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RESEARCH AND DEVELOPMENT PROJECT MANAGEMENT

Study book

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Introduction

Global competition encourages companies to seek for a more innovative way to survive. More and more complex R&D-based activities are introduced and the managerial approach is extremely important, while R&D by its nature requires special managerial attitude. However, as time and money-consuming activities, R&D activities are under high risk and uncertainty. Therefore, public and private partnership seems to be a plausible measure that could be exploited as a stabilised factor for the private sector for sharing the risk on the one hand and increasing the performance and effectiveness for the public R&D sector on the other. The other benefits include: helping focussing public R&D programmes, increasing awareness between industry, regulators and researchers, closing the gap between theory and technology¹.

However, the fact that those public research institutions, as new knowledge generators, represent a different approach towards R&D results from R&D intensive businesses, which presuppose the exploitation of R&D results, and these differences should be taken into consideration when talking about public and private partnerships. Meanwhile, public R&D institutions act in a less competitive environment, which has conditioned lower tension and less stressful environment resulting in less innovative output. As a consequence, the managerial approach for public R&D institutions is left out of day-to-day processes. Private and public institutions have different attitudes towards:

- driven targets,
 - availability of time for innovation,
 - motivation, and
 - desirable results,
- which places a dual obligation on an R&D manager.

¹ Sperling, D. Public-private technology R&D partnership: lessons from US partnership for a new generation of vehicles / *Transport policy*, 8, 2001. P. 247-256.

The purpose of this study book is to review all issues of R&D project management with the focus on duality R&D activities and adapt the project management technics to the best needs of R&D management.

Study book gives overview of development R&D management over the last 4 decades. The R&D project concept is presented together with R&D project management risks, variances and project success criteria. Specific R&D project life cycle with special focus on product and technology development are discussed. All other issues as R&D project team, communication, quality management are overviewed.

Chapter 1.

DEVELOPMENT OF R&D PROJECT MANAGEMENT

The main concepts²

Research	Research is a systematic study directed towards fuller scientific knowledge or understanding of the subject studied. Research is classified as either basic or applied research
Research and development	Used to refer to activities for intellectual work creating new knowledge (research) and developing new products. Common abbreviation is R&D

R&D management as a research topic is relevant for the countries where strong industry has built its success on R&D for years and represents prominent R&D outputs suitable for further use, for instance – UK³, Italy⁴, New Zealand⁵, China⁶, Sweden⁷.

- 2 Washington State Department of Transportation (WSDOT). PROJECT MANAGEMENT GLOSSARY OF TERMS, SPRING 2005. <http://www.wsdot.wa.gov/nr/rdonlyres/3dde6d10-c5fb-4d45-8386-4180ce905bd0/0/wsdotpmglossary.pdf>. 25/08/2013.
- 3 Winter, M.; Smith, C.; Morris, P.; Cicmil, S. (2006) "Directions for future research in project management: the main findings of a UK government-funding research network". *International Journal of Project Management*, Vol. 24, p. 638-649.
- 4 Cesaroni, F.; Di Minin, A.; Piccaluga, A. (2004) "New strategic goals and organizational solutions in large R&D labs; lessons from Centro Ricerche Fiat and Telecom Italia lab", *R&D management*, Vol. 34, No. 1, p. 45-56.
- 5 Elias, A.A; Cavana, R.Y.; Jackson, L.S. (2002) "Stakeholder analysis for R&D project management", *R&D management*, Vol. 32, No.4, p. 301-310.
- 6 Yunsheng, Z.; Deming, Z.; Lifei, Z.; Lu, L.Y. (2007), "R&D team governance and R&D performance. Empirical evidence from Chinese software enterprises", *Journal of Technology Management*. Vol. 2, No. 1, p. 71-83.
- 7 Wincnet, J.; Anokhin, S.; Boter, H. (2009) "Network board continuity and effectiveness of open innovation in Swedish strategic small-firm networks". *R&D management*, Vol 39, No. 1, p. 55-67.

Traditional distinction between research and development has gradually vanished and was integrated in the entire system as a management volume. That greatly impacts new R&D project models in which separation between research and development phase vanishes in favour of integration of both efforts to develop a creative environment for research and make it strict in terms of time and a very competitive space for product orientation, as it is important to understand that new product management scheme cannot always lead to new product and can fail in spite of efforts.

1.1. R&D: The main concept

According to Frascati manual⁸, research and development is an ability to conduct different type of research and use created knowledge for product and technology development. Therefore, pure research and innovative activities together with rational use of costs and optimisation of products is abbreviated as R&D. Here is the final list of activities that could be attributed to R&D:

- Basic/applied research;
- Ability to maintain state-of-the-art knowledge;
- Technical forecasting ability;
- Well-equipped laboratories;
- Proprietary technical knowledge;
- Innovative and creative environment;
- Offensive R&D capability;
- Defensive R&D capability;
- Ability to optimise cost with performance.

The value of R&D for the sake of quality of life is highlighted in every strategic plan of every European country and within EU policies. That is why in Europe R&D is conducted in both public and private organisations with governmental support. It must be noted that during the last decade the majority of research initiatives were funded for the development of technology-oriented projects and few initiatives were supported for fundamental research. This proportion is very clear in the USA⁹ and finds

8 OECD. Frascati Manual 2002. Standartinė praktika, siūloma mokslinių tyrimų ir eksperimentinės plėtros statistiniams tyrimams. Vilnius, Eugrimas, 2007, p. 286.

9 Karthik, Mahesh, Varadarajan *et al.* *International Journal of Advanced Economics and Business Management*, No. 1, Issue No. 1, p. 052–057.

certain expression in Europe and is different in regard to fundamental research, when additional funds are allocated to support new ideas, whereas technological development extends the needs to keep pace with the support of private initiatives.

1.2. Evolution of R&D management

R&D management generations. During the last century, R&D management as an innovation stimulator has passed the evolution of 5 generations, characterised by simultaneous progress of handling R&D activities^{10,11}. The complex attitude to the effective management of R&D according to a wide variety of management targets turns the R&D management process into multidimensional tasks. Every new generation adds an extra managerial task to the list of manager duties. The first generation of R&D management was expressed by corporate lab creation. The second generation emerged when R&D was incorporated into the entire business system. The third generation is represented by R&D project management and portfolio management. The fourth generation put suppliers and customers on the R&D management scene, while the next generation consists of a network of innovation actors and stakeholders.

R&D management derives from knowledge management. While being responsible for the creation of new materials, processes and technologies, R&D seeks to respond to societal and market needs, when the society and the market shape the trend of R&D. Therefore, knowledge about society's expectations as to the new R&D products shapes R&D (the concept of product or process design). In the chain of knowledge management, R&D has a role of primary source of knowledge, so that R&D management and knowledge management concepts have the same origin. R&D management has survived different practices and developed management principles that evolved over time. The changes of approach to R&D management could be divided to sequences of time series called generations. The transformations represented by generations are more evolutionary than revolutionary, as external changes and new challenges push to seek for new lines of action and generate new understanding that could be called R&D outputs and the

10 Jincao, W. and Kleiner, B.H. (2005) The evolution of R&D management, *Management research News*, Vol. 28 No.11/12, p.88-95.

11 Park, Y. and Kim, S. (2005) Linkage between knowledge management and R&D management. *Journal of knowledge management*, Vol. 9 No. 4, p. 34-44.

new ways to enhance R&D productivity. By screening the main drivers of change in every new R&D management generation, the main determinants can be listed: the demand to speed up R&D output creation. Earlier, R&D was driven by human curiosity and willingness to explore the dark part of knowledge. By reason of such attitudes, in the R&D goals and the time needed for developing the final product were not interrelated. Meanwhile, external market pressure, growing competition, the primacy of business practice, globalisation created a positive environment to speed up R&D evolution with the creation of a new R&D management model.

From the review of the scientific literature two competing explanations of R&D generations could be found. Roussel¹² et al. have recognised three R&D management generations according to the recognition of R&D strategies, organisational forms, financial criteria, mechanisms of accountability (see Table 1).

Table 1. R&D management classification according to Roussel (1991)

Generation	Period	Characteristics
The first generation	1950-1960	Independent strategy of R&D Independent scientific laboratories R&D activities Real organisations
The second generation	1970-1980	Partly strategic competitive environment Needs-oriented R&D and risk-sharing R&D budgeting Differentiation of R&D activities Binary system of R&D management while centralisation and decentralisation is aligned. Matrix organisation Peer review evaluation process
The third generation	1990-	Holistic approach Partnership Market oriented Project management to R&D Target oriented evaluation and assessment

12 Roussel, P.; Saad, K.; Erikson, T. (1991) *The Third Generation R&D*, Harvard Business School Press: Boston, MA.

Subsequently, Rothwell¹³ proposed a typology of five generations of R&D management. He focused his research on technological innovation in start-up companies and proposed five generations of innovation and provided R&D management generational classification from the 1950s onwards. He found that each new generation was a response to a significant change in the market. He explained connections between economic growth, industrial expansion, more intense competition, inflation, stagflation, economic recovery, unemployment and resource constraints (see Table 2).

Table 2. R&D management classification according to Rothwell (1994)¹⁴

Generation	Period	Characteristics
The first generation	1950-1960	Technology development Linear model of innovation
The second generation	The end of sixties	Primacy of needs Market-oriented innovations
The third generation	1970-1980	Synergetic model Chain Linked Model
The fourth generation	1980-1990	Integrated model Horizontal and competed innovation
The fifth generation	1990	System and networking models Flexible innovation process

The first generation

After the Second World War the importance of R&D was conceptualised. New industrial development was based on R&D knowledge. That period is famous by the creation of new industrial sectors, such as semiconductors, pharmacy, electronics, computer industry, new materials. Traditional industrial sectors, such as textile or steel production heavily relied on new technology. That was a period when well-being was accepted as a productive use of R&D outputs, thinking that social problem will be solved simultaneously together with R&D. That determined understanding about

13 Rothwell, R. 1994. *Industrial Innovation: Success, Strategy, Trends*. See in Dodson, M. and Rothwell, R. (ed.) *The Handbook of Industrial Innovation*, Edward Elgar, Aldershot.

14 *Ibid.*

linear development of R&D, when R&D was at the first stage, led by new technologies and finished by new products.

Organisational response:

That period is characterised by corporate R&D lab creation. It was a time when new technologies were created. The main task of R&D management is to increase the productivity and quality of R&D outputs. The geographical distribution of such centres and managing of their activities was the second task of R&D management. It is the period of technology park creation. Looking at the development of the most successful centres, e.g. self-developed Silicon Valley or policy-driven Research Triangle Park in North Carolina (founded in 1958), Austin in Texas (founded in 1950), San Diego in California (founded in 1950)¹⁵, there is evidence that the first prominent commercialisation activities and attraction of companies have started after 15 years of founding of technology parks and strengthening of research universities.

The second generation

The second generation started in the sixties and lasted up to the seventies. The demand and supply balance became stable in the market, the competition increased and became the main driver for R&D orientation to the market. Short-term goals became dominant in the face of long-term objectives of fundamental R&D. The linear R&D management model was still active, but complemented by the element of marketing for the starting and closing phases.

Organisational response:

R&D labs were integrated in to the whole organisational system and became an equally important structural division as any other corporate division. The task for R&D divisions was oriented to customer needs. New ideas for further development were necessary in the market.

15 Smilor, R.; O'Donnell, N.; Stein, G.; Welborn, R. S. (2007). *The Research University and the Development of High-Technology Centers in the United States*. Economic Development Quarterly, 21, 203-222.

The third generation

The two oil crises in the global market in the seventies were the reason for inflation and increased unemployment. That situation pushed to reoriented R&D management, as companies reorganised their strategic thinking towards more rational activities. Companies were forced to consolidate, rearrange their costs and minimise the path between new knowledge and new technologies.

Organisational response:

This generation is famous for project management incorporation into R&D management. Portfolio management and project development became the main challenges for R&D. The long-term strategic goals were again recognised as important and decisions for the selection of particular goals were based on thorough evaluation. As the market is the customer for R&D, the focus was even more concrete.

The fourth generation

This generation is relates to the eighties and nineties, when strong corporations were gaining their power. The economy was in permanent positive development. Strong industry giants, such as Toyota, Sony and Honda made progress with R&D. The focus from the product itself was transferred to the entire business system while planning, production and product marketing were integrated into the entire process.

Organisational response

The R&D management objectives cover wider elements, such as indirect activities. Stakeholder role was recognised as important. Users were no longer the main shapers of R&D targets. Together with others stakeholders, suppliers were seeking to invite to the R&D management

pool. The multifunctional and the multidimensional content was integrated into R&D management.

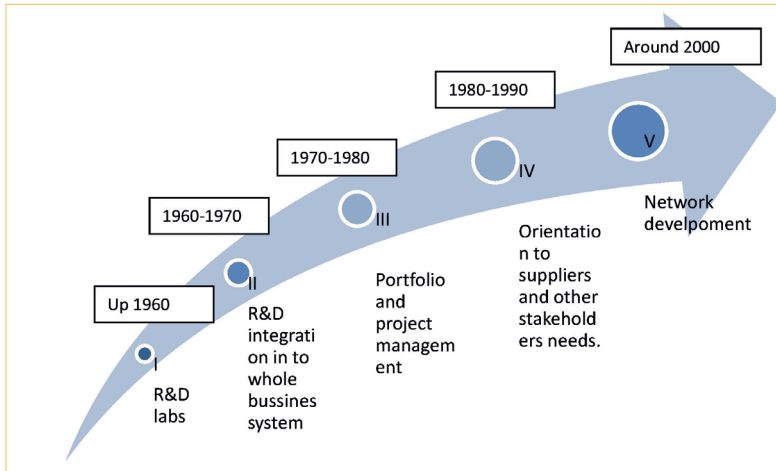


Figure 1. Evolution of R&D management generation^{16,17}

The fifth generation

The fifth R&D management generation is famous for wider understanding of R&D management activities. Globalisation and rapid creation of new technologies is responsible for the fact that companies which were competitors in the past started to share investment into R&D in the future and build partnership clusters. The list of R&D stakeholders was expanded again. New players were recognised as valuable contributors to R&D. A researcher is not a single stakeholder in front of producers, dealers, users and suppliers. Global companies, such as Microsoft, Netscape and Dell become prominent players in the R&D market.

