfaction level	1. Low level 4. Medium level 7. High level 10. Very high level
			Claims	1. Very high volume 4. High volume 7. Medium level 10. Moderate level
			Transfer	Percentage of under-scheduled cases
			Connection to strategies	1. Low level of connection to global strategies 4. Medium level of connection but not to important parts 7. Good connection to strategies 10. High level of fitting to the whole set of key strategies
3	O_3	Internal matters	Importance level	1. Low impacts with no damages if projects cancelled 4. Relative competition with impacts to financial situation 7. Considerable impacts. Very difficult to recover if projects are found unsuccessful or cancelled 10. Successful outcome of strategies depends on this project
			Integration with other activities	1. Limited 4. Applicable for some few concrete activities 7. Applicable for many other activities 10. Applicable largely for all activities

No.	Codes	Aspects	Indicators	Measurement units
			Satisfaction level for concerned parties	1. Low level 4. Medium level 7. High level 10. Very high level
			IP right status	1. Easy to copy 2. Protected but no prevention measures 7. Trade secrets wholly protected 10. IP rights wholly protected including trade secret, use of materials and etc.
4	O_4	Learning and development	Background for development	1. No opportunities for development created 4. Other opportunities created for extension 7. There are chances for diversity 10. New aspects opened for techniques, technologies or trade
			Sustainability (technical, commercial)	1. Now clear advantages 4. Minor advantages 7. Medium life time (4-6 years) with low chances for improvement and extension 10. Long life time with chances for improvement and extension
			Training for participating members	Number of trained members
			Probability of success in terms of techniques and trade	Probability value of success
5	O_5	Risk management	Technical shortages	1. New knowledge is to be created 4. Large scope of changes 7. Partial changes 10. Improvement required
			Complexity level	1. Very difficult to make contents clear, so many barriers 4. Easy to make content clear, many barriers 7. Challenges exist but possible to be carried out 10. Contents are clear, no considerable

No.	Codes	Aspects	Indicators	Measurement units
				difficulties visible
			Basis of technological skills	1. Technologies are found novel to organizations/enterprises 4. Some experiences exist already 7. Some parts already realized by organizations/enterprises 10. Practiced already largely
			Availability of human resources and equipment	1. Not available. Required to be leased or hired 4. Shortages in some main aspects 7. Resources may be mobilized to meet needs 10. All resources are available
			Market demand	1. Required to develop markets 4. Demands exist but marketing activities are required 7. Close links between projects and market demands 10. Projects are designed on basis of demands
			Impacts from adjustments (laws, Government, hosting institutions)	1. Negative impacts 4. No impacts 7. Some positive points 10. Fully positive
6	I_1	Resources	Total investment	VND
			Human resources	Equivalent working times of engineers, managers and scientists

Source: A.D. Henriksen, A.J. Traynor in "A practical R&D project-selection scoring tool".

Notes:

1. *Indicators listed in this table were applied in Israel (2010) and they were adjusted for local evaluation.*
2. *Some indicators can be evaluated when projects are fully or partially completed.*

2.2. Data Envelopment Analysis method (DEA)

DEA is a method to analyze input and output data of Decision Making Units (DMU) which can be interpreted as production options, branches of a system or investment options and etc., and then outcomes are lists where DMUs are put in increasing order of relative effectiveness factors [4,5,8].

The relative effectiveness factor of projects is calculated as ratio of weighted outputs and inputs.

$$\textit{Relative effectiveness} = \frac{\sum \textit{(Outputs) x (Weighted)}}{\sum \textit{(Inputs) x (Weighted)}} \quad (1)$$

The main idea of DEA is the following: let have a set of *n* projects to be evaluated where input and output data exist. For example, Project A needs an investment of VND1.5 billion. On basis of existing technological capacities, the probability of success is 80%. When the project in completed the turnover is VND2 billion by higher selling prices, the score of credibility by clients increases from 4 to 7, internal regulations get standardized from level 5 to level 7. In addition, the project is the platform for further development of other projects which is evaluated as increasing by 4 levels. Similar works are also conducted for all the other projects. Input and output values may be measures with different units then it is impossible to compare them directly. So, for this purpose, DEA uses synthetic parameters called relative effectiveness factors as in (1). Projects are then compared and classified exactly by using these factors. Weights are introduced for normalization of input and output data. This normalization can not only to lead data to the same platform but also to compute the relative effectiveness of projects.

