Full Length Research Paper

A formula for prioritization and optimized selection of research projects in research and development departments of industrial factories

Alireza Shahraki¹ and Morteza Jamali Paghaleh²*

¹Department of Industrial Engineering, University of Sistan and Baluchestan, Zahedan, Iran.  
²Department of Industrial Engineering, Young Researchers Club, Islamic Azad University, Zahedan Branch, Zahedan, Iran.

Accepted 4 October, 2011

Research and development play key roles in different industries success. However, the significant point is how to organize related activities so that growth and progress would be realized in a department as a result of appropriate organization. In other words, research and development activities could lead to growth when systematically conducted. These all would be accomplished via comprehensive analysis of factors effective in research and development. In the current study, effective factors in research and development activities are identified based on the investigations done, existing resources, and scientifically recognized methodologies. Then, the said factors’ relationships are systematically provided for the purpose of research projects optimized selection and prioritization in Research and Development (R and D) departments. This paper uses data and information gathered from engineers and managers of Sarcheshmeh Copper Complex, analyses the said data, and applies relevant softwares and applications along with statistical methodologies to finally propose R and D department a formula for prioritization and optimized selection of research projects in an industrial entity.

Key words: Research and development, systematic designing, industrial complex, process.

INTRODUCTION

Changes and development in the external and internal setting of business enterprises have been running in such a fast, multidimensional, complicated, and pervasive way that these commercial institutions cannot survive, grow, and develop without appropriate evaluation of prospects, planning, and strategy evolving. Through the last decades, since the market has not been competitive under certain circumstances, many enterprises could manage to thrive well in the domestic market; however, with today’s competitive market and global economic status, they no longer manage to survive without development; while development and progress is impossible without appropriate reaction and conscious response to the ever-changing and dynamic environmental condition. Appropriate reaction and conscious response to the complicated developments put the commercial enterprises in the theoretical position of open social systems. Permanent change and development is a vital element of such system’s nature. Business enterprises, in a constant interaction with the environment, must make changes both in the internal and external environment elements. They must actually develop a mercurial structure so that they can acquire the required flexibility through changing the customers’ needs and demands in the market in order to give them positive responses before the rivals do so. This feature is realized in business enterprises when they have adequate, on-time, up-to-date, appropriate,
and relevant information, and this is impossible unless they do the properly effective studies and researches.

Different industries annually spend millions of dollars to improve their products and procedures; chip designing, engineering, financial analyses, research and development are of such measures (Balachandra and Friar, 1997). Organizations’ methods to reach permanent competitive advantage are a challenging issue in the current competitive world (Pano et al., 1997). There are organizations who struggle to create value for their clients via focus on their own distinctive capabilities (Fernando et al., 2004). Most investments are made in “product development” and “operations” producing major effects there. These costs include research and product development, system updates, investments in construction and equipment supply, and even human resources increase (Temouri and Hafez-Al-Kotob, 2008).

Nowadays, each and every company focuses on its own pivotal strengths, and cooperates with the other companies which possess complementary qualities in products design and delivery to market (Hogus, 2008). Enterprises’ growth and success could be realized through technology promotion. Since technology level is promoted in the Research and Development department, investment in research and development is thus significantly effective in the enterprises’ success. In order to achieve growth in enterprises via investment in research and development, a well-organized system is required to manage research and developments activities in the companies. The said system, by means of planning and organizing research work, paves the way for the enterprise’s future growth in addition to the desired output for the investment made in research and development. The objective of all these activities is to enable the customers to enjoy high-quality products and reliable services with the minimum possible charges (Lancioni, 2000).

In the recent years, the rapid growth in science and technology has made individuals’ patterns and tendencies to change. These changes in patterns and tendencies on one hand, and reduction of natural resources accompanied by increase in intense competition among enterprises to gain more income on the other, have destabilized the environment in which enterprises are running their businesses. The environment was stable with gradual changes in the past; therefore, managers had to work on efficiency increase in production, marketing, and product improvement in a traditional framework. However, today, success of these managers lies in the availability of an environment-compatible management system. This management system must be capable of evolving appropriate strategies to confront environmental changes and organize the respective organization according to the external variable environmental needs all through a proper evaluation of the environment and analysis of the enterprise’s internal competence (Helfat, 2003). A most important strategy to stabilize the enterprises is to reinforce innovative competence and use of advanced technology in order to provide more efficient goods and products to meet the society’s requirements. And since new products creation is in close relationship with the concept of market, need arises in the market upon innovative product creation (Lukas and Bell, 2000; Francois et al., 2004).