Organisational response

Companies are building clusters and cooperate in both formal and informal networks. That system helped optimising investment into R&D,

16 Jincao, W. and Kleiner, B.H. (2005) The Evolution of R&D Management, *Management Research News*, Vol. 28 No.11/12, p. 88-95.

17 Park, Y. and Kim, S. (2005) Linkage between Knowledge Management and R&D Management. *Journal of Knowledge Management*, Vol. 9 No. 4, p. 34-44.

as the necessary investment level overcomes the abilities of a one single company or even their groups.

Figure 1 represents the evolution of R&D management generations.

However, the scheme with the fifth generation is not the end of the path and now more and more researchers and practitioners start discussing the sixth generation. The new R&D management generation should be realised with the help of the actors within the multi-technological network equally affecting product success, and R&D loses its leading function and is integrated in the common cooperation network sharing a common objective. *Organisational response R&D budgeting. Tacit knowledge and new technologies could be shared equally and generate new and specific applications of fundamental R&D findings.*

R&D and organisational design. To facilitate public and private partnership management and coordination, certain infrastructure that could act in line with organisational design is needed. It is possible to distinguish two types of infrastructures: temporary (coordination body)¹⁸ and permanent (R&D manager or R&D support structure). The coordinating body takes the leading role for public and private partnership coordination and steering, it acts as an independent entity in the “zone” free from individual public institution or private company stakes, and moves forward on the basis of unified stakes. This coordinating body could act effectively only with the support of each organisational design (permanent infrastructure). As for the organisational structure, the balance between R&D centralisation and decentralisation is under discussion¹⁹. The tendencies of downsizing, outsourcing and internationalisation in coherence with decentralisation of R&D²⁰ were demonstrated for the last three decades. Thus, organisational design in public R&D institutions should respond to the decentralisation approach for R&D management, while a R&D manager is incorporated in the hierarchic structure of an organisation.

18 Sperl, D. Public-Private Technology R&D Partnership: Lessons from US Partnership for a New Generation of Vehicles / *Transport Policy*, 8, 2001. P. 247-256.

19 Chiesa, V. *R&D Strategy and Organization. Managing Technical Change in Dynamic Contexts*. Imperial College Press, 2008.

20 Christensen, J. F. Incongruities as a Source of Organizational Renewal in Corporate Management of R&D / *Research Policy*, 31, 2002. P. 1317-1332.

1.3. Project management maturity model

It takes time and effort to reach the appropriate level of excellence in project management. This process passes certain stages and could be viewed as maturity of project management practice. The project management maturity model proposed by Kerzner gives a quick overview of what is essential and what stages need to be followed in order to reach excellence²¹. The model is based on five levels and characterised by different degree of maturity (see Figure 2):

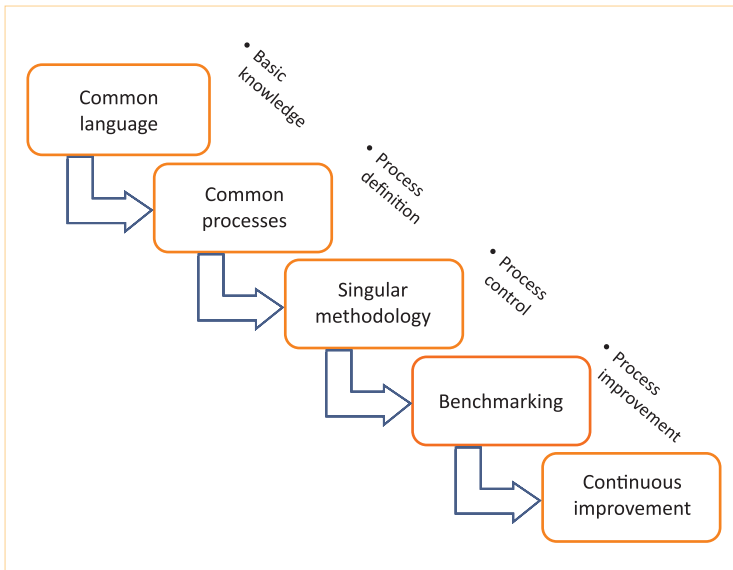


Figure 2. Five levels of project management maturity by Kerzner²²

- **Common language.** At this level, an organisation acknowledges project management and creates a common language to describe the procedures based on basic knowledge.
- **Common processes.** At this level, an organisation recognises the need to identify the project processes in order to unify it for the repetition of future projects.

21 Kerzner, H. 2001. *Strategic Planning for Project Management Using a Project Management Maturity Model*. John Wiley & Sons, Inc.

22 *Ibid.*

- Singular methodology. At this level, project management based methodology becomes a central methodology and incorporates all other methodologies used in a single one.
- Benchmarking At this level, origination grounds its competitive advantages based on common practice and permanent improvement of methodology.
- Continuous improvement. Singular methodology is going to be improved based on benchmarking information provided by continuous improvement at this level. Every single portion of information is evaluated in advance before input into methodology.

Kerzner emphasises that maturity process is linear with possible overlapping of some stages. No stage could be omitted or escaped. Even some stages, such as the second (Common Processes) and the third (Singular Methodology) are unlikely to overlap. Once a singular methodology is elaborated, older methodologies are abandoned automatically. Some stages of maturity tend to be interrelated with each other with more complicated dependency, the so-called feedback improvement. The speed with which an organisation makes continuous improvement strongly depends on benchmarking and singular methodology improvements, so that the last stage uses a feedback to third and fourth level of maturity.

Review questions:

1. What are the differences between research and development?
2. What are the main differences between R&D management generations?
3. Describe the project management maturity model.
4. What is the reason to understand the maturity model?

Chapter 2.

CONCEPT OF A R&D PROJECT

The main concepts²³

Project	A unique set of co-ordinated activities, with definite starting and finishing points, undertaken by an individual or organisation to meet specific objectives within defined schedule, cost and performance parameters
Finish Date	A point in time associated with the completion of a scheduled activity. Usually qualified by one of the following: actual, planned, estimated, scheduled, early, late, baseline, target, or current.

R&D activities are customary for both the public and the private sector. Global competition turns companies to seek for more innovative ways to survive. More and more complex R&D-based activities are introduced into business schemes not only by high technology companies, but also by low and medium-technology companies. On one hand, public R&D institutions can stand outside global competition for new added value solutions easier than businesses, while competition for new ideas is nevertheless the driver for public R&D.

Although some managerial differences still exist between R&D management practice in a private company and in a public R&D institution, a unified approach is applied and R&D nature requires special managerial dealing. When introducing R&D management measures, one should

23 Washington State Department of Transportation (WSDOT). PROJECT MANAGEMENT GLOSSARY OF TERMS, SPRING 2005. <http://www.wsdot.wa.gov/nr/rdonlyres/3dde6d10-c5fb-4d45-8386-4180ce905bd0/0/wsdotpmglossary.pdf>. 25/08/2013.

take in to account the background of public institutions who act in a less competitive environment, possibly leading to:

- less tension;
- less stressful environment;
- resulting in a less innovative output.

In spite of R&D management specificity, no one can argue that it is necessary to apply project management as an instrument to make activities more effective.

2.1. Project management development phases

Project management was first recognised in the construction industry. Aeronautics, space and security industry together with construction invest huge amounts of money into large-scale projects, where different activities proceed in parallel and require wide-scale skills and competences. The application of project management sharply increased in the sixties with a focus to develop technique for scheduling. Later on, after twenty years, project management was introduced into wider industrial sectors, and high technology and multidisciplinary sectors and new user-friendly techniques were created. IT programming products were introduced to help project managers modernise their day-to-day project management. At that moment organisational structural changes are introduced and adapted to the project management needs. Matrix organisational structure was introduced. It took thirty years to collect a sustainable body of knowledge on projects and a new academic discipline was recognised. Table 3 presents the summary of short evolution of project management.

Table 3. Evolution of the approach to project management

Period	Phase	Application sector	Methodology
1960-1970	Traditional project management	Construction Aeronautics and Space Defence industry	Scheduling and charting technique
1970-1985	Concentrated project management	High technologies Multi-disciplinary industries	IT packages, software for project management, matrix management ▶

1985-1993	Regeneration of project management	Every organisation uses it and develops formal methods	Quality management
1993 and later	Modern project management	Project management is recognised by top managers. The beginning of academic discipline	Changes and risk management

2.2. R&D project characteristics

We can find many project definitions, each of them lists the same essential characteristics that especially define a R&D project. Therefore, if led by “A Guide to the Project Management Body of Knowledge” after stating project management standards by the Project Management Institute (USA), we can define a project as “a unique set of co-ordinated activities, with definite starting and finishing points, undertaken by an individual or organization to meet specific objectives within defined schedule, cost and performance parameters”²⁴. Pooling the main characteristics, “project management” as a term has become a synonym with certain activity descriptions, e.g.:

- Activities should be
 - unique;
 - temporary (have its own completion date);
 - accomplished at a certain time;
 - fitted within the budget.
- Activities are accomplished by joining the capabilities of their execution teams.
- The goal, activities and performance are matched as perfectly as possible.

Once we have a unique and new idea, for the realisation of which we need time and financial resources, we can engage a hard-working and supportive team with a progressive and well-informed leader and supporters

²⁴ Project Management institute (PMI) (2013). A Guide to the Project Management Body of Knowledge, 5th ed., p. 589.

as stakeholders, we also need a well-organised plan. Such description leads us to project management. For more visualisation see Figure 3.

R&D project notion. When talking about a R&D project R&D specificities such as complexity, high uncertainty and high risk should be respected, some adoption of project management application could be applied or some approaches could be softened, however the main project characteristics need to be respected in full meaning. Time scheduling and strict compliance, keeping proper budget distribution or team mobilisation are the key points that should be carefully planned and followed during project implementation.

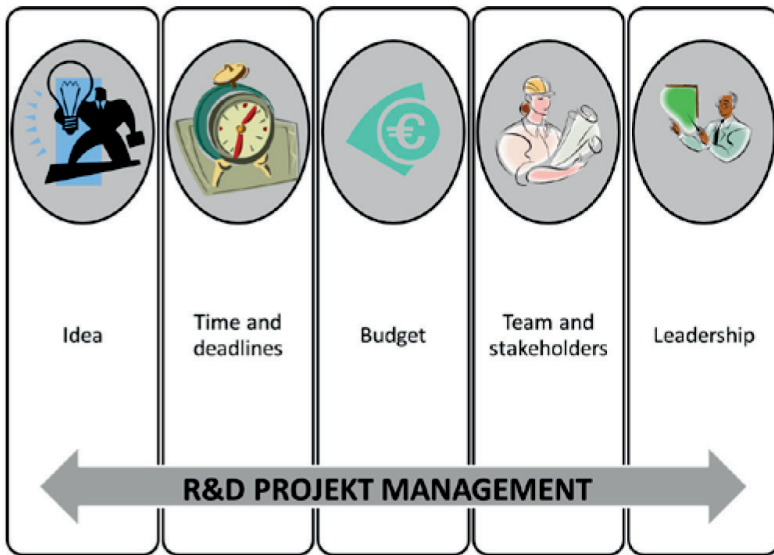


Figure 3. The concept of R&D project management

Project management helps mobilise human efforts to accomplish activities at a certain point in time. Deviation between the scheduled project completion time and the actual finish date of activities occurs naturally and varies largely (see Figure 4). Such a situation could be damaging for interconnected processes, as the delay could break contracts, ruin confidence, postpone product elaboration for an unpredictable period of time and reduce productivity. Therefore, project management seeks for

supportive measures how to carry out activities at moderate speed during all the project phases and to avoid a situation whereby efforts needed to complete the project increase dramatically to an enormous level.

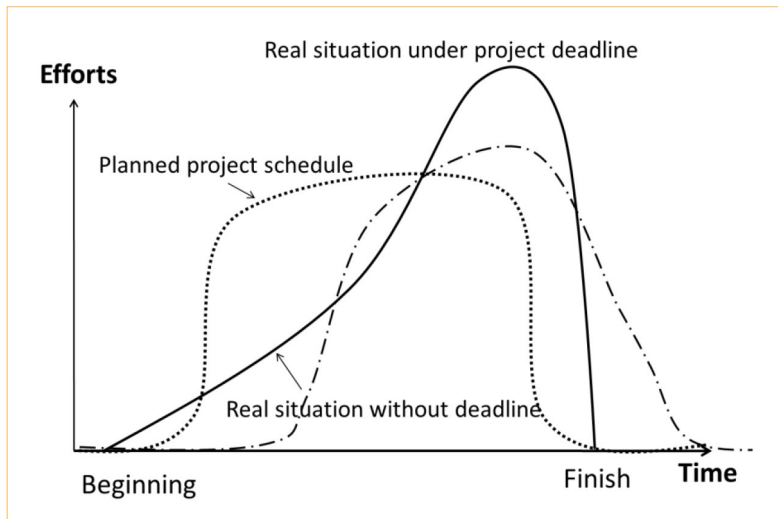


Figure 4. Efforts and time interdependency with and without project

R&D project in the scale of any type of project. Once we define the main characteristics of the project and distinguish special type of projects as R&D projects, we need to classify the whole range of possible projects. The typology could be based on the clarity of the goals and methods used to implement projects. From this perspective, we can distinguish four groups of projects. When the goals are clear and the method is well-defined, we have the production projects operated in the well-defined environment with well-defined parameters of success (first group). When the goal is clear but the method is unique and not very clear at the starting phase, we operate in the range of product development projects – namely innovation projects (second group). The third group consists of projects with a clearly defined method but with a less clearly defined goal. This group is called system development. The last group is represented by R&D projects with uncertainties in regard to the definition of both the method and the goals (see Fig.5).

