Success factors of public funded R&D projects

D. S. Nagesh[1,*] and Sam Thomas[2]

[1]Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram 695 011, India
[2]School of Management Studies, Cochin University of Science and Technology, Kochi 682 022, India

Research and development (R&D) projects which are classified into basic research, applied research and product development are being carried out by industries, academia and R&D institutes. Such projects funded by government agencies are common among nations all around the globe. They are basically aimed at developing national science and technological competence than direct market orientation or commercialization and are in many respects different from industrial R&D projects. Most of them are handled by the academic/R&D institutions. Their target is long term, need high intellectual input, benefits may not be tangible and risk is high. The outcome of such R&D projects is not always successful and the underlying reasons may vary widely. Various factors have been identified and projected: out of which many are common, some are contextual and the rest are even contradicting. Not many attempts were carried out to identify the factors which contribute to the success of projects carried out by academic/R&D institutions, which is of high relevance to the Indian context. Hence in this article, we attempt to review various factors contributing to the success of projects which are funded by the government and grouped them into common eight categories such as type of the project, leader's competence, team, environment, funding and other resources, management support, collaboration and degree of difficulty.

Keywords: Project management, R&D, success factors.

PROJECTS are carried out in a wide range of areas of life including construction, finance, new product development, information technology, healthcare, research and development (R&D), etc. Projects are important because they are meant to produce a definite outcome, within a planned schedule and cost. The Project Management Institute, USA[1] has defined project as a temporary endeavour undertaken to produce a unique product, service or result. A project should have definite starting and ending points (time), a budget (cost), a clearly defined scope – or magnitude – of work to be done, and specific performance requirements that must be met.

Projects are aimed at a successful outcome; however, in reality only few projects are successful. Why is it so? This question has been a cause of concern. Studies have been carried out and the reasons influencing the success or failure of a project have also been found to vary, as some are within the organization and others are external and many of these factors are also contextual.

All around the globe, public-funded R&D projects are carried out by academic and R&D institutions with the aim of enhancing the national scientific/technological competence. Type of the project may vary from basic science, applied science to product development but in general the projects are not directly oriented towards the market in contrast to market-oriented industrial research projects. In India, such projects are highly encouraged by government and supported through different departments.

The National Science Foundation, USA[2] has defined R&D as: 'activities comprising creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.'

R&D projects stand apart from other projects in the sense that their outcome may be of long term. Ultimate benefits may be intangible and/or be a more informed basis for future projects. Research or policy environment may change with new breakthrough or problems affecting the relevance of the projects. Project may necessarily of high risk. This necessitates a need for a robust supporting framework for project management[3].

In addition, these projects may not necessarily use the project monitoring tools extensively as their industrial counterpart.

In general, R&D projects similar to any other project is, analogous to the seed in the soil. Quality of the sprout and the plant depends on the quality of the seed, quality of the soil and caretakers. The project is the seed, organization and its environment is the soil, and caretakers are the project leader and the team associated with the project. In addition, they require resources and also collaboration when external knowledge/facilities are needed.

The factors that influence the outcome of such projects are discussed below.

Project management success versus project success?

Project success and project management success are not one and the same. Usually project management success is measured by the management of triple constraints, namely the cost, quality/objective and time. However this

*For correspondence. (e-mail: dsnagesh@rediffmail.com)