At the current age, with the knowledge increasing expansion and its application scope in finding solution for a large number of problematic issues, research and development play the most significant role different industries progress. This process could manage to win the competition in the international arena when done in terms of an organized department enjoying all the required investments. On the other hand, a typical research and development department would not be truly realized without innovation. Innovation in technology means making more significant and efficient progressions leading to rather proper use of financial resources, and in a nutshell, resulting in economic growth. Public organizations throughout the world face various challenges; therefore, administrative, executive, judiciary sections continue their developmental movement toward electronic workplace (McKinnon, 2005).

There are different definitions of innovation in various references. Some of them are as follows: According to London Innovation Institution, “Innovation means exploiting new ideas, and is of vital requirements for competition, production, and social interests in the organizations and trade centers”. Innovation is the process of adopting a creative idea and its conversion into new product, service, and methods of the operations. Innovation brings about aptitude and capability to either change or adapt.

Exploit + New Creation + Deduction = Innovation

In the aforesaid definition, “deduction” means getting new ideas via some mental reference frameworks. “New creation” refers to any new idea which is potentially capable of being converted into reality, and “exploit” refers to use of new creation (Abdolkarimi, 2006). Dictionary has pointed out to ‘innovation’ as “introduction of anything new”. Fundamental innovation leads to creation of new markets (Hadizadeh and Rahimi, 2005).

LITERATURE REVIEW

Research and development process

According to Dumbelton, research and development process modeling is generally advantageous since by doing such, effective factors in research and development
success could be identified. He argues that no general always-appropriate model for research and development process has been identified yet; thus, instead of looking for such model, we try to provide a simple linear model (Figure 1). Dumbelton argues that research and development inputs are divided into two groups namely Resources and Information. “Resources” consists of human resources, equipments, tools, building, etc. In other words, these are amounts of money spent on research and development; therefore, return of capital is important for the respective managers as far as these amounts of money are concerned. “Information” is also a significant part of the inputs. Thus, research and development process is the process of information production and conversion. Accordingly, a considerable percentage of the outputs will be released in the form of project plan, article, and information related the product’s structure and design.

Economists are on the belief that science and technology are strong and effective tools which can play key role in the development process. Nowadays, developed countries are those who enjoy a high level of technology. Thus, many advanced products, methods, tools, and technologies are the results of such countries’ progress in science and technology. The only indisputable fact in such a new economy is that knowledge is the sole permanent source of competitive advantage (Buttler et al., 2003). In the new world, informational economy lies in developed countries’ use of up-to-date technology via which they can collect, distribute, store, and apply that type of knowledge which distinguishes them from the others (DCMA, 2004). Based on the economists’ studies in the advanced countries, extensive use of technological innovations is the reason of high growth rate in such states. Basis of these technological innovations is the fast progress made in the field scientific knowledge storage adding to this database content through the increasing additional wealth which has been achieved for the purpose of science and technology development. Figure 2 shows the cause-and-effect relationship between technological innovations use and economic growth (Movahedidyesobhani, 1995). Therefore, research and development is
deemed as a major factor of scientific and technological progress along with economic development in any state. This is indicative of the fact that efficient and proper management of research and development activities would accelerate a country's growth trend. A number of impediments on the way of getting adequate efficiency out of research projects in big firms are as follows:

1. Creation and implementation of similar projects in different subsidiaries.
2. Incompatibility of research projects with the objectives and strategies of firm development.
3. Research projects irrelevant to the problems and issues which threaten the whole company.
4. Rather high probability of failure rooted in not having a delineated process of planning, creation, evaluation, implementation, and control concerning the respective research projects.