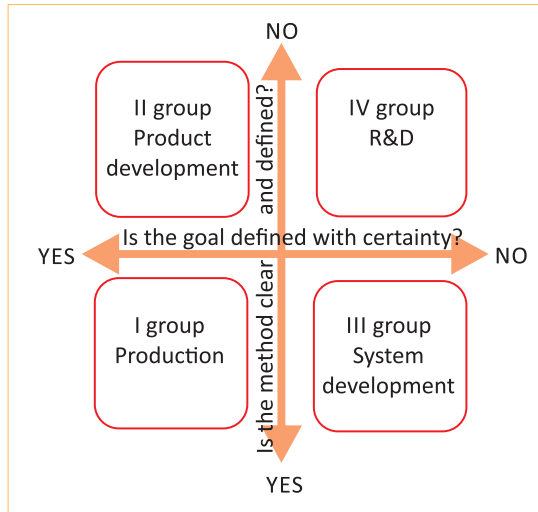


Figure 5. Four groups of projects types²⁵

2.3. R&D project management risks and variances

Every investment decision, into R&D project in particular, is highly uncertain and usually irreversible in terms of future rewards. Every new investor is keen to have an instrument to measure the risk and be able to evaluate possible variance of project outputs. If variations of the main project results are not allowed for standard project management, some flexibility “to alter the initial operation strategy adopted for investment”²⁶ is a common practice for R&D project. Acceptable variation from planned performance outputs realises the flexibility models of R&D project management. Huchzermeier, A. and Loch, C. (2001) have proposed a model with five types of operational uncertainty that allow R&D managers to decide whether to continue, abandon, expand, contract, or switch the project from the planned stage. This model recognises five possible variances of the project that has crucial impact on project performance. Those variances represent five sources of risk that R&D project could meet.

25 Barkley, B.T. 2007. *Project Management in New Product Development*. McGraw-Hill Professional Publishing, p. 397.

26 Huchzermeier, A. and Loch, C. (2001) Project management under risk: using the real options approach to evaluate flexibility in R&D. *Management Science*, 47(1): 85-101.

1. **Market payoff variability.** It is prices and sales forecasted. They depend on the external factors that are outside the project control: for instance, demographic changes, behaviour of competitors etc.
2. **Budget variability.** The running project cost is hard to keep at planned level for R&D projects. Both the direction overspending and underspending could occur, however the direction of overspending is more common.
3. **Performance variability.** It corresponds to uncertainty of product development. Some technical aspects of technologies could be developed in multiple ways and which one will gain better performance is hard to predict.
4. **Market requirement variability.** Market requirements are almost unknown, especially at the beginning phase of the project and in the idea conceptualisation phase.
5. **Schedule Variability.** Project performance impacts scheduling and the project could be completed earlier or later than planned in advance.

Figure 6 represents the interconnections of R&D project variances and their risk sources. Market payoff variability usually is the main parameter that helps deciding on the R&D project progress. Based on the market payoff situation, the manager chooses a strategy to continue or abandon the project at this particular stage.

The flexibility of R&D management via controlling variances for the risky project management characteristics realise the instrument for a manager to obtain additional information to make decisions in a timely manner.

Benefits of R&D project management. In order to reach the best possible effect of applying project management technique to R&D activities, one needs to realise the benefits that can be obtained out of these efforts. First of all, project management approach manages to cope with R&D uncertainties via helping in objective setting. Planning techniques help manage time and resources and assist the team with:

- seeing the big picture
- better understanding difficult tasks ahead and when they will happen

- putting first things first by prioritising important tasks above less-important tasks
- minimising efforts on unfruitful side tracks
- staying focused on the objectives
- making better estimates of time and resource needs
- improving communication among key personnel (6)
- seeing the need to look at alternative approaches or technologies
- making better decisions when dealing with trade-offs between time, performance and resource constraints²⁷.

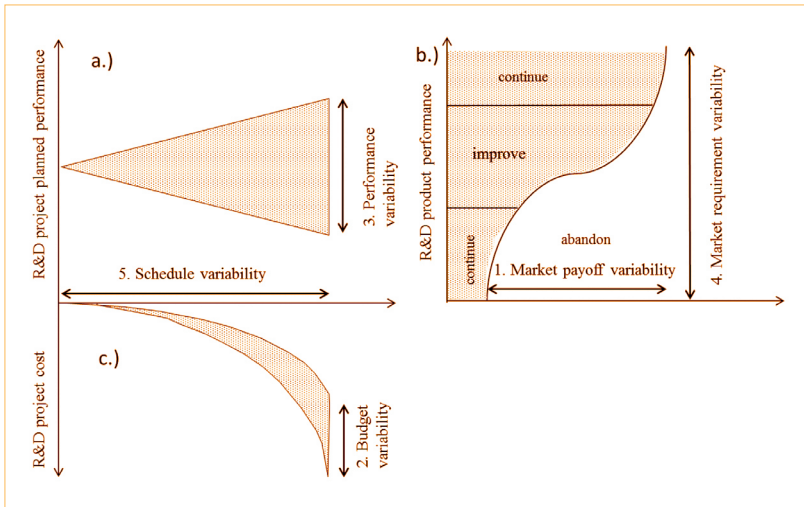


Figure 6. Five types of R&D project operational variability²⁸.

2.4. R&D project success criteria

Summarising the most commonly used criteria for project success evaluation, the following set of criteria can be listed:

- Organisational value:

²⁷ Larsen, E. R., 2004. Adapting Project Management Principles and Tools to Research and Development, Proceedings of the 2004 Fall National Annual Meeting of the American Institute of Chemical Engineers, Austin Texas, November 2004.

²⁸ Huchzermeier, A. and Loch, C. (2001) Project management under risk: using the real options approach to evaluate flexibility in R&D. *Management Science*, 47(1): 85-101.

How perfectly will results help company in R&D cooperation in the future? Whether any new idea has been created for the next R&D stage? If many partners took part in the project, added value for all organisations needs to be evaluated.

- Social value:

Sooner or later, R&D output usually becomes a public good, social value for the city, region or country could thus be evaluated.

- Professional value:

Renewing and regaining professional competence is as relevant as primary goal achievement of the project. The individual professional competencies of a researcher are equally valuable as research competence of the whole organisation.

- Economic value:

Economic value is the most widespread practice to value project success, however it is rather complicated to measure it directly for a R&D project. Nevertheless, the supplementary economic value, such as new jobs, economic growth or increase innovation capacity needs to be evaluated jointly.

In summary, project success could be evaluated from both project organisation and societal perspectives. The main criteria applied for R&D project success is the added value to knowledge creation and systematisation.

Review questions:

1. What is project management?
2. What are the main characteristics of a project?
3. What are the main differences between construction projects and R&D projects?
4. What is more important: scope quality or cost?
5. How are projects linked to the strategic plan?

Chapter 3.

PROCESS OF R&D PROJECT MANAGEMENT: PROJECT LIFE CYCLES

Main concepts²⁹

Project Life Cycle	A collection of generally sequential project phases whose names and numbers are determined by the control needs of the organisation or organisations involved in the project. A life cycle can be documented with a methodology.
Project Phase	A collection of logically-related project activities, usually culminating in the completion of a major deliverable. Project phases (also called phases) are mainly completed sequentially, but can overlap in some project situations. Phases can be subdivided into subphases and then components; this hierarchy, if the project or portions of the project are divided into phases, is contained in the work breakdown structure. A project phase is a component of a project life cycle. A project phase is not a project management process group.

R&D activities can be described as complex, interdependent, highly intelligent activities characterised by the following expressions: breakthroughs, new barriers, collaboration changes, heavy reliance on expert judgment to maintain quality, relevance, and performance. Research environment tends to change suddenly, thus R&D project customers or

²⁹ Washington State Department of Transportation (WSDOT). PROJECT MANAGEMENT GLOSSARY OF TERMS, SPRING 2005. <http://www.wsdot.wa.gov/nr/rdonlyres/3dde6d10-c5fb-4d45-8386-4180ce905bd0/0/wsdotpmglossary.pdf>. 25/08/2013.

supporters prioritise their efforts by playing an optimisation game within three constraints:

- scope of the project– specifications and capabilities;
- cost – different types of resources – money, human, infrastructure, or
- schedule – intermediate deliverables and completion of the final report.

The process as the main R&D project characteristic varies greatly across projects and programmes. If linear approach to construction projects gives a clear understanding of the relationships between activities and makes background for quality management, this approach is not appropriate for R&D projects or innovation projects. Some reasonable flexibility of project phases and interconnection between activities and schedule is needed.

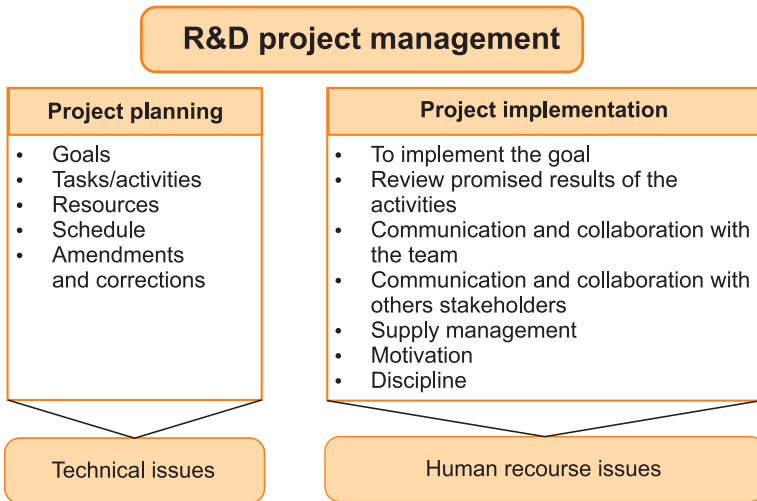


Figure 7. Two-stage approach to R&D project management

From the perspective of project management, R&D project should also deal with many different issues, such as planning of goals, tasks, allocation of resources, scheduling and making corrections if needed. Once we discuss about the project management process, two phases are clear. It is the planning phase and the implementation phase. Those phases differ

from each other primarily by their nature of activities. The first planning phase is more technical, whereby different technical issues should be solved and foreseen. Whereas the implementation stage is mostly characterised by the human resources issues, when team, stakeholder and other partner motivation is the key element for every single activity (see Figure 7).

3.1. Four-phased project life cycle

R&D project life cycle could be analysed as a four-phased process. See Figure 4.

- Project concept (initiation) – what is to be done;
- Project planning (growth) – what and how to do;
- Project implementation (production);
- Project completion (shut-down).

The concept of a four-phase project cycle was proposed by PMI (Project Management Institute) in the first textbook “Implementation of Project Management” edited by Dr. Linn Stuckenbruck in 1981.

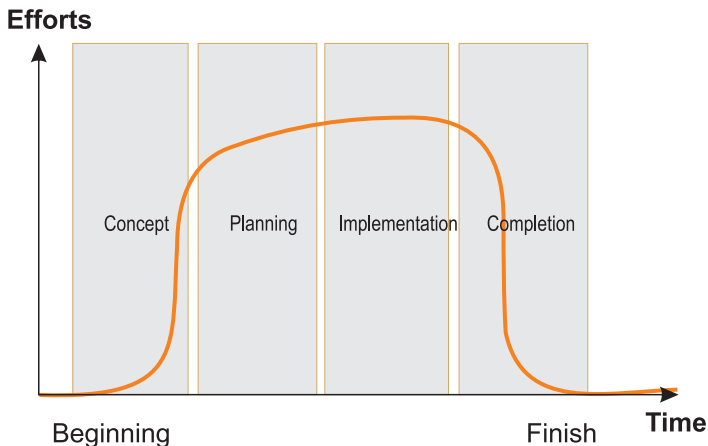


Figure 8. Project life-cycle according to Stuckenbruck³⁰

30 Stuckenbruck, L.C. ed (1981). *The implementation of project management: The professional's handbook* (p. 1-23). MA: Addison-Wesley Publishing Company.

Four-phased project life cycle realises the linear approach to project process management. However, it is not that natural when R&D activities are taking place. R&D and innovation is more likely to occur after non-linear phases³¹. Despite the fact that a project is always initiated based on the idea of conceptualisation, returning back to the project idea at every new project phase is a common set-up for R&D and it could save project when new contradictory knowledge appears. Once returning back to beginning, the project idea is rethinking and new R&D objectives and task could be set.

- Project idea:

During this phase the goal of the project is set. The goal for R&D projects is characterised as “ambitious”, “optimistic”, and “challenging”. If goals are recommended to be set strictly and be followed during the entire project, some flexibility is allowed for R&D projects. It is even recommended to set more abstract and less strict goals, leaving some flexibility for creativity and researchers’ motivation to improve the research plan if necessary during the implementation phase. It goes in hand with uncertainty and complexity of R&D.

- Project planning.