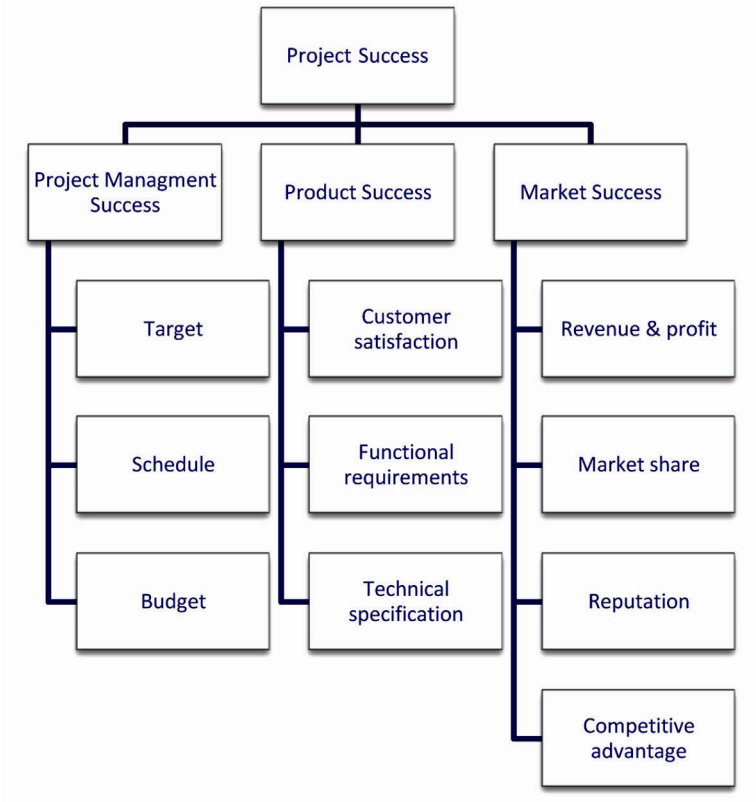

Figure 1. Success criteria of building projects.

is not the same as project success and has to be differentiated from project management success *per se*.

Overrun of cost, quality and time can lead the project to be considered as failed on project management, but not necessarily on project success, which ultimately depends on its outcome, impact and also on the satisfaction of stakeholders and customers.

The factors affecting success of the project have been a topic of interest since the early 1960s. There are many reviews in the literature from 1960 onwards.

Kylindri *et al.*[4] have reported that there is no single uniform measure for project success and they have classified success criteria of building projects as shown in Figure 1.

Khang[5] has defined project success as effective use of a project's final output and sustained achievement of project purpose and long-term goal.

Value capture and benefit realization are the ultimate determinants of project success. It is also important to note that presence of success factors does not guarantee success, but their absence is likely to lead to failure. Project can be a success despite poor project management performance and vice versa. Good project management can contribute to project success but it is likely to be able to prevent project failure. Usually government programmes can be defined in terms of satisfaction by those affected[6].

Project life cycle

Mian and Dai[7] classified project life cycle into four phases by as conceptualizing, planning, execution and closing phases; whereas Project Management Institute[1] called it as starting of the project, organizing and preparation, carrying out the project work and closing. In the conceptualizing stage, scope, specification and objectives of the project are defined. In the planning stage, schedule, budget, resources including manpower and risk are developed. In the execution stage, time, cost, objective and quality are monitored and managed. The closing stage is the deliverable phase where the output is made available, feedback is taken, analysis is done and recommendations are formulated.

Success factors

Bland and Ruffin[8] have listed 12 characteristics that are found in research-conducive environment. They are clear goals that serve a coordinating function, research emphasis, distinctive culture, positive group climate, assertive participative governance, decentralized operation, frequent communication, accessible resources particularly human, sufficient size age and diversity of the research group, appropriate rewards, concentration on recruitment

and selection, and leadership with research expertise and skill in both initiating appropriate organizational structure and using participatory management practices.

Balachandra[9] has identified 78 critical factors of success and failure of R&D projects and new product development. He has classified them into four categories on basis of being related to market, technology, organization, environment. He concluded that impact of many of these factors is contextual.

Ernst[10] reviewed new product development (NPD) and listed the factors based on NPD processes, organizational aspects, cultural aspects and role of commitment of senior management aspects. Under NPD process quality of planning, continuous commercial assessment, orientation towards market, market orientation and customer integration are listed. Multidisciplinary nature of team members, qualities of project leader, autonomy, commitment of the project leader and team members, communication, type of organization are listed under organization.

van der Panne *et al.*[11] have reviewed 43 studies dealing with success and failure of innovation and have grouped the factors under four categories on basis of being related to firm, product, project and market.

Smith[12] identified nine key factors that impact on ability of the organizations to innovate. They are management style and leadership, resources, organizational structure, corporate strategy, technology, knowledge management, employees and innovation process. Smith has also proposed a model.

The authors have identified a large number of factors which leads to the success or failure of R&D projects. They conclude that, though there are common factors, many of them are contextual.

Jain *et al.*[13] have identified people, idea, funds and culture as the four basic elements needed for an R&D organization. Trott[14] extensively covered various factors essential for R&D and product development.

Nine factors identified by Cooper and Kleinshmidt[15] are processes, strategy, resources, R&D spending, team, senior management commitment, organizational climate and culture, cross functional teams and senior management accountability.