In order to define values of parameters, DEA uses an optimal model. This model targets the optimization of weighted parameters where the main parameters are to define to satisfy constraints of values of relative effectiveness factors. The values of relative effectiveness factors must be positive and inferior 100%. The model can be presented in the following canonic form.

Optimization: The total of adjusted outputs.

Satisfaction of constraints:

- The total of weighted outputs deducted by the total of weighted inputs must be less or equal to zero.
- The total of adjusted outputs must be equal 100%.
- Values of factors corresponding to inputs and outputs must be positive.

After fixing the model consecutively for all the projects, we will see them, in terms of effectiveness, from the highest one to the lowest ones. With given inputs and outputs, there exist many softwares to define the optimal

options. One of the most easy-to-use and friendly softwares is the Microsoft Excel-embedded DEA-add-in. Readers can refer to the Excel Help.

2.3. BSC - DEA combined method

As analyzed above, every of these methods have its own weak points. Now the author presents the combined method to maximize strong points and to minimize weak points of these two methods. We call this model as the combined model.

The combined model is a mix of the two above presented methods. Here all the inputs and outputs used as variables of the optimal model of DEA method are the evaluation indicators in BSC method and versa. The structure of BSC is embedded into the DEA model through balanced constraints which are realized by limitation of weight values (which are DEA variables) in certain ranges. In the initial DEA model, the constraints were proposed to secure the positive values of weights and the 100%-less value of relative effectiveness factor. In order to enhance exactness and to reduce risks of evaluation the combined method set lower bounds and upper bounds for various indicators.

In this part, BSC is supposed to have a two level structure (see Table 1), indicator levels (O_k) and concrete levels for every indicators. There are two methods to set up the optimal model of DEA which are to maximize outputs and to minimize inputs. Here the maximization of outputs are chosen. The reasoning for minimization of inputs is quite the same.

Likely, to the initial DEA model, the combined model takes the total of weighted outputs as target of maximization where the main variables are corresponding weights for different input-output pair. However, there is a difference between the initial model and the combined model. In the initial model, weights are also variables but the range of constraints vary from 0% to 100%. This large range of variation allows to find out all the possible values but there is a disadvantage that in some cases output parameters are not too important but have high weights. This situation could lead to wrong evaluation of projects. Upper and lower bounds are introduced for purpose to reduce this possible wrong evaluation. Lower bound is denoted by L_d and an interval, called limit interval, is added to the lower bound to get the upper bound. Many researchers show that the interval of 40% is suitable.

Briefly, the model can be described as follows:

Maximization (of target function): The first weighted total of the i-th project (i varied from 1 to n).

Satisfaction of constraints:

- Ration between weighted inputs and outputs of the k-th project (k varied from 1 to n) must be superior or equal to the upper bound and inferior or equal to the upper bound.
- Value of factors must be positive.

The problem can be programmed on computers and run n time to find out suitable weights. Readers can use also Excel DEA-Add-in for application of the model. However, constraints should be changed from 1 (100%) by arranging lower and upper bounds as presented above. In addition, results can be tested again by its induced problem.

2.4. Orientations for application

The evaluation of R&D projects is a difficult work because the work deals with so many qualitative indicators. Even many of them can be known after completion of projects. Difficulties will be more added in case the financial aspect is not (or at low rate) the objective of projects of Government organizations and NGOs. Therefore, it is necessary to follow the hereunder procedure to get the right evaluation according to the presented models.