At this stage, the real deadlines and the time schedule is defined and the results are matched within the available time and resource limits. Same as for any other project, R&D project planning becomes challenging in setting the time scale, anticipate the results and the efforts needed to achieve each particular result. This is the perfect stage to plan the list of deliverables and match it with the breakdown project structure, by incorporating the real and the achievable results within the project phases. For a R&D project, there is a contradiction between “real and achievable results” and “the best results”. That contradiction seems as a good reason to seek for less ambitious goals and prevent from exploring the boundaries of knowledge. To some extent, an unrealistic plan is more preferable for a R&D project, as unrealistic plans stimulate higher results than planned in the beginning of the project. At the same time, high uncertainty of R&D limits our ability to predict results and no one could measure it and prove it before certain results show up. Therefore, the main task for a manager is to seek

31 Nelson, R. and S. Winter (1982), *An Evolutionary Theory of Economic Change*, Harvard University Press, Cambridge, Ma.

the balance between ambitions and the achievable goals at the planning phase. Tangible recommendations as to how this balance could be achieved are lacking. We only have one small recommendation, the so-called “five minute prediction” to plan the activities by seeing the future beyond five minutes ahead.

- Project implementation.

For a R&D project, it is a rather tricky task to set the specific starting and finishing time for any activity. In the real world, we usually have a totally opposite situation: floating deadlines with flexible task changing scheme. That project characteristic challenges the implementation phase and asks for a more precise and careful monitoring of project progress at every new project implementation cycle. Implementation phase becomes more crucial for a R&D project than for any other project: monitoring focus on the supervision of project environment, observation of new possibilities and constraints.

- Project completion.

Project results are evaluated at this phase. The traditional way to evaluate project success is to measure how perfectly the goals set at the beginning of the project fit the results. However, straightforward application of a single criterion for R&D project success is insufficient, considering that the situation can be changed during implementation and even goals could be affected by changes. Nevertheless, it is not a good reason to avoid widely accepted practice. It is worth adding some additional criteria, such as the range of applicability of results, usefulness for the future of an organisation and other added value, if any. Special attention could be paid to the social value for the society and beyond one particular organisation.

3.2. Five phases of project life cycle

Project life cycle could be analysed based on the five phase attitude when a R&D project is on the scene and a new product is developed. 5 phases are recognised here, such as:

- Conceptual;
- Planning;
- Testing;

- Implementation;
- Closure.

It must be noted that a clear distinction must be drawn between product life span and project life span and that these concepts do not fully coincide. Kerzner was the first to recognise that distinction in his book “Project management: a system approach to planning, scheduling and controlling” (1989). Using the systems theory, Kerzner³² discuss the new product development life cycle and recognised the complicated relationship between investment and return, where the gap in return occurred in every R&D project as a natural project development phase. A detailed graphical representation of R&D product development life span and project life cycle relationship is presented in Figure 9.

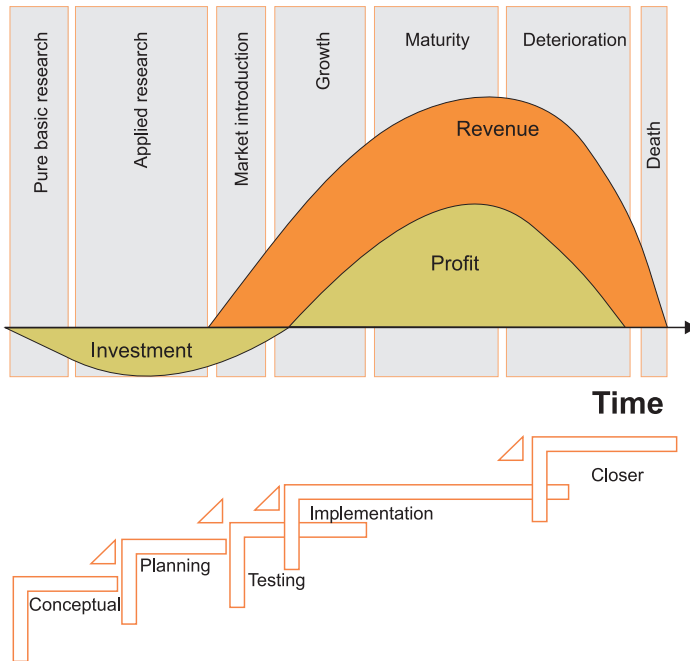


Figure 9. R&D product and project life cycle by Kerzner³³

32 Kerzner, H. 2009. *Project management: a system approach to planning, scheduling and controlling*. Wiley & Sons, Inc. Tenth edition.

33 *Ibid.*

While a R&D product is developing, at the stage of pure and applied research, a project sticks to the concept and planning phase. Some project phases overlap later. This situation is common for the production phase at the product growth stage. It is therefore rational to break down a long-lasting product development project into smaller projects and manage it as a portfolio of R&D projects.

3.3. Six-phases project life cycle

The best R&D project management practical fit represents flexible interpretation of project life cycle breaking it down into 6 phases. The six-stage model is commonly called as a basic model and covers the following phases:

- Initial scoping;
 - Project specification;
 - Detailed planning;
 - Implementation via actions and review;
 - Completion (with delivery);
 - Post-project evaluation.
1. Initial scoping. During this phase, the primary goal of the project is set. We use the words “ambition”, “challenged”, “optimistic” to describe R&D project goals and they drive the recommendation for goal-setting. Some differences are discerned in project management literature between projects outside R&D and R&D project management practice. If goals need to be fixed at the beginning of the project and should they be followed during the entire project cycle unchanged for projects other than R&D projects, it is recommended to set flexible goals for R&D projects. It goes in hand with uncertainties of R&D activities, creativity of researchers and ensuring the continuation of the project.
 2. Project specification. Project specification regarding resources needed, availability of technological knowledge and team skills mapping should be completed before detailed planning. The available know-how and the needed additional knowledge for the initiated project needs to be mapped before planning, as it considerably impacts project success.

3. Detailed planning. Detailed planning consists of time, resources and personnel management plans, when input and output of project activities are particularised. This phase is finalised with a time schedule, when the project period is broken down into phases with their particular tasks and indicators for success evaluation. This phase ensures the balance between the unrealistic goals that researchers want to attain and the practical implication that goals could be achieved during the particular period with the available resources.
4. Implementation stage. This stage covers the main proposed activities in the approved plan that mainly contribute to the essential results of the project. Intellectual property-related issues should also be taken into account at this particular stage. The implementation stage involves knowledge management issues. Intellectual property rights protection cycle could be broken down into smaller steps, such as:
 - Protection of know-how. Protection could be divided to even smaller elements. There are three types of knowledge that could be subject to protection: pre-knowledge – knowledge that is brought to the project but developed outside the project before its start.
 - Using protected knowledge.
 - Dissemination of knowledge that can serve as an additional source for the next R&D.
5. Completion. It is a critical phase for project management, during which the activities are finalised, the quantitative criteria and project success indicators are evaluated and presented in the final report. The easiest way to evaluate project success is to measure the ratio between the goals and project results. However, this method is rather limited for a R&D project. Some implementation elements could be changed during project implementation and the initial goals corrected.
6. Post-project evaluation stage. This phase is a critical phase for future practical lesson learning. During this phase, we evaluate the match of our efforts and outputs reached. Now is time to use and diffuse success stories. In order to maximise project impact, it is our goal to share the results as wide as possible.

3.4. R&D project cycle benchmarking

It is understandable that some deviations in phase concrete titles are allowed for specific R&D project, depending on the type of a R&D project. Considering the type of R&D, Coombs *et al.* (1998)³⁴ listed three different types: 1. projects oriented to new product or process; 2. product or technology enhancement; 3. creation or development of new product technology platform.

Let us review the differences of R&D project phases according to the R&D outputs and their types.

1. **First type: R&D projects oriented to new product or process.** This project starts from a scientific investigation phase which corresponds to the first project management phase “Initial scoping”. The next phase is very short: it is the decision moment. Then full scale product development begins with some elements of planning day-to-day activities. The fifth phase is implementation/ launching of the developed product or process and the project is completed with a post-launch management and control phase (See Figure 8.)

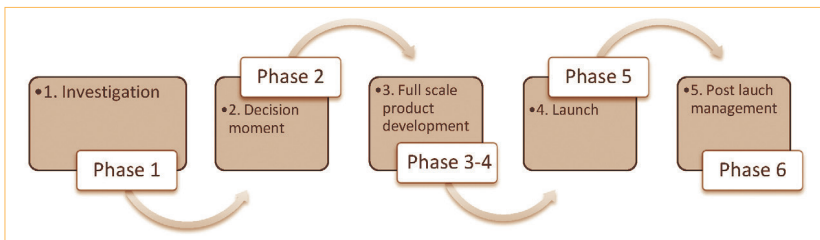


Figure 10. Project cycle of R&D projects oriented to the creation of new product or process.

2. **Investigation.** During this stage, the resource analysis is on the priority list. It is necessary to evaluate the market and the competitive advantages, to make the forecast of available

34 Coombs, R.; McMeekin, A. and Pybus, R. (1998) Toward the development of benchmarking tools for R&D project management. *R&D Management*, 28: 175–186. doi: 10.1111/1467-9310.00094.

technologies and to seek for available skills and competencies. This phase is complete after preparing the performance specification, the price specification and the list of requirements for new product or process. Usually agreed and widely used methods are applied to facilitate this stage. We can perform a stakeholder analysis, market and customer needs analysis, team building and leader searching, searching for business cases, collect knowledge and identify the knowledge gap. For the above-mentioned analysis, focus groups, literature screening, product modelling with computer-based systems and even production of prototype are recommended. The phase progress could be measured during the post-launch phase in accordance with the tasks. Matching between the plausible results and the obtained results, acceptance of the business model, the accuracy of forecast, project phase effectiveness as the cost benefit analysis is evaluated.

3. **Decision moment.** A 'go/not to go' decision is taken based on the output of the investigation phase. At this stage, particular alternative for project development is chosen in accordance with the first stage output.
4. **Full scale product development.** For a R&D project, merging of the detailed planning phase and the product development phase is recommended and it is to be analysed in one stage. Therefore, during this phase planning activities smoothly transit to plan implementation activities. The main result of this phase is the elaborated product or process that is ready to use, sell or distribute. In order to create and later produce a new product or process, it is necessary to plan technical production, inter and outer communication, marketing, supplying activities together with multifunctional team recruiting. Knowledge-sharing and new knowledge registration schemes are crucial for R&D project success. Intermediate milestones, the deliverable plan and the reporting period is fixed and followed with care. Some changes are acceptable and the main factor that legalises the changes is market changes. During this stage, a detailed schedule is prepared using PERT. This stage employs steering groups and committees that have a role of monitoring the progress of development.

Team motivation strategies and career development plan is incorporated in the main plan. Communication and decision-making is supported by a computer-based system that is created in accordance with team requirements. Progress evaluation is rather complicated to describe, as it depends on the specificity of product or process developed. Usually, the criteria of project management phase coincide with the product criteria. There is only one main recommendation: to analyse how product criteria settled in the first R&D project phase are met after the third phase.

5. **Launch.** This phase is dedicated to the launch of the product on the market. Thus all activities that help launching the process are now employed: it is necessary to prepare a sales strategy and support it with personnel having adequate skills, to produce reports with the purpose of self-learning for the future project; to use motivation schemes to recognise good performance and celebrate success. This phase success is sensitive to the quality of product or process that is created during the previous phase. As a consequence, multifunctional team partnership between R&D professionals with marketing specialists is needed. This phase success is evaluated according to the criteria stated above.
6. **Post-launch management.** The last project phase as a completion phase is dedicated to final report and lesson learning. Thus, the deliverables and reports need to be overviewed and the lessons regarding project cycles, costs, scheduling and performance need to be drawn. The tools assisting in this process are usually integrated into the organisation system and those tools are sufficient. We can list different type of reports as the outputs of this phase, such as technical assessment of product and tuning details for product improvement in its second generation, prepared customer support system, the list of new ideas for new projects. The recommended best practice is to make a formal evaluation of matching between the actual and the forecasted values for performance, financial benefits, product/process reliability, cost, time and management practice. Furthermore, it is necessary to evaluate new knowledge and skills.

The entire overview of the project cycle and its phases is presented in Table 4.

Table 4. The overview of the first type (a cycle of R&D projects oriented to the creation of a new product or process) project cycles in terms of activities, outputs, using tools and progress evaluation

Type 1: Project cycle of R&D projects oriented to the creation of a new product or process		
1. Investigation		
Type monitoring issue	Content	Tools
Activities	<ul style="list-style-type: none"> • To evaluate the market and competitive advantages, • To make forecast of available technologies; • To seek for available skills and competencies. 	Focus groups; Literature screening; Product modelling with computer-based systems; Production of prototype.
Outputs	<ul style="list-style-type: none"> • Performance specification; • Price specification; • The list of requirements for new product or process; 	
Practical recommendations	<ul style="list-style-type: none"> • Stakeholder analysis; • Market and customer needs analysis; • Team-building and leader searching; • Searching for business cases; • Knowledge collection; • Identification of knowledge gap. 	
Progress evaluation	<ul style="list-style-type: none"> • Matching between plausible results and obtained results; • Acceptance of the business model; • The accuracy of forecast; • Project phase effectiveness as a cost benefit analysis. ▶ 	

3. Full scale product development		
Type monitoring issue	Content	Tools
Activities	<ul style="list-style-type: none"> Detailed planning and implementation 	<p>Project steering groups and committees Motivation strategies and career development plans Program Evaluation and Review Technique (PERT) New product development decision support systems (computer based) Risk analysis</p>
Outputs	<ul style="list-style-type: none"> New product or process. Ready to be launched. 	
Practical recommendations	<ul style="list-style-type: none"> Planning: <ul style="list-style-type: none"> Identification of the best R&D project scheme (the best possible use of resources (project team, heir motivation scheme, technical supply and equipment) Identification of multifunctional project team: R&D personnel, technicians, marketing service, production service. Setting the information and knowledge sharing scheme. Setting product development task sequences Identification of cost and setting the expenditure plan. Programme milestone, reviews, deliveries, success criteria Implementation: <ul style="list-style-type: none"> Periodic progress review; Changes according to market factors; Arrangements for the next phase: product exploitation; Intellectual property right issues: product registration, recording of knowledge, patenting if possible. 	
Progress evaluation	<ul style="list-style-type: none"> Meeting the phase criteria 	

4. Launching		
Type monitoring issue	Content	Tools
Activities	<ul style="list-style-type: none"> • New product launching 	No specific tools
Outputs	<ul style="list-style-type: none"> • New product sales 	
Practical recommendations	<ul style="list-style-type: none"> • Sales strategy • Reporting, mutual learning; • Recognition for achievements 	
Progress evaluation	<ul style="list-style-type: none"> • Meeting the phase criteria 	
5. Post launch management		
Type monitoring issue	Content	Tools
Activities	<ul style="list-style-type: none"> • Assessment and evaluation of success 	Reporting system
Outputs	<ul style="list-style-type: none"> • Lesson learning; • Technical tuning for further development • Customer support system • New ideas for new projects 	
Practical recommendations	<ul style="list-style-type: none"> • Formal evaluation of matching between actual values and forecasted values <ul style="list-style-type: none"> a) Performance b) Financial benefits c) Product/process reliability d) Cost, time and management • Evaluation of <ul style="list-style-type: none"> – New skills – New knowledge • Identification of possibility of new product generation. 	
Progress evaluation	<ul style="list-style-type: none"> • Meeting the phase criteria • Actual and real cost assessment • Cost/benefit analysis • Capital productivity • Project criteria assessment (cost, time, performance) 	

2. Second type: product or technology enhancement

This type of project is focused on improving a particular product or technology characteristic with the specific purpose to enter the market (for instance, to reduce production cost, or to elaborate the family of the product). With the specific purpose of product and technology enhancement, individual project management is less essential with regard to the whole project portfolio.