Ginevicious and Vaitkunaite[16] found 12 significant dimensions such as involvement, cooperation (collaboration), transmission of information, learning, care about clients, adaptability, strategic direction, reward and incentive system, system of control, communication, agreement, coordination and integration.

A study conducted on 432 new product development programmes in USA and Europe[17] found that an organization valuing innovation and globalization, and with active support of senior management will lead to making the firm truly global.

Leadership, organization researchers and capacities, and research processes are factors that influence success[18]. Bland *et al.*[19] conducted a study among 465 faculty members from University of Minnesota, USA to better understand how to facilitate faculty research. The questionnaire consisted of 56 primary questions on about 150 items. They have identified 27 factors under three major categories of individual, institutional and leadership. Individual factors include socialization, motivation, content knowledge, basic and advanced research skills, simultaneous projects, orientation, autonomy and commitment, and work habit. Institutional factors include, recruitment and selection, clear coordinating goals, research emphasis, culture, positive group climate, mentoring, communication with professional network, resources, sufficient work time, size/experience/expertise, communication, rewards, brokered opportunities, decentralized organization, assertive participative governance; and factors under leadership include, scholar, research orientation, capability fulfils all critical leadership, participate leader, etc.

Jordan *et al.*[20] conducted a study with the aim of assessing and improving the effectiveness of research organizations and identified 36 attributes which classified under four groups as human and physical resource development; innovation and cross fertilization of ideas; management and internal processes; setting and achieving relevant goals.

Some of the causes of project failure according to State System Development Life Cycle (SDLC) are lack of executive support, technological incompetence, insufficient resources, unrealistic expectations, unclear objectives, unrealistic timeframe, new or untested technology[21].

In India, a report prepared by FICCI[22] concluded that lack of appropriate mindset, insufficient resource base, lack of commercialization capabilities, lack of intellectual property infrastructure, lack of incentives, absence of collaboration and regulatory framework are the major hurdles for institute–industry collaboration in India.

The National Knowledge Commission's report on innovation in India has pointed out that 'lack of collaboration with other firms' is one of the major barriers to innovation[23]. Other factors include shortage of skills, lack of internal and external pressure, inability to move beyond first innovation, organizational hierarchies, etc.

A study and analysis of 15 research environments in Denmark[18] has yielded characteristics of good research environment such as input (funding), organization, research process and outcome. It also specifies the necessary preconditions for excellence as organization and leadership, framework and structures, and resource allocation.

Resources

Resources consist of both human and non human. Under human resources both leader and team are important. Non-human resources consist of factors like funding, equipment, laboratory space, etc.

Funding consistent with realistic project expectations, availability of funds throughout the duration of the project, accessibility of state-of-the-art equipment in key areas and adequate laboratory space are the key factors.

Non-human resources – leader and team

The relationship between intrinsic motivation and risk taking is demonstrated in a study conducted by Dewett[24] among R&D personnel consisting of 165 employees and their supervisors in USA.

Jain *et al.*[13] mentioned that compared to other areas in R&D personnel are unique in features such as good academic training, high aptitude, intelligent, creative and motivated with little or no training in managing people. They have also pointed out that the best work occurs in an environment that is not too tightly controlled, provides with enough challenge as well as adequate security, does not impose rigid goals, has moderate coordination, allows individual autonomy, usually results in finding best solutions, has a sense of control and specific goals that are difficult but attainable.

In a study based on the cross functional teamwork, Holland *et al.*[25] categorized success factors into six such as task design, group composition, organizational context, internal processes, external processes and group psychological traits. They showed the importance of strategic alliance between functions, a climate supportive to team work and team-based accountability.

Mishra *et al.*[26] reported that communication within the project team and emotional quotient of the project manager was relevant. Hemlin[27] found that perception and leadership style have positive impact on output whereas work pressure affects it negatively. Based on 400 responses, Muller and Turner[28] observed that intellectual, managerial and emotional competences are the major requirements of a project leader. Daniel and Davis[29] showed the importance of community and commitment. In contrast, Turner[30] showed that the leader has less of an impact on the success of the project.

Features such as right mix of adequate technical competence and team strength was above the 'critical mass'. Everyone was doing what they do best. Internal cross-fertilization of scientific/technical ideas, open discussion on disagreements, member's awareness about their performance evaluation criteria, mutual respect/trust among members and good leader/member relationship are found to be the assets of a good team[18,24,31].