Analysis of the aforementioned problems indicates that lack of an appropriate pattern to create and define research projects in the headquarter along with headquarter inability to conduct and coordinate subsidiaries' research projects are of the major factors challenging investment in research and development projects of the big companies. According to a headquarter's responsibility for identification of objectives and strategies and its approval role regarding subsidiaries' plans and performance, a certain system must be defined in the headquarter to conduct subsidiaries' research activities in line with threats combat and opportunities exploit throughout the whole company added to the fact that the said system must identify the headquarter's research projects creation and identification process (Movahhedyesobhani, 1995, 1996). Thus, an appropriate research and development system in the headquarter brings about the following items:

1. The headquarter's role in creation and approval of subsidiaries' research projects will be identified so that all the subsidiaries' research projects would be coordinated with the headquarter ones in line with the long-term objectives of the whole company.
2. Creation and description process of the research projects will be identified in the headquarter; therefore, it will be enabled to define projects appropriate to its current status in order to counter the whole company threats.
3. Implementation of research projects not in line with development objectives and strategies will be aborted.
4. Implementation of research projects inappropriate to enterprise's internal competence will be aborted.
5. The company's limited resources will be allocated to its main research projects.
6. The planning and control process for both headquarter and subsidiaries' research activities will be defined, implemented, and controlled in terms of a consolidated system so that the respective costs and risk factors will come under control.
7. Major research objectives and plans will be revised and adjusted.

All in all, it can be concluded that in case of an R and D system availability in the investor company's headquarter, the managers know how to allocate the respective budget to the research projects in order to get the maximum possible output and achieve the company's long-term objectives.

Askari (1996), for the purpose of selecting effective factors in prioritization and also choosing for the selected projects along with establishment of a logical relationship between them, has proposed criteria for evaluation of research and development entities. He has actually provided a picture of methodology in R and D departments' performance evaluation including the need for performance evaluation, its form and content, process and scope of performance evaluation, and finally methods and management of evaluation process. Fadæe (1999) investigates a typical research and development department's effect on the production industries.

His research statistical population is the car manufacturing industry. Eliasi (2001) studies strategic planning of research and development task at the level enterprise. He has proposed a helpful model for identification of research and development task in interaction and coordination with an industrial organization strategy. A number of non-Persian researches have been done on the said research subject, for the purpose of selecting effective factors in prioritization and optimized selection, and establishment of a logical relationship between them. Some of them are as follows:

1. Kusong-dong, Yusong-ku, and Taejon's paper. In this paper, different factors of public and private sectors industrial projects selection in R and D departments.
2. V. A. Il'yashenko and A. S. Baleevskikh's book. The book points out to the most effective principles and factors via review and analysis of industrial projects implemented by the Soviet Union's Ministry of Industries during a 10-year timeframe. In this research, effective factors on the research and development activities have been identified based on the studies done during the research, existing reference resources, and scientifically recognized methodologies. And finally, a formula has been proposed to a typical R and D department for prioritization and optimized selection of research projects in an industrial business unit.

**METHODOLOGY**

Research methodology of the current paper is survey-descriptive
which consists of descriptive analysis is to identify and describe variable features under comprehensive circumstances, and to be aware of the features while describing them for a special case (Danaeeifar et al., 2004). It is also to be said that a structure will be designed for the R and D process via systematic designing, taking the effective factors into consideration. In order to complete the structure which is the main part, the projects have been prioritized through mathematic planning and statistical analysis using some relevant applications such as Minitab, Expert Choice, SPSS, and Excel with respect to the existing constraints so that the optimized selection could be done at the end. In the current paper, “research project selection” is the dependant variable while problem solving immediacy; costs, expert workforce, and study time are the independent variables. The required data has been collected by means of questionnaires. The questionnaire consists of two parts: The first part includes independent variables questions while the second part contains the dependant variable questions that is, research project selection. 14 and 7 questions have posed in the first and second parts respectively. Of the first part 14 questions, 5 questions have been allocated to the problem solving immediacy whilst each of the other independent variables that is, costs, expert workforce, and study time have been addressed by 3 questions. Likert 5-rate scale has been used to measure the said variables. Rating has been done in terms of a 5 to 1 manner (“5 = very much” and “1=very low”). The maximum and minimum scores for problem solving immediacy could be 5 and 25, respectively. The other 3 factors of costs, expert workforce, and study time each one can get a minimum score of 3 and maximum score of 15.