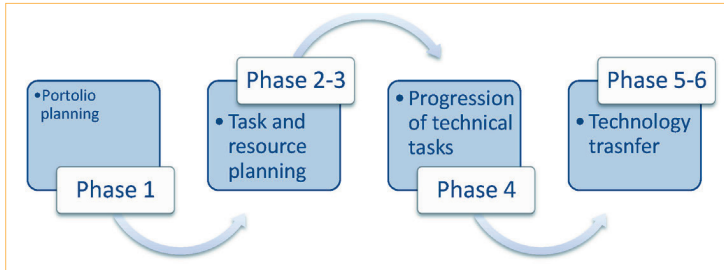


Figure 11. Project cycle of R&D product or technology enhancement

The set of projects cover product translation into a business plan, change of the selling range, product family extension, improving plan productivity, and change in production processes. In order to start this type of R&D project, the market needs to be established, so that customer relationship appears as a consequence. Business team has become a leading team for this type of project, since they set the targets and monitor the progress of the portfolio.

- **Portfolio planning.** During the first phase of portfolio planning, decision on the product and process development plan is made by business executives. That decision is based on market forecast and business strategy. As an output for this phase, a detailed plan of the works needs to be set. Those works are the elements of portfolio and produced as a document case with a detailed description and list of deliverables for monitoring the progress. This phase is devoted to identify the knowledge gap (technological, legal or marketing), if any. There are plenty of wide-spread tools to facilitate this phase, such as competitor analysis, market forecast, legislation analysis, standardisation analysis, resource planning. During this phase, the priority list of projects needs to be elaborated in order to help decision-makers sanction the projects and nominate the manpower.

- **Task and resource planning.** This phase is devoted to the specific project portfolio implementation plan. A research and technology manager assumes responsibility for this phase. The manager prepares the portfolio programme overview with the resource allocation plan and produces individual project plans with the list of intermediate milestones. The technical task and the sequences are identified. At this stage, it is necessary to take time to analyse the combination of project competences and other resources. Particular teamwork, communication, resource sharing plans are developed. Based on the analysis, team leaders are nominated for every project. A special plan for reporting arrangements is stated regarding customer needs. To ensure cross-connection between projects, each individual project should match the portfolio. We are using scheduling techniques as the main tools, such as Gantt charts and R&D skills mapping. Project management software is very important as well.

- **Progression of technical tasks.** This phase is based on day-to-day project management and reporting. After completing this phase, project is generating scientific or technological data; and progress assessment is produced via reporting. A solution ready for application comes as the main output. As a complementary output, we can list knowledge for learning about project management improvement and technological or scientific improvement. While planning experimental activity, experimental uncertainties are defined. This phase is led by documentation of technical activities. The team discusses lesson learning and what stimulates new idea creation within the team network. Of course, formal progress review is essential and produces rich body of information useful for the learning process.

- **Transfer.** Transfer activities entail an action when a technical solution is transferred to a new product. It is followed by the evaluation of the technical success of the project. The most common practice is to identify the most effective ways of transfer in order to ensure the best use of intellectual property rights. It is essential to set a clear distinction between transfers of property and the intention to exploit knowledge in the next stage. The effectiveness of the technical solution is evaluated with regard both to sales and production process. Research personnel are providing technical support for the transfer. Once we measure the success of the project phase, we can evaluate many quantitative outputs, such as the ratio between the actual and the planned cost, the ratio between the sales of a new product and the total sales, the cost benefit analysis, and capital

productivity. The accuracy of forecast provides additional information for project management learning purposes.

Table 5. The overview of the first type of (**project cycle of R&D product or technology enhancement**) project cycles in terms of activities, outputs, usage tools and progress evaluation

Type 2: Project cycle of R&D product or technology enhancement.		
Portfolio planning		
Type monitoring issue	Content	Tools
Activities	<ul style="list-style-type: none"> • A decision on the product and process development plan is made by business executives. That decision is based on market forecast and business strategy 	<ul style="list-style-type: none"> • Competitor analysis • Market forecast • Legislation analysis • Standardisation analysis • Resource planning • Project prioritisation methods (e.g. analytical hierarchy process)
Outputs	<ul style="list-style-type: none"> • Portfolio of R&D works • The document case: description of portfolio elements. • Portfolio deliverables 	
Practical recommendations	<ul style="list-style-type: none"> • To set formal procedure to prepare documentation • Identify risk and opportunities for <ul style="list-style-type: none"> – technical implementation, – market – legislation – standards – patents • Identify skills and other resources • Supply analysis for an optimal process • Prioritise projects • Prepare the detailed plan and the milestone list for portfolio progress evaluation, to set a business team responsible for progress monitoring • Identify the knowledge gap and knowledge needed to start development • Check the portfolio strategic fit and portfolio size. ▶ 	

Progress evaluation	<ul style="list-style-type: none"> • Meeting the phase criteria • Percentage of projects that were accepted according to the criteria: added value. 	
2. Task and resource planning		
Type monitoring issue	Content	Tools
Activities	<ul style="list-style-type: none"> • Project portfolio implementation plan. Responsibility for the research and technology manager. 	<ul style="list-style-type: none"> • R&D skills mapping • Project definition • Schedules: Gantt chart • Project management software
Outputs	<ul style="list-style-type: none"> • Portfolio programme overview with resource allocation plan, • Individual project plans with the list of intermediate milestones. 	
Practical recommendations	<ul style="list-style-type: none"> • Analysis of combination between project competences and other resources: teamwork, communication, resources sharing • Based on the analysis, nomination of team leaders for every project • Technical task and sequence identification • Identification of reporting arrangements: forms and deadlines focused on customer needs. • Cross interconnection between projects with portfolio 	
Progress evaluation	<ul style="list-style-type: none"> • Meeting the phase criteria 	
3. Progression of technical tasks		
Type monitoring issue	Content	Tools
Activities	<ul style="list-style-type: none"> • Day-to-day project management and reporting 	<ul style="list-style-type: none"> • Organisational reporting system • Organisational structure within R&D teams ▶
Outputs	<ul style="list-style-type: none"> • Data, progress assessment, reporting • Solutions ready for application 	

	<ul style="list-style-type: none"> • Learning for project management improvement 	<ul style="list-style-type: none"> • Organisational reporting system • Organisational structure within R&D teams
Practical recommendations	<ul style="list-style-type: none"> • Planning of experimental activity • Defining experimental uncertainties • Documentation of technical activities • Team discussions about lesson learning • Idea creation within the team network • Formal progress review • Project output measurement and reporting (conclusions, data, interpretation, learning from technical, scientific and project process point of view) 	
Progress evaluation	<ul style="list-style-type: none"> • Meeting the phase criteria 	
4. Transfer		
Type monitoring issue	Type monitoring issue	Content
Activities	<ul style="list-style-type: none"> • Transfer 	<ul style="list-style-type: none"> • No specific tools
Outputs	<ul style="list-style-type: none"> • technical solution transfer to new product • evaluation of the technical success of the project 	
Practical recommendations	<ul style="list-style-type: none"> • identify the most effective ways to ensure the best use of intellectual property rights • set the clear distinction between transfer of property, responsibility to the next stage of knowledge exploitation • provide technical support for transfer • evaluate the effectiveness of technical solution regarding sales and production process. 	
Progress evaluation	<ul style="list-style-type: none"> • ratio between actual and planned cost • ratio between sales of new product and total sales • cost benefit analysis • capital productivity • forecast accuracy. 	

Type 3. Creation or development of a new product technology platform

This type of R&D project is characterised by higher risk than any other. This project is in search for new conceptual possibilities to explore the existing R&D knowledge in the market and social environment. These opportunities could be hidden in the whole range of products, technologies and other competencies. The risk is associated with market demand in the longer run, which is hard to predict, and market demand usually does not exist at the present time and no forecast is available.

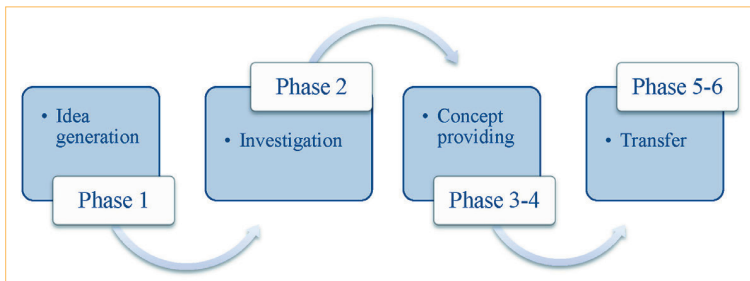


Figure 12. Project cycle creation or development of a new product technology platform

- **Idea generation.** This phase begins with an exploratory study to search for potential application of the available technology. As the target of the project is to elaborate a creative technological concept in the frame of existing forecasting technological demand, technological and market trends investigation could help making a final decision to go or not to go for the next phase. As an output, we are going to present the rational motivation to continue research which is done based on the definition of the project for the new technology platform. Usually we build a team from creative thinkers and assess how the new concept could fit into the company strategy, identifying state of the art technologies and analysing the global trends, risks and opportunities for technology development together with investigation of customer demand. At this stage, brainstorming, forecasting, organisational structure for R&D team formation could help as practical tools. This phase is complete when a decision to continue or not to continue is made.

- **Investigation.** This stage is devoted to preliminary experiments and a feasibility study with the focus on the more detailed concept and its impact on business. Networking between R&D and business departments, production and marketing units merging different approaches triggers real creativity that is extremely useful here. This phase is evaluated according to the defined criteria for project termination. Potential application for business unit is supported with business sponsorship, since the decision for continuing depends on the business interest and possible exploitation. As this stage, a feasibility study is produced and the knowledge that should be recorded and fixed in progress reports is generated. The most helpful tools are different types of internal and external databases for data storage, classification and categorisation.

- **Concept provision.** During this phase, the concept is elaborated and the proof is produced on the implementation capabilities. The main result of this phase is either prototype or data needed for implementation. There are some satellite activities that contribute to the success. They are setting a team of R&D and business managers based on multifunctional skills, reviewing and reporting for self-learning, checking the risks and opportunities for patenting and standardisation. Usually phase success is measured according to the criteria set for the phase. We are also interested in the number of possibilities to transfer research output to business. Based on transfer possibilities level, a strategic decision is made to pass or not to pass to the next phase.

- **Transfer.** This phase is devoted to final data, prototype and knowledge collection into one synergetic file and preparing it for integration into business. Self-learning should also be mentioned as a phase product, since it can improve project management skills for the future. It is the right time to analyse and evaluate R&D activities, produce project records, capture new ideas, ensure smooth transfer from R&D to business unit and select the right audience to present the outputs. The progress is measured by evaluating how phase criteria are met and by value of ultimate exploitation.