Ability to foresee the future and plan ahead, technical competence to lead the project, ability to distinguish between right ideas and bright ideas, serving as a sponsor and mentor to team members and lead them by example, ability to attract and retain top quality colleagues and being part of the organizational decision making are the factors of a good leader[1,32].

Internal environment

Internal environment consists of work environment, organizational culture and top management support.

As creativity is considered as the root of innovation, a study was conducted using the instrument 'Assessing the climate for creativity (formerly known as work environment inventory)' by Amabile and colleagues[33]. The study was based on 30,000 employees working on electronics products in USA. The variables considered are organizational and supervisory encouragement, work group supports, resources, challenging work, freedom (stimulant scales) and organizational impediments and work load pressure. The authors concluded that perceived work environment influences the organizational creativity.

An exploratory study was conducted by Heinze *et al.*[34] based on 20 case studies on nanotechnology and human genetics fields in Europe and USA. According to the authors, the previous studies were based on outcome variables such as productivity, recognition and research breakthroughs, whereas the present emphasis is on recent research organizations and research environments based on three themes: specialization, communication and research autonomy; group size and departmental effects; and resources, recruitment and leadership. The findings are that small group size consisting of 4–6 members, organizational context, complementary and variety of technical skills and resources and leadership are influencing positively whereas pressure from funding agencies affect it negatively and in a multidisciplinary environment, cognitive distance inversely affects physical distance. The authors also suggest flexible core funding from their own institutions to overcome this. They also stress the need to develop a 'Governance theory of research organizations'.

The programme Director's support for research and time for research are found to be important in a study on research culture conducted among 428 participants by telephone, mail survey and interview[35]. Aronson and Lechler[36] found that organizational culture can create good citizen behaviour in a study of 222 participants from 71 product development, IT and engineering project firms in USA. Jeff[32] reported that people in supportive environment take more risk. Project manager, team and environmental factors are listed as apparent by Belassi *et al.*[37]. Gassmann *et al.*[38] have identified orientation of processes, increased autonomy and tighter integration decentralized units as key factors.

Shenhar *et al.*[39] identified variables from literature and conducted a multivariable analysis and found out 13 success measures under 3 categories of meeting design goals, benefit to customers and commercial success and failure potential; and 360 managerial variables under 5 categories of idea origination and project milestones, planning and control, policy and design consideration, organizational factors documentation, reporting and managerial policy.

Table 1. Factors that influence the outcome of the project

Success factor	Reference												
	20	19	13	40	44	26	31	42	41	28	43	22	23
About the project			X	X	X							X	X
Physical and financial resources	X	X	X	X	X	X						X	
Team	X	X	X		X	X							X
Leader	X	X			X	X				X			X
Organizational culture and support	X	X	X	X	X	X						X	X
Collaboration with other organizations									X			X	X
Difficulty of the project					X		X	X			X		

Organization with a clear vision, laboratory and staff with a history and, reputation of producing excellent and relevant research, organizational climate characterized by high morale, existence of a spirit of innovation, dedication to work, existence of a high receptivity to new ideas, high encouragement given for doing projects, freedom of choosing right course of action among alternatives, high risk tolerance and acceptance of failures, existence of a high level of integration between basic and applied research and technology development, timely feedback and encouragement by the top management, help from support services, top management supports during crisis, organization supports on effective utilization of project output and decentralization lead to higher success[19,20,31,40].

External environment – collaboration

Reports by the National Knowledge Commission and FICCI have pointed out the need for collaboration in R&D which is very much lacking in India[22,23].

Factors that necessitate/affect collaboration are knowledge, equipment/facilities/processes, different ways of working, higher visibility, availability of collaborators and their willingness to collaborate, availability of clear agreement/mutual understanding among collaborators, even risk distribution, existence of a common purpose, open communication and synergy among collaborators and effective sharing of resources[41].

Degree of difficulty

Difficulty of the project or risk involved play a significant role in its effective completion.

NASA has developed a method for measuring degree of difficulty related to development of technology. Here risk is classified into five categories such as low risk (probability of success 99%), moderate risk (probability of success 90%), high risk (probability of success 80%), very high risk (probability of success 50%) and in the so high risk category, where fundamental breakthrough is required (probability of success 10–20%)[42].