- *Identification of the name and detail plan of the projects and the related information of project hosting organizations.* It is very important initial point impacting the quality of project evaluation. The name of projects should be short and clearly indicate the main project targets. At the initial stage, the name usually is selected to cover largely eventual extensions. Regulation for naming should be introduced to limit this case. The detail project plan needs to highlight main parameters such as actual status, problems to be treated, effectiveness in case of success, detail expenditures for every project stages and etc. The hosting and supporting organizations have the deciding role to approve and to provide necessary supports. Therefore, the information about short and long-term strategies and S&T development policies should be collected fully.
- *Set-up of scorecard:* A scorecard is called good if it reflects all the project evaluation indicators as well as legal regulations and wills of leading bodies [9]. Methods of information collection and statistic calculation need to be identified together with the set-up of the scorecard. Market data can be taken from public made secondary documents and project related data need to be investigated. For example, the satisfaction level of users need to be investigated by direct questionnaires to potential customers. The wills of leading bodies should be presented largely and deeply in evaluation (number of indicators and scoring methods). Documents on the set-up of balanced

scorecards proposed 5 evaluation indicators and some concrete indicators for R&D projects [6,9,10,11]. The author had studied and adjusted indicators to practical conditions in Vietnam which are seen in Table 1.

- *Decision for importance of every evaluation element.* In case of use of single scorecards, the value for importance (weight) of indicators is decided by leading bodies and scientific councils on basis of global development strategies. When the set of these weights is established the value (scores) of absolute effectiveness of every project is established. These scores are used for selection of projects for implementation or necessary rectifying actions for projects under implementation or selection of projects to be standards for next activities (i.e. for acceptance evaluation). However, the above qualitative nature of weights would make lost some aspects in evaluation works such as impartiality and scientific nature of evaluation. In order to cover this weak point, the DEA model is introduced to identify the maximal values of weights. In the initial DEA version, the algorithm automatically selected the values of the most optimal weights to maximize the value of target function. This impacts the quality of evaluation (not reflecting the nature of projects) as well as does not reflect the wills of leading bodies in evaluation. Then in the improved DEA method, presented in this report, instead of the selection of all the possible values of weights in the range from L_B (Lower bound) to U_B (Upper bound) is made by algorithms, they are now decided by leading bodies and the scientific council on basis of global policies and strategies of organizations.
- *Establishment and solution of the optimal model:* On basis of principles to establish the optimal model including the definition of variables, target functions and constraints. Here the main variables are weights for every indicators and targets to maximize the total of weighted outputs. The constraints of the model including constraints for lower and upper values of weights as well as conditions for weights to have sense. Once the model is established clearly the existing softwares such as Excel add-in, Lingo, Lindo and etc. can be applied to find out results. The number of times to run them is equal to the number of projects to evaluate.
- *Ending of evaluation process:* Results obtained when running these softwares are the list of projects in reducing order of relative effective values. So related parties can use can use the results for selection of

projects for implementation, additions, amendments or rejection (in case of low effectiveness).

3. Conclusions and recommendations

The report presented the background and the procedure to use popular tools of evaluation, namely DSC method, DEA method and the combined method. On basis of this report, readers can set up their own models for concrete cases. The report presents also some popular softwares for programmed calculations by computers. The two BSC and DEA models are used popularly in the world. However, since the initial purpose of these models was not R&D projects the report deals with some adjustments for better use for evaluation of R&D projects in Vietnam. The combination of BSC and DEA method is the natural way because BSC has some weak points of result processing work while DEA needs the pre-evaluation of inputs and outputs. This combination would perfect them.

Comparing the content of the report to the documents for evaluation of local R&D projects [1,2,3] the author notes that the report deals in more details with evaluation indicators which are recognized in the world. In addition, the actual selection procedure in organizations is usually conducted by evaluation panels through voting. This leads to different results because of different concepts of evaluation indicators.

The target of the report is to propose a vision and a method of evaluation for large discussion and further research then may have some shortages. It particularly relates to the scorecards of indicators since it was used only for pilot scale. In comparison to the practice of voting by panel members, this method consumes more time and efforts then leads to higher costs. For successful application of this method, it is necessary to establish the scoring method in an unified and transparent manner. This would eliminate disputes during evaluation and orient projects to the defined strategies of organizations/enterprises.

These shortages would put next research directions for the author to perfect and standardize evaluation procedures and to provide Vietnamese language software for more convenient use./.

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