Cronbach’s alpha has been calculated by means of SPSS for the purpose of questionnaire’s reliability measurement. Concerning the reliability of the question in the first part of the questionnaire, Cronbach’s alpha range for the factors is 0.75 to 0.93, and the Cronbach’s alpha for the whole variables is 0.72 confirming the questionnaire’s reliability. Cronbach’s alpha for the questionnaire’s second part questions is 0.78 indicative of high reliability in the questionnaire. In this part, range of reliability coefficient is 91 to 99 while reliability coefficient for the whole factors is 89. Reliability coefficient of the second part is 99.

Research hypothesis

Hypothesis 1: Problem solving immediacy is of the effective factors in research project selection.

This hypothesis can be expressed in the two following forms. Two methods can be applied to achieve the correct results.

H_0: There is no significant relationship between research project selection and problem solving immediacy.
H_1: There is a significant relationship between research project selection and problem solving immediacy.

Significance level is under \( \alpha = 0.05 \) (0.05 > 0.008); therefore, \( H_0 \) of test (1) is rejected at \( \alpha = 0.05 \) level meaning that there is a significant relationship between research project selection and problem solving immediacy with 95% confidence.

Hypothesis 2: Cost is of the effective factors in research project selection.

This hypothesis can also be expressed in the two following forms:

H_0: There is no significant relationship between research project selection and costs.
H_1: There is a significant relationship between research project selection and costs.

Significance level is under \( \alpha = 0.05 \) (0.05 > 0.002); therefore, \( H_0 \) of test (5) is rejected at \( \alpha = 0.05 \) level meaning that there is a significant relationship between research project selection and costs with 95% confidence.

Hypothesis 3: Expert workforce utilization rate is of the effective factors in research project selection.

H_0: There is no significant relationship between research project selection and expert workforce utilization rate.
H_1: There is a significant relationship between research project selection and expert workforce utilization rate.

Significance level is under \( \alpha = 0.05 \) (0.05 > 0.015); therefore, \( H_0 \) is rejected at \( \alpha = 0.05 \) level meaning that there is a significant relationship between research project selection and expert workforce utilization rate with 95% confidence.

Hypothesis 4: Required time for research project study is of the effective factors in research project selection.

H_0: There is no significant relationship between research project selection and required time for research project study.
H_1: There is a significant relationship between research project selection and required time for research project study.

Significance level is under \( \alpha = 0.05 \) (0.05 > 0.029); therefore, \( H_0 \) of test (11) is rejected at \( \alpha = 0.05 \) level meaning that there is a significant relationship between research project selection and required time for research project study with 95% confidence.

Hypothesis 5: There is a relationship between research project selection and (1) problem solving immediacy (2) costs of a project (3) utilization rate of expert workforce to accomplish a project and (4) required time to do a research project.

In the current study, experts of Sarchesheh Copper Complex are the statistical population. The said population consists of 130 persons.

Data analysis

Kai-2 tests, One-way variance analysis, Pearson correlation coefficient, stepwise regression, and Anderson Darling test have been done in order to address existing relationship among the variables (Figure 3).

Project optimized selection and prioritization model

In this model, the main effective factors in research project selection are first selected. Then 35 experts will be randomly selected to answer the questions concerning the said variables so that we manage to achieve rather accurate results. It is also to be pointed out that the experts explained that they must prioritize the said
different variables through giving each one of them a number from 1 to 10 according to the effect that each variable has in research project selection. Upon analysis of the expert’s answer, the following results were obtained (Figure 4).

**RESULTS**

31.4% of the experts recognized problem solving immediacy factor as the most effective factor in research project selection (Table 1). 31.4% of them identified
Table 1. Regression coefficients in the model of research project selection and problem solving immediacy, Cost, time, expert workforce.