The indicators of difficulty are project strategy (newness to the firm newness to the market) and business strategy which were found to be critical[31] and the following are the parameters used to estimate the newness of the outcome: Cost reduction, repositioning, improvements in/revisions to existing product/process or new product/process that provide improved performance or greater perceived value and replace existing product/process, addition to existing product/process lines, new to the organization, new to the nation, new to the world, availability of knowledge for execution of the project within the group, the organization, the nation, or with global linkage partners, number of parallel approaches tried in the most crucial processes[42].

In addition to the cost, time and objective-based success criteria, the number of publications, patents, technology transfer, etc. are a measure of the outcome in R&D projects[43].

The relevant factors that influence the outcome of public-funded R&D projects, which are not directly market-oriented and their sources from the most relevant literature are given in Table 1 and Figure 2.

Conclusion

It is evident from this review that factors which influence the outcome of the R&D projects vary considerably, they are contextual and to some extent contradictory also. Hence, it relevant to identify variables based on the need from the basic factors. Once market orientation is exempted, the other three fundamental factors are the project itself, the resources and the environment. Project characteristics include its relevance with respect to the vision of the organization and the degree of difficulty of idea. Resources can be human and non human. Under human resources, the leader and the team are vital. Non-human resources consist of funding, laboratory equipment and space. Environment includes both internal and external. Under internal factors, organizational culture and top management support are essential. External environment for the R&D projects collaboration is most important and also found highly relevant in studies

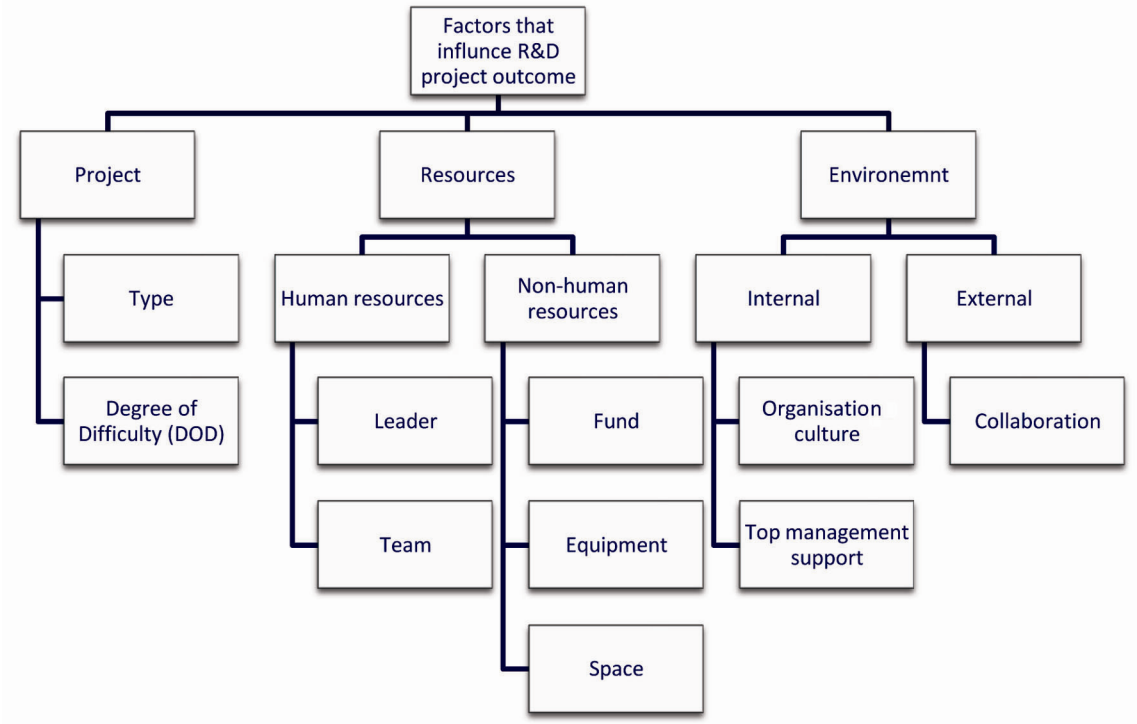

Figure 2. Success factors that influence the project.

conducted by FICCI, NKC, etc. These factors are represented in Figure 2, and will help organizations and principal investigators of the projects on effectively managing the project to achieve the desired outcome.

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Received 13 November 2013; revised accepted 13 November 2014