Table 6. Overview of the first type (**project cycle of creation or development of new product technology platform**) project cycles in terms of activities, outputs, using tools and progress evaluation

Type 3: Creation or development of new product technology platform		
1. Idea generation		
Type monitoring issue	Content	Tools
Activities	<ul style="list-style-type: none"> • Exploratory study to search for potential application of available technology. • Development of a creative concept . • Investigation of technological and market trends. 	<ul style="list-style-type: none"> • Brainstorming, • Technological forecasting, • Organisational structure for R&D team formation
Outputs	<ul style="list-style-type: none"> • Rational motivation to continue research, • Definition of project for new technology platform 	
Practical recommendations	<ul style="list-style-type: none"> • Build a team from creative thinkers • Asses how the new concept fits the company strategy • Identify state of the art technologies • Analyse the global tendencies for technology development • Investigate customer demand • Assess risks and opportunities 	
Progress evaluation	<ul style="list-style-type: none"> • Phase criteria evaluation, decision to continue and start the next phase 	
2. Investigation		
Type monitoring issue	Content	Tools
Activities	<ul style="list-style-type: none"> • Preliminary experiment and feasibility study for more detailed concept and its impact on business 	<ul style="list-style-type: none"> • Internal and external databases
Outputs	<ul style="list-style-type: none"> • Potential application for the business unit. • Business sponsorship. 	
Practical recommendations	<ul style="list-style-type: none"> • Networking between R&D and business departments, production and marketing. • Defined criteria for project termination. • Knowledge records and progress reporting. ▶ 	

Progress evaluation	<ul style="list-style-type: none"> • Meeting the phase criteria 	
3. Concept providing		
Type monitoring issue	Content	Tools
Activities	<ul style="list-style-type: none"> • prove the concept and prepare it for implementation 	
Outputs	<ul style="list-style-type: none"> • Prototype and data 	
Practical recommendations	<ul style="list-style-type: none"> • Set the team of R&D and business managers based on multifunctional skills, • Review and report for self-learning, • Check the risks, opportunities for patenting and standardisation, 	
Progress evaluation	<ul style="list-style-type: none"> • Meeting the phase criteria, • Level of transferring possibilities, • checking for rationality to pass to the next phase. 	
4. Transfer		
Type monitoring issue		
Activities	<ul style="list-style-type: none"> • Transferring the results 	<ul style="list-style-type: none"> • no specific tool available
Outputs	<ul style="list-style-type: none"> • Learning, • Prototype, data and knowledge, • New products 	
Practical recommendations	<ul style="list-style-type: none"> • Evaluation of R&D activities, • Project records, • Capture new ideas, • Ensure smooth transfer from R&D to business unit, • Select the right audience to present the outputs 	
Progress evaluation	<ul style="list-style-type: none"> • Meeting the phase criteria, • Value of ultimate exploitation 	

Review questions:

1. What is a project phase?
2. How is a project phase defined?
3. At which stage a typical project has the maximum cost?
4. In a typical project, at which stage do stakeholders have maximum influence?
5. At what stage of the project is the documentation prepared on the lessons learnt?
6. What is knowledge management transfer?
7. What is the sixth phase of the project life cycle?

Chapter 4.

PLANNING AND PROJECT SCHEDULING

The main concepts³⁵

Milestone	A significant point or event in the project.
Deliverable [Output/Input]	Any unique and verifiable product, result, or capability to perform a service that must be produced to complete a process, phase, or project. Often used more narrowly in reference to an external deliverable, which is a deliverable that is subject to approval by the project sponsor or customer.
Scheduling	The process of converting a general or outline plan for a project into a time-based schedule based on the available resources and time constraints.
Critical Path Method (CPM) [Technique]	A schedule network analysis technique used to determine the amount of scheduling flexibility (the least amount of float) on various logical network paths in the project schedule network, and to determine the minimum total project duration. Early start and finish date are calculated by means of a forward pass using a specified start date. Late start and finish dates are calculated by means of a backward pass, starting from a specified completion date, which sometimes is the project early finish date determined during the forward pass calculation.

35 Washington State Department of Transportation (WSDOT). PROJECT MANAGEMENT GLOSSARY OF TERMS, SPRING 2005. <http://www.wsdot.wa.gov/nr/rdonlyres/3dde6d10-c5fb-4d45-8386-4180ce905bd0/0/wsdotpmglossary.pdf>. 25/08/2013.

Program Evaluation and Review Technique (“PERT”)	A project management technique for determining how much time a project needs before it is completed. Each activity is assigned a best, worst, and most probable time estimate. These are used to determine the average completion time, which is used to figure the critical path and completion time for the project.
Work Breakdown Structure (WBS) [Output/ Input]	A deliverable-oriented hierarchical decomposition of the work to be executed by the project team to accomplish the project objectives and create the required deliverables. It organizes and defines the total scope of the project. Each descending level represents an increasingly detailed definition of the project work. The WBS is decomposed into work packages. The deliverable orientation of the hierarchy includes both internal and external deliverables.

One of the most significant definitions in project management is deliverables and milestones. Both definitions are equally important for scheduling, since they shape the timeline and engage project team to produce measurable output that could be evaluated after every single project phase. Once we incorporate the milestones and deliverables into project management, we need to describe its main characteristics. Deliverable is a synonym of project end result or output and it is usually a unique product, result, or capability to perform a complete process, phase, or project. Milestone is an intermediate step, significant point in project development, that could be controlled and help monitoring project success. Approach to project management through managing deliverables coincided with the movement of managing the outputs. Now more and more researchers state that “Rather than viewing project management as a time-driven support function, project management is factored into the deliverables budget, allowing project management performance to be monitored against outputs (deliverables) rather than inputs (time spent)”³⁶.

36 Bryde, D.J. and Joby, R. 2007. Product-based planning: the importance of project and project management deliverables in the management of clinical trials. *R&D Management* 37, 4, p. 363-377.

While selecting a special technical tool for planning and scheduling a R&D project, a manager should acknowledge that common project management tools are effective only if rational technique is combined with soft managerial tools for team management. In the general project management literature, more attention is paid to rational technique, while other methods are less discussed. Nevertheless, the rational technique needs to be aware of and used in cooperation with other methods. The purpose of this section is to overview the technical planning tools.

We can list a series of tools, such as Gantt charts, Critical Path Method (CPM), Program Evaluation and Review Technique (PERT), Critical Chain Project Management (CCPM), Extreme Project Management (XPM), Event Chain Methodology, PROMPT, PRINCE, PRINCE2, Process Based Management and Agile Management.

For better understanding the added value of specific tools, we can use a typology of two groups³⁷:

1. Network techniques (also known as 'logic diagrams'). In terms of network techniques, we quite extensively use the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT). Network techniques strive to demonstrate a project as a sequence of activities in a diagram, where activities are the nodes of network and sequence of activities are represented as arrows. A network represents the links and interconnections between every single task. When the network is analysed, the completion time of every task is calculated and leads us to the critical path – the longest way following the nodes from the beginning to the end of the project. We can also state that this path demonstrates the earliest possible completion time of the project. The earliest and the latest task completion time becomes the main feature of the network. Slack time is a derivative parameter. Although the techniques have the same attitudes and recommendations for method application, CPM is realised by the deterministic approach when activity completion time is estimated. Whereas PERT is based on the probabilistic approach and it comes close to R&D uncertainties. While CPM is more applicable in the construction industry, PERT

37 Ernø-Kjølhed, Erik. 2000. Project Management Theory and the Management of Research Projects, MPP Working paper, 1-37.

is more suitable for R&D project management. Nevertheless, both methods are eligible for use in R&D projects.

2. Non-network techniques.

The well-established non-network techniques are the Work Breakdown Structure and the Gantt chart. WBS is based on breaking down project activities into sub-activities as individual tasks. This task identification produces project overview and facilitates project planning and control (see Figure 13). The Gantt chart as a static graphical representation of tasks produces a momentum photo of project development. The tasks are listed on one axis, the completion time of tasks is listed on another axis. Both methods are recommended as a conventional tool for monitoring project success. Every project management book presents an extended description of WBS and the Gantt chart, so that any further explanation is unnecessary.

4.1. Creative work brake-down structure

R&D activities are very specific in terms of planning. Creativity that needs to be burst and uncertainties of expected outputs unknown at the beginning of the project make project time scheduling very complicated and uncertain. A situation where researchers do not know how they are going to resolve the problem and what type of research design they are going to apply is very common for R&D.

R&D deals with problem solving when the final product is a novel way of producing and using it, so usually the researcher knows the requirements and criteria for the desired product, but has no idea of the particular product. Therefore, creative approach to problem solving is needed and should be given room in R&D project management. CCBS realises the creative approach and helps the manager break down the general problem into its components for problem solving purposes.

Nevertheless, the traditional project management tool of the Work Breakdown Structure (WBS) helps resolving some R&D uncertainties and provides a tool for project monitoring. Of course, some deviation from traditional management tool could be admitted.

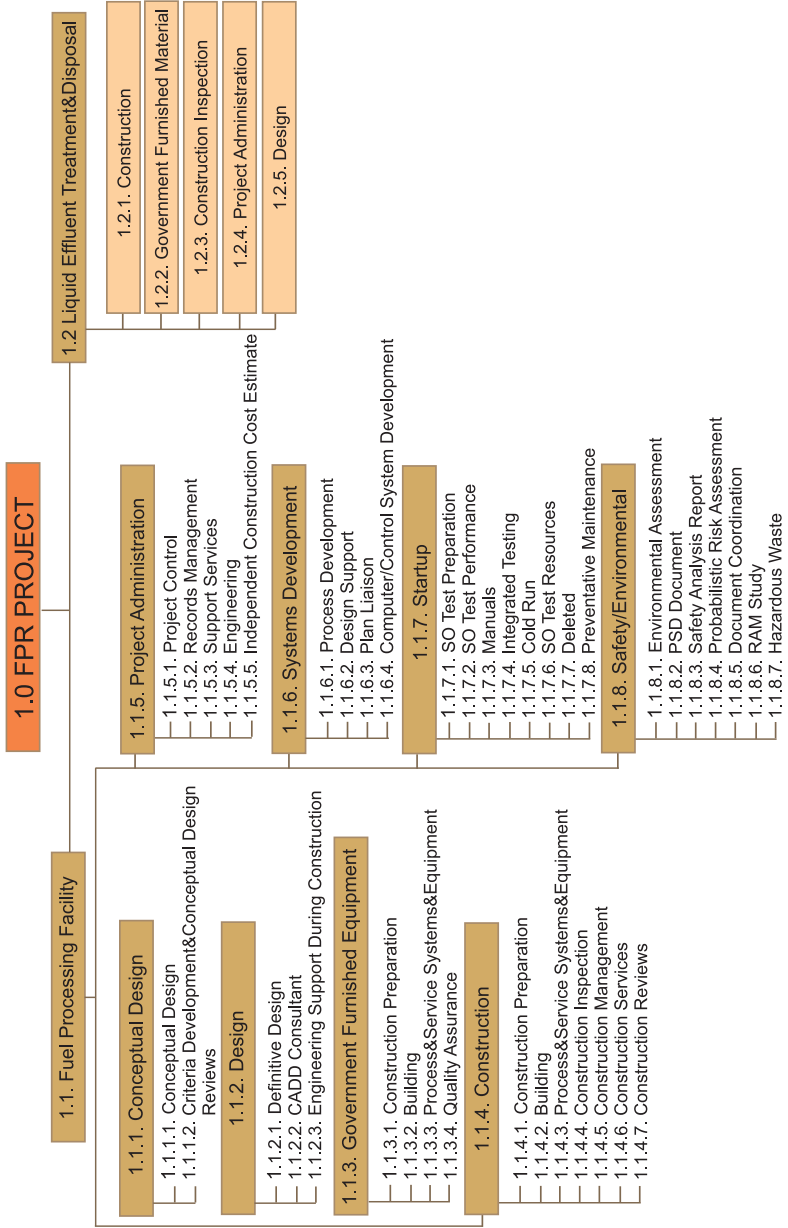


Figure 13. Example of project break-down structure³⁸

38 US Department of Energy. 2003. PROJECT MANAGEMENT PRACTICES, p. 18.

A Work Breakdown Structure as a tool helps breaking the overall project into smaller and manageable sections that could be applied in a one single task and align it with the organisational structure for sharing the responsibility inside organisational sections. It is hard to break the overall project into smaller elements if components are not known and organisational structure is not available and it is the case with R&D. The most dangerous for a R&D project is breaking the works according to the available organisational structure, as creativity is limited to an existing system and innovation would not be attained. For a R&D project, an adjusted tool is proposed, namely the Creativity Breakdown Structure (CBS)³⁹. CBS is based on the recommendation to break works into packages according to the specific research problem (knowledge, theory, energy source, materials, components, mechanical design, timing, cost, equipment, etc.). For resolving each fundamental problem within one package, creativity could be applied with adequate resources allocated for those needs. Breaking down the works into packages is a natural way of doing research. Researchers process it mentally. However, CBS documentation has an additional advantage in terms of using it for project communication, control and monitoring. CBS produces information valuable for both researchers/project designers and managers.

- Based on CBS, a researcher/designer can more accurately estimate the resources and time needed to solve problems and recognise the problematic works at the planning phase. In addition to ordinary WBS, CBS helps identifying the creativity level of every single work needed and to make decisions for scheduling according to it.
- A manager obtains a view on the project construction details, the research design applied, and the ways that the results are to be achieved. CBS helps the manager be aware of the needs and problems the research team can face and be assisted to overcome the problems with information and resources. The smaller part of the project becomes measurable more easily and facilitates monitoring the progress of the entire project. CBS also helps find out the activity that is more critical and needs more creative thinking and could be solved with different alternative solutions that can have an effect on project design.

39 Diegel, O. 2005. Breaking Down Innovation: New Tools for Project Managing Innovative Projects. *The Innovation Journal*, 10, 3, p. 1-14.

- In order to make Creativity Breakdown Structure effectively, some steps are recommended to follow in an organised and well-documented manner:
- Create traditional WBS or PBS (create a research design and break down the problem into smaller measurable tasks)
- Create a sequence or order of tasks and group them into packages
- Analyse the dependencies between packages and develop a relationship between every work.
- Break down the tasks into problems
- Assign resources for task implementation.

4.2. Gant Diagram

Gant Diagram is primarily applicable to project progress monitoring. However, the dynamics of delays, if any, will not be possible to track if any changes are made during the implementation phase. Nevertheless, the Gant Chart is quite popular among managers due to its simplicity to create and to read afterwards.

In order to create the Gant Chart, the following sequence of steps is recommended:

- Define the activities: we need the list of all activities that have their unique identification number;
- Sequence of activities: all activities are recognised as a sequence of tasks.
- Estimate the time – the starting and completion time of every activity needs to be calculated, slack time is estimated.

That data is shown in a two-dimensional graph.



Figure 14. Simple Gantt Chart view.

Review questions:

1. What is a milestone?
2. What is a deliverable?
3. What are the differences between project plan and project schedule?
4. What is a critical path?
5. What techniques and tools are used for project management?
6. What does work brake-down structure define?

Chapter 5.