<table>
<thead>
<tr>
<th>Model</th>
<th>Coefficients</th>
<th>Test statistics</th>
<th>Significance level</th>
<th>Partial correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fixed</td>
<td>16.702</td>
<td>12.201</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Problem solving immediacy</td>
<td>0.425</td>
<td>5.503</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Fixed</td>
<td>21.334</td>
<td>12.196</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Problem solving immediacy</td>
<td>0.388</td>
<td>5.321</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Cost</td>
<td>-0.474</td>
<td>-3.884</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Fixed</td>
<td>23.306</td>
<td>11.980</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Problem solving immediacy</td>
<td>0.375</td>
<td>5.221</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Cost</td>
<td>-0.396</td>
<td>-3.171</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>-0.245</td>
<td>-2.158</td>
<td>0.033</td>
</tr>
<tr>
<td>4</td>
<td>Fixed</td>
<td>24.449</td>
<td>12.259</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Problem solving immediacy</td>
<td>0.385</td>
<td>5.438</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Cost</td>
<td>-0.3</td>
<td>-2.275</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>-0.242</td>
<td>-2.168</td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td>Expert workforce</td>
<td>-0.247</td>
<td>-2.0241</td>
<td>0.044</td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>-0.242</td>
<td>-2.0241</td>
<td>0.044</td>
</tr>
</tbody>
</table>

costs variable as second priority while another 28.6% of our statistical population selected the required expert workforce as the third priority. And finally 28.6% of the 35 experts in question chose the required expert workforce as the third priority. And finally 28.6% of the 35 experts in question chose for the required time as the fourth factor which can affect project selection. If we apply mode index to the first 4 priorities, the problem solving immediacy, costs, required experts, and required time factors will enjoy the most frequency in terms of 1 to 4 priorities. They are selected as the 4 effective factors in project selection. However, if we calculate total ranks given to different factors by the addressed experts, the following results will be achieved. Using experts' points of view and by means of hierarchical process (AHP), value of each effective factor is achieved in terms of the following table.

Note: Obviously, the lower rank of a factor indicates its wider significance. Problem solving immediacy factor outranks all its counterparts with a total score of 101. Costs factor is ranked second with a score 115. Expert workforce factor has received 121 scores ranked as the third. And the required time factor is ranked fourth with a score of 123. As shown, the two aforementioned methods (Statistical and AHP) lead to the same result. Since quantitative measures have been applied to the variables in question, Pearson correlation coefficient was used to address the existing relationship among them. Research project selection is in direct relationship with problem solving immediacy with 95% confidence (Table 1). In other words, the higher significance of problem solving immediacy in the research project leads to the higher probability of the project in question to be selected.

The project cost is directly related to the research project selection with 95% confidence meaning that the research project is less possible to be selected if the respective costs are high. With 95% confidence, the required time factor is in inverse relationship with research project implementation probability; the more required time for project implementation, the less probability of project selection. With 95% confidence, research project selection is in inverse relationship with expert workforce utilization rate for project implementation; the more expert workforce utilization rate, the less probability of project selection. Including the achieved Pearson correlation coefficients without taking their signs, that is, positive and negative coefficients into consideration, it is absolutely obvious that research project selection depends on the factors of problem solving immediacy, the research project costs, required time for project implementation, and expert workforce utilization rate respectively. According to the following table and the coefficients column, the regression relationship between research project selection and each factors of problem solving immediacy, costs, time, and expert workforce could be obtained:

\[ Y = 24.449 + 0.385X_1 - 0.3X_2 - 0.242X_3 - 0.247X_4 \]
This equation can identify regression relationship between the dependent variable that is, project selection and independent variables that is, problem solving immediacy, costs, time, and expert workforce. In this equation, \( Y \) stands for project selection (dependent variable), \( X_1 \) represents problem solving immediacy, \( X_2 \) is indicative of the project costs, \( X_3 \) stands for required time for research project implementation, and \( X_4 \) is representative of expert workforce utilization rate for project implementation. Now, we can use the above-mentioned formula and the values determined by SPSS, Minitab, Excel, and Expert Choice. It is to be said that the 4 factors' values are first entered into the formula. The results are as follows:

\[
Y = 24.449 + [0.385 \times (533.064)M1] - [0.3 \times (366.548)M2] - [0.247 \times (99.580)M3] - [0.247 \times (71.548)M4]
\]

There each \( M \) stands for the factors previously mentioned. Value of each \( M \) can be extracted from the help table so that it can be entered into the formula. The values entered are the maximum ones; however, a certain project needs coefficients appropriate to its own conditions.