R&D PROJECT SELECTION AND EVALUATION

The main concepts⁴⁰

Impact	An assessment of the adverse effect of the risk occurring. Used in risk analysis as one part of the assessment of a risk, the other being a likelihood
Criteria	Standards, rules, or tests on which a judgment or decision can be based, or by which a product, service, result, or process can be evaluated.

5.1. R&D project funding

R&D projects are funded by different sources:

- Governmental funding. This type of source is usually scarce, with some exceptions in certain well-developed countries (e.g. the USA in the mid-sixties, Sweden and Finland in late twenties).
- Industrial funding. Private sources provide entire funding for research with the purpose to use project result locally in the company.

Every funding scheme has its own regulations and rules as to the funding of a project and to the possible redistribution of financial resources within the project activities. During the last 20 years of supporting R&D, the EU has introduced and spread widely the applicable rules for public money distribution. Where a project is proposed by a public institution, the

40 Washington State Department of Transportation (WSDOT). PROJECT MANAGEMENT GLOSSARY OF TERMS, SPRING 2005. <http://www.wsdot.wa.gov/nr/rdonlyres/3dde6d10-c5fb-4d45-8386-4180ce905bd0/0/wsdotpmglossary.pdf>. 25/08/2013.

funding reaches up to 100% of the eligible costs, with some small deviation. Private companies are also eligible to obtain public support for R&D and the government is willing to share the risk of doing research. Those company research activities are supported up to 50%, ensuring fair and reasonable competition. Now it is more and more common to use a shared funding scheme, when the cost of the risk of doing R&D is shared between public and private funding sources. In order to encourage the motivation of a project participant to strive for better project results, institutions are promoting contribution to the project by additional self-funding.

Funding is tightly coupled with project selection, ranking and evaluation techniques.

5.2. Fundamental evaluation difficulties

As R&D funding is often underinvested, every research team faces immense competition for resources. Solid and transparent project proposal evaluation and selection methods and clear procedures are necessary.

Every method that proposes clear procedures and ensures:

- reliability of the evaluation output;
- reduced subjectivity;
- stimulation of innovation;
- is valuable and needs to be applied.

Every evaluation cycle faces the challenge to recognise the most profitable and the most promising future projects from the list of proposals. All of the selected projects need to ensure the continuation of project team operation.

5.3. R&D project selection and evaluation criteria

R&D projects are evaluated according to common criteria and the latter could be broken down into certain groups, such as organisational, technical, strategically, financial criteria. Every criterion is evaluated based on a grading and weighting system with the strong emphasis on the evaluation process, in order to:

- enhance transparency;

- avoid subjectivity;
- recognise innovative ideas.

There are plenty of project selection and evaluation criteria, but only some of them are perfectly fit for R&D project selection and evaluation. The common applicable technique is a multi-criteria approach, when certain criteria are evaluated by experts, when the latter set grades for the criteria according to the strategy that is discussed in advance. Other quantifiable techniques are: economic modelling, discounted cash flow calculation, linear programming, weighted multiple criteria. The above methods require both very precise data and ability to use mathematical procedure. In addition, difficulties occur in attempting to calculate socio-economic returns and project benefits. All of those methods could be grouped into three types according to the basic approach and attributed certain features⁴¹:

- Decision theory. Such models rely on subjective decision and qualitative variables. Models derive scoring variables using the empirical scale. Each individual score is later multiplied or normalised according to heuristic rules in order to produce quantitative measures and to derive the ranking list.
- The economic analysis. All of the models are based on forecasting the profitability of every single project in a certain time period and at a certain investment level. Cash flow and cost benefit analysis require solid data that are rather complicated to produce for a R&D project, when there is high risk and high level of uncertainty as to result forecasting.
- Operational research. This is a mathematical procedure to produce an optimised set of projects, when constraints are established in advance. The main limitation to apply this method to R&D project selection and evaluation is related to the adequacy of the goals: there are no methods to evaluate how perfectly the goals are settled according to constraints.

41 Kumar, S. 2004. AHP-based formal system for R&D project evaluation, *Journal of Scientific & Industrial Research*, vol.63, p. 888-896.

5.4. Peer review for R&D project judgment

The excellence of R&D activities is largely assessed using peer review approach when the peer review of a R&D project is implemented by advisory committees or independent experts and their panels. Merit evaluators are invited in the role of experts acting in the committee to realise a collective decision. Different forms, such as workshops, expert panels, and committees are employed. In order to ensure the relevance of R&D programmes, trained technical programme managers combine information from experts into knowledge about R&D projects.

5.5. Project selection and evaluation techniques

The common approach to project selection and evaluation is multi-criteria analysis (MCA). This approach is based on the criteria and their weighting. This technique is practicable mostly due to its specific feature to produce a ranking list of projects forming the basis for the decision-makers to decide on project selection.

Multi-criteria decision analysis

MCDA is a decision support tool to structure the complex multi-criteria problem. The procedure includes breaking the problem into smaller parts to be analysed and evaluating the number of alternatives as single possible solutions against a certain number of criteria. MCDA application requires precision during the decision-making process management, identification and involvement of the proper decision actors and MCDA methodology.

There are plenty of practical applications of MCDA, solving socially-oriented problems on state and local government issues around the world. This method was adopted for priority setting for Australian public administration as a tool for problem-solving⁴², while management of contaminated sediments was defined by MCDA in the USA⁴³, sustainable land policy planned in Germany⁴⁴, bioenergy system assessment was

42 Mabin, V.; Menzies, M.; King, G. & Joyce, K. (2001). Public sector priority setting using decision support tools. *Australian Journal of Public Administration*, 60, 2, 44-59.

43 Linkov, I.; Satterstrom, F. K.; Kiker, G.; Seager, T. P.; Bridges, T.; Gardner, K. H.; Rogers, S. H.; Belluck, D.A. & Meyer A. (2006). Multicriteria decision analysis: a comprehensive decision approach for management of contaminated sediments. *Risk Analysis*, 26, 1, 61-78.

44 Henn, A. & Patz R. (2007). A multicriteria approach for corporate decisions in sustainable

conducted in Uganda (Buchholz & al., 2009), to apply to social problems⁴⁵. MCDA has been proved to be a very suitable tool for creative and innovative thinking⁴⁶.

One of the most widespread sets of MCDA is the multi-attribute utility theory (MAUT)⁴⁷. Every alternative is evaluated according to its value and criteria weights. The alternatives are ranked with respect to their values.

The utility function is written as follows:

$$U_i = \sum_j w_j \cdot u_{ij} \quad (\text{Equation 1})$$

where U_i is the overall value of the i^{th} alternative, u_{ij} is the utility of the i^{th} alternative with respect to the j^{th} criteria measured by means of the utility function, and the weight w_j is a normalized weight or scaling constant for criteria j , so that $\sum w_j = 1$.

It is very common in R&D project selection to use two groups of criteria with a sub-criteria system⁴⁸:

- Intellectual set of proposals:
 - innovativeness of the idea;
 - clarity of the idea and objectives;
 - probability of technical success;
 - plausible results applicability;
 - attractiveness of technological routes;
 - technological relevance;
- allocation of organisational resources:
 - rationality of budget distribution
 - financial feasibility of the project;
 - commercial sponsorship for the project;
 - available research skills:
 - available human expertise

planning policy. *International Transactions in Operational Research*, 14, 15-23.

45 Munda, G. (2004) Social multi-criteria evaluation: Methodological foundations and operational consequences. *European Journal of Operational Research*, 158(3), 662-677.

46 Čečner, V. & Mulej, M. (2006) Systemic decision analysis approaches. Requisite tools for developing creative ideas into innovations. *Kybernetes*, 35, 7/8, 1059-1070.

47 Malczewski, J. (1999). *GIS and multicriteria decision analysis*. John Wiley & Sons.

48 Kumar, S. 2004. AHP-based formal system for R&D project evaluation, *Journal of Scientific & Industrial Research*, vol. 63, p. 888-896.

- available facilities:
 - availability of technologies;
 - availability of material resources and consumables;
- strategic management:
 - anticipating completion time
 - extent of tie-in with existing projects;
 - relevance of objectives to the social needs;
 - reputation of the project leader and the team.

Analytical hierarchy process

Analytic hierarchy process (AHP) has been developed by Saaty⁴⁹ in 1980 with the purpose to structure a complex problem and analyse its parts in a comparable manner. As this technique falls into the multi-criteria analysis branch of decision-making methods, the evaluation is based on the setting of criteria. Each criterion is evaluated with respect to each other and this procedure is called pairs-wise comparisons. Below is the list of the main advantages of AHP:

- Broadening the decision-making capabilities. Help focussing attention on the most specific components of the problem via problem structuring.
- Simple and clear mathematical procedure. Simplicity becomes obvious in comparing the AHP procedure with the procedure of weighting the utility models.
- Trustworthy. Since all the multi-criteria methods for project evaluation incorporate subjective evaluation, when an expert expresses his or her opinion on every criterion, AHP with pair-wise comparison minimises accidental and contradictory evaluation.

There are many cases of successful AHP application reported in the scientific literature and in practice. It was used for health care, strategic planning, tactical R&D project evaluation, prioritising telecommunication for long-range R&D planning, reorganisation of the air force medical service, quality management, public policy⁵⁰.

49 Saaty, T.L. (1980). *The analytic hierarchy process: Planning, priority setting, resource allocation*. New York: McGraw-Hill.

50 Forman, Ernest, H.; with Gass, Saul, I. The Analytic Hierarchy Process – An Exposition, *Operations Research*, vol.49, No. 4, July-Aug 2001, p. 469-486.

Mathematical procedure starts from building a pair wise comparison matrix, each element of which represents the comparison of alternative I to alternative J in the effect on some stated factor. The resulting matrix is a square, positive and reciprocal:

$$a_{ij} = a_{ji}^{-1} > 0 \tag{Equation 2}$$

The matrix elements are normalised according to the agreed scale. This scale was tested practically and suggested as the best for AHP.

Table 7. AHP scale for criteria weighting.

Impotence (in numeric values)	Definition
1	Equally important pairs
3	Moderate important of one over another
5	Important one factor in front of other factor
7	Very important
9	Extremely important
2, 4, 6, 8	Intermediate values

Pair wise comparison matrix is analysed: the largest eigen value is computed. The eigen vector represents the ranking of analysed elements. The above-mentioned procedure is repeated for criteria analysis and for alternative upon every single criterion analysis. Eigen vector calculation:

1. Calculation of normalised criterion eigen value v_i :

$$v_i = \frac{k_i}{\sum_{m=1}^M k_m} \tag{Equation 3}$$

k_i – geometrical mean for i criterion,
 $m = (1 \dots M)$ – M number of criteria.

2. Calculation of alternative eigen value p_i :

$$p_i = \frac{K_i}{\sum_{l=1}^L K_l} \quad \text{Equation 5}$$

K_i – geometrical mean for *alternative i*,
 $L = (1 \dots L)$ – L number of alternatives.

Calculation of eigen vector:

$$P_l = \sum_{m=1}^M P_{lm} v_m \quad \text{Equation 7}$$

Review questions:

1. What causes fundamental difficulties to evaluate R&D projects?
2. What are the main differences between MCDA and AHP?
3. What are the preconditions for R&D projects selection?

Chapter 6.

COOPERATION AND R&D PROJECTS TEAMS

The main concepts⁵¹

Team	Two or more people working interdependently toward a common goal and a shared reward.
Project Management Team	The members of the project team who are directly involved in project management activities. On some smaller projects, the project management team may include virtually all of the project team members.
Project Manager (PM)	<ol style="list-style-type: none">(1) The person assigned by the performing organization to achieve the project objectives.(2) Any person assigned to lead a team toward completion of a project. A project manager applies specialized knowledge, skills, tools, and techniques in order to meet customer expectations of a project.(3) The person who heads up the project team and has the authority and responsibility for conducting the project and meeting project objectives through project management.(4) A qualified individual or firm authorized by the owner to be directly responsible for the day-to-day management and administration, and for coordinating time, equipment, money, tasks, and people for all or specified portions of a specific project.

51 Washington State Department of Transportation (WSDOT). PROJECT MANAGEMENT GLOSSARY OF TERMS, SPRING 2005. <http://www.wsdot.wa.gov/nr/rdonlyres/3dde6d10-c5fb-4d45-8386-4180ce905bd0/0/wsdotpmglossary.pdf>. 25/08/2013.

6.1. Cooperation in R&D projects

R&D project team management approach could differ depending on the cooperation that is needed for the research. According to Thompson⁵², there are 3 types of internal dependency.

- Pool interdependency. Partners are almost independent from each other, especially in terms of research results. They conduct research independently and produce research output independently. The cooperation lays down on coordination management. The most common example of using such cooperation in practice is EUREKA programme of the EU.

- Sequential interdependence. Project team is partly integrated as project activities are sequential and follow each other, so partner efforts depend on the results of the results of the other partners reached during the previous stage. Cooperation management has the function of technical supervision. It helps structuring the process, providing a reaction to changes, and monitoring the results.

- Reciprocal interdependence. Partners are fully integrated in the project team and interrelated with each other in terms of activities and results. This type of project needs active management technique.

In practice, inside a formal institutional structure, R&D project constructs its team on virtual or informal spontaneously grouped teams of researchers and these informal groups are rather stable through the years. One of the successful project management factors is the manageable size of the group, which, together with the leadership, stimulates team identity and secures high project performance. The leaders of smallest teams express less demand in assistant R&D managers, while leaders of larger teams seek for additional managerial support more often. The strong need for managerial approach is easily conceptualised for teams oriented towards knowledge commercialisation, as the time for product development is more valuable than in fundamental research projects.

The most complicated and challenging task for a project manager is to manage the dynamics of a team and predict the unpredictable friction between “expectations, work modalities, throughputs and parameters for evaluation of work”⁵³.