Projects A and B can be defined as follows:

Project A is a project which costs $2000, and will be accomplished in a 12-month timeframe. It requires one expert as an industrial consultant. The arising problems include (1) Very urgent, (2) Urgent, (3) Normal, and (4) Long-term ones will be solved immediately. Project B costs $25000, and will be finished after 24 months. It requires an industrial consultant or expert during the implementation course to solve our normal problems. Now it is possible to do the prioritization by means of the said formula. As far as research part is concerned, 1 negative point will be scored to each 3-month expert meaning that, in the project A, \( X_4 \) must be multiplied by \( \frac{2}{12} \). Every 2 months will be scored with one negative point. One negative point will also be considered for every $5000. Since the three \( X_4 \), \( X_3 \), and \( X_2 \) coefficients are negative, a project which has the best status as far as \( X_3 \) is concerned must be multiplied by zero; however, it must be multiplied by 100% if in the worst status so that all negative points will be added to the total points. Now, the projects can be formulated:

\[
A = 24.449 + [0.385 \times 533.064 \times 75\%] - [0.3 \times 366.548 \times 0] - [0.242 \times 99.580 \times 0] - [0.247 \times 71.548 \times 4/12] = 74.27
\]

\[
B = 24.449 + [0.385 \times 533.064 \times 50\%] - [0.3 \times 366.548 \times 4/12] - [0.242 \times 99.580 \times 6/12] - [0.247 \times 71.548 \times 8/12] = 57.42
\]

According to the data achieved, it can be concluded that project A priority is higher than project B’s to be selected.

Now, the following question can be posed: Is it possible to implement all the projects based on the priority and then look for the desired results through implementation? The answer is that there is another step after prioritization. The step in question is budget allocation to every project according to the priority. For instance, the project No. 11 is at the door and there is more budget while the previous 10 projects have been allocated R and D budget. It also applies to expert workforce or any other factor brought about in the project or algorithm. Obviously, upon changes in any of the hypotheses or constraints, the plan must be modified accordingly. Therefore, it is necessary to update the hypothesis-related data at certain junctures to optimize the respective decisions. The planning has been done for a “one-year” timeframe because of more access to the required information. However, the methodology used can also be applied to rather long-term periods. In such circumstances, for the purpose of making financial figures and time role effect in it comparable, the factors can be made of the same type as the annual average value via methods of change-to-current value so that they can be evaluated.

**CONCLUSION AND SUGGESTIONS**

According to the linear model we created in the current paper, project received from all departments in R and D department, who has the most significant role in project selection and project implementation planning, can be systematically prioritized. For instance, problem solving immediacy is a factor which has a substantial effect in project selection and, with 95% confidence, is in a significant relationship with research project selection. Prioritization can be done according to the algorithm, which is to be given to R and D senior managers, and based on the values assigned during each step. In other words, in the first step, a value number must be given to every factor according to the results achieved from Expert Choice while looking at the maximum value of each factor along with its either negative or positive effect, for example, when “time” is a factor with negative coefficient in the linear planning formula, the highest value must be assigned the lowest number, that is, 0 so that it can have the most significant effect in the final result of formula leading to a higher number in the to-be output in line with a logical basis. The next step requires placement of values in the formula so that the respective number for each project could be specified. This can be done for numerous projects to finally prioritize them (projects) based on the output numbers. All in all the said method is helpful since it is flexible as far as qualitative factors are concerned, and can be easily addressed by the company’s viewpoints and policies. It could be the
most appropriate method provided that the number of projects does not exceed a certain maximum. Naturally, upon increase in project numbers, computer and the other methods can also be included.

REFERENCES