52 Thompson, James D. 1967. *Organizations in Action: Social Science Bases of Administrative Theory*. McGraw-Hill, New York.

53 Karthik Mahesh Varadarajan. 2011 *Research Project Management in the United States*

6.2. R&D project teams

Many R&D actors feel uncomfortable when having to use formal procedures. Project management is one of the ways to formalise researcher activities. They try to avoid hierarchy and too detailed structures. They usually do not wish to use detailed plans and suppose that they prevent their scientific creativity. Whereas in the worse case scenario they do not see the value of using project management techniques. This attitude leads to the scepticism towards project managers and their added value to the research.

Below are some tips useful for R&D project team mobilisation:

- Objectives need to be defined together with the team planning to work on the project. Otherwise, people will give up when faced with the first difficulties.
- It is dangerous to move to conclusions too early. It is better to ask more questions than less and to define the real problem as to what needs to be solved at a particular phase of the project. The right time to solve the right problems raises credibility and motivates people to use their efforts.
- Take time to analyse more alternative solutions before the final decision is taken.
- Inspire the team to produce their input at every project stage.
- Use team input for producing draft reports and motivate people to obtain feedback.

Among different extremely valuable recommendations for motivating the project team to seek for better results are some special issues for the R&D project team to be analysed and attended. Karthik highlighted some characteristics that require special attention of a research project manager:

- **Independence.** Researchers usually tend to work independently and prefer to choose the methods and procedures that they select individually. At the same time, cooperation between researchers becomes more and more common practice, since more diverse research competencies are needed. That expectation needs to be respected when a research project team is working and cost, time

and other constraints are implemented. Strict compliance with the schedule could damage researcher creativity. Those types of constraints could be solved by the project manager when researchers need to have creative environment for individual activities and project manager needs to complete the project on time within the budget and the planned deliverables are merging for the sake of research outputs. Delegation of sub-tasks to the project team members could be proposed as a major recommendation. Delegation needs to proceed with full responsibility and independency to select the methods and make the technical decisions.

- **Cultural heterogeneity.** Research institutions are heterogeneous in terms of organisational structure, budgeting source, and the way they report for the support. Research is conducted in universities, research institutes, private companies. The personnel of such institutions are also very heterogeneous in terms of nationality. R&D projects are more and more based on international cooperation. Cultural differences, language and political orientation have a direct impact on team consolidation.
- **Motivation.** Researcher's motives to reach better performance more often relate to an area other than common practice of motivation in other activity areas. More often researchers seek for recognition when intellectual affords are transferred to new knowledge, and sometimes satisfaction with research depends only on personal satisfaction. Monetary reward is also a motivating factor for researchers. Some motives work better for short-term goals and others are more effective for long-term goals. Motivation measures could differ depending on the stage of personal career of an individual researcher.
- **Evaluation of contribution.** In general, project team efforts are evaluated based on their efficiency and contribution to the final results. Due to their value to the society, significance and contribution to the body of knowledge R&D activities create additional values that need to be appreciated . This nature impacts the payment system employed by research projects. The traditional monthly payment system is applied together with contract-based payment for R&D activities during project elaboration. Evaluation

of a contribution can be combined with promotion, however, there is not much space for it within a formal research institution, but in project management a project leader or a project manager could be the posts for promotion.

6.3. The role of the R&D project manager

If we argue that a manager obtains the mandate to make actions coherent, we must describe the component of coherence. Previous investigations based on large prosperous international companies, such as Nissan or Erickson⁵⁴, have revealed that R&D project success depends on “appropriate managerial and organizational tools and mechanisms”, quality of which is sought to improve with every new challenging technological task.

Managerial approach to R&D activities is based on project management concerning the conceptualisation of a project idea, project timing, budget, project teams and leadership. In order to describe the main manager duties of R&D in sixth evolutionary generations⁵⁵, first we need to classify R&D performance components that are outside direct R&D activities but cannot be separated from the whole system.

6.3.1. Responsibilities of a R&D manager

Scholars do not make much effort to describe the qualification requirements for R&D managers, but among others they mention technical skills⁵⁶ and technology management. However, many scholars agree that people can learn from practice, thus formal training is not a requirement. At the same time, in practice researchers are supposed to work with a R&D manager having the same or similar background as the team, and “only leadership sets them apart ...and performance oriented”⁵⁷.

54 Chiesa, V. (2000), Global R&D project management and organisation: taxonomy. *Journal of Product Innovation Management*, Vol. 17, p. 341-359.

55 Wang, J. and Kleiner, B.H. (2005), The Evolution of R&D Management by Six Generations of R&D Management. *Management Research News*, Vol. 28 No.11/12, p. 88-95.

56 Clarke, T.E. (2002) Why do we still not apply what we know about managing R&D personnel? *Research Technology Management*, Vol. 45 No. 2, p. 9-11.

57 Huang, E.Y. and Lin, S. (2006) How R&D management practice affects innovation performance. An investigation of the high-tech industry in Taiwan, *Industrial Management & Data Systems*, Vol. 106 No. 7, p. 966-996, DOI 10.1108/02635570610688887.

- *R&D activities.* R&D organisations carry out the following activities: fundamental research, applied research, development, demonstration, technology scanning, and entries to the market. Described activities are characterised by different time scale (short term – from 1 to 3 years for entry to the market and more than 3 years for applied research), funding resources (internal for entry to the market, external for fundamental research, mixed for any other). Due to high uncertainties, long lasting R&D activities is more and more often outsourced due to economical and managerial reasons⁵⁸. This does not mean that it makes manager life easier. On the contrary, a new duty is a complement to the list with a strong mediation role.
- *R&D project team.* Innovation is the result of integrated and diverse efforts across different units in an organisation. There are evidences of positive relationship between R&D team managing and R&D performance⁵⁹. The same situation is observed in formal and informal groups, where responsibilities are shared among participants. Organisational framework must create supportive environment for informal group activities in order to successfully create the project management culture. Organisational structure has a crucial impact on the duties of a manager. In building a successful project team, four components are essential: accountability, adequate information and resources, appropriate staffing and training, rewards for efforts⁶⁰. Therefore, a R&D manager must take the responsibility to assist the R&D team and ensure that all of the above-mentioned components are implemented. Good R&D performance prevails in organisations where informal teams of researchers are established according to the bottom-up approach, assisted by a manager and supported by organisational structure.

58 Mukherjee, A. and Ray, A. (2007) Strategic outsourcing and R&D in a vertical structure. *The Manchester school*, Vol. 75 No. 3, p. 297-309.

59 Yunsheng, Z.; Deming, Z.; Lifei, Z.; Lu, L.Y. (2007) R&D team governance and R&D performance. Empirical evidence from Chinese software enterprises, *Journal of Technology Management*. Vol. 2 No. 1, p. 71-83.

60 Kolb, J.A. and Sandmeyer E. (2008) Supporting project teams: a framework used in a university-community collaborative initiative, *Performance Improvement Quarterly*, Vol. 21 No. 1, p. 61-76.

- *Funding.* Searching for the source of project funding, participation in funding competition is a long-lasting and time consuming activity accompanying any R&D activity and requiring high skills. This duty might be delegated to finance a friendly person that a manager is.
- *Stakeholders.* Scientific references have distinguished the importance of timely recognition of stakeholders and their proper involvement in R&D project as a managerial task⁶¹. Stakeholders involve a long list of interest parties, equally sharing the responsibility of success of R&D project development. They include sponsors, consumers, distributors, suppliers and any other parties interested in R&D. The list of stakeholders cannot be static and may vary depending on project type, research or development project underway. Since project task responsibilities are shared among the project team, the duty to identify the stakeholders and communication should be delegated at an appropriate time to an appropriate team member. As this is not a direct R&D activity, but part of management, the list of manager duties could be extended by one more very significant responsibility.

6.3.2. Duties of a R&D manager

It is no surprise that there is a gap between R&D performance and professional management practice, which causes misalignment of R&D project duties towards project management. Determining the hypothetical requirements for R&D managers, only the supporting R&D activities at micro level (assisting a scientific leader) were stressed as the main concern.

Despite the fact that no unified description of the duties of R&D managers is traced, it is possible to define the desirable requirements for a R&D manager as a R&D project team member. The role of a manager varies within an organisation depending on the units or type or R&D project he or she could assist. The full list of a manager's duties is oriented to support researchers in their every occupation, making the researchers' mind free for their direct activities and to stimulate business-oriented thinking.

61 Elias, A.A.; Cavana, R.Y.; Jackson, L.S. (2002) Stakeholder analysis for R&D project management, *R&D management*, Vol. 32 No.4, p. 301-310.

Communication is critical to a R&D project manager. According to the respondents, a manager must keep the following duties:

- Administrative assistance in everyday duties;
- Communication (internal and external).

The list of duties fully corresponds to the following conceptualised requirements:

- Non-specified higher university degree, preferably in the same field as that of the management team;
- Creative and communicative person;
- Commitment and good organisation, negotiation and presentation skills;
- Fluent foreign language (English is preferable) for scientific communication;
- Experience in the particular field is of great importance;
- Experience in international R&D project management;
- Skill to establish balance between power and influence;
- Commitment and responsibility;
- Technical expertise;
- Problem solving.

When enumerating the requirements for a manager, researchers were guided by the aim to have scientific freedom for themselves and delegated those activities that were extra to them. Actually, researchers emphasised the commitments of a manager but nobody asked for leadership.

All researchers still suspiciously analysed the hypothetic suggestion to hire a manager for project management from outside, if the manager's background were other than that of the project team. They worried about losing the control of the project performance, R&D results development and letting the project success to the hands of the manager who "could not understand the R&D particularities"⁶².

Despite the similarities of attitudes to R&D project management role, the strong antagonism between researchers from public research institutions and R&D intensive companies still exists when partnership on R&D project

62 B. Mikulskienė (2010). The Role of R&D Manager For Public And Private R&D Partnership. European integration studies. Research and Topicalities. Kaunas, ISSN 1822 – 8402 Nr. 4, p. 53-59.

development is discussed. A company manager stated that researchers from Lithuanian public institutions performed high-quality research, created wonderful, inspired fundamental theories, but, at the same time, the national research system worked in regime of “performance”, but not in regime of “production”. That is the main obstacle that makes R&D oriented companies to keep away from universities R&D. At the same time, researchers from the public sector claim that companies avoid investing into fundamental research, prefer partnership only in commercialisation project phases and tend to invest into short-term projects. The antagonistic nature has proved the duality of managerial approach and is tightly related with the interpretation of stakeholders’ input. However, stakeholder management is let out of manager duties and still not conceptualised as an additional success factor for R&D.

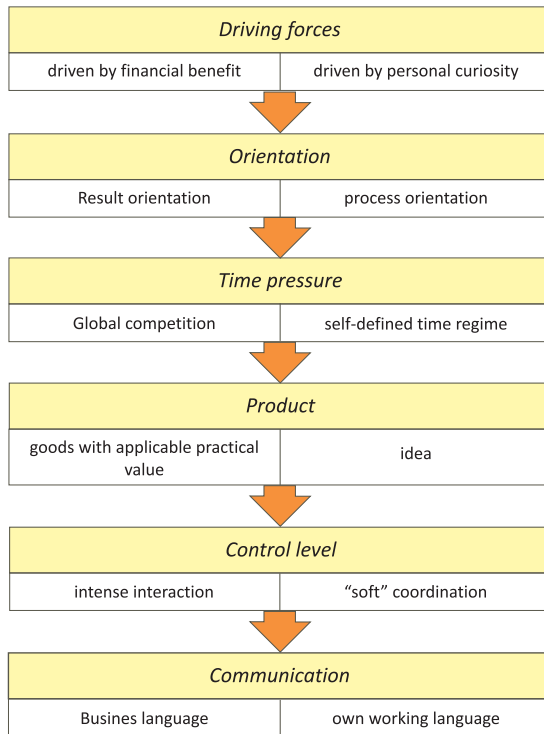


Figure 15. Different attitudes to R&D in research-based and production-based R&D labs.

That could be generalised as a weak comprehension of benefits gained from public and private partnership. Different expectations, driving forces, timing pressure, commitments, organisational culture make a R&D manager's role highly complex.

The full set of a manager's duties could be formulated as follows:⁶³

- Administrative assistance in everyday duties;
- Communication (internal and external);
- Communication with a stakeholder (stakeholder identification and involvement in the project);
- Outsourcing of management;
- Searching and competing for funding;
- Equipment support.

Organisational structure has a crucial impact on the duties of a manager and managerial impact on public and private partnership. Therefore, a R&D manager must take the responsibility to assist the R&D team and put all of the above-mentioned components into the whole active system. Thus, the organizational design in public R&D institutions should respond to decentralisation approach for R&D management, while a R&D manager is incorporated in the hierarchic structure of an organisation. The degree of hierarchy is tightly related with the certainty of task units are dealing with. Due to R&D uncertainty, high risk and duality of R&D management, the hierarchic degree is accepted as low as possible.

On the contrary, highly bureaucratic R&D organisations are an obstruction for a public and private partnership. Such organisations still avoid managerial view in the micro level of organisational design despite permanent efforts to introduce managerial offices in between the administration and R&D performers. Such kind of managerial support serves more to the administration functions for the upper hierarchical level administrators ensuring better administration and control targeted at the lower hierarchy level of R&D performers instead of implementing all R&D manager duties. Such kind of organisational structure contradicts the nature of R&D management and has negative impact on the emergence of public and private partnerships.

63 B. Mikulskienė (2010). The Role of R&D Manager For Public And Private R&D Partnership. European integration studies. Research and Topicalities. Kaunas, ISSN 1822 – 8402 Nr. 4, p. 53-59.

Therefore, good R&D performance exists in organisations with informal teams of researchers formed according to the bottom-up approach, assisted by a manager and supported by the organisational structure on the macro level. A R&D manager could be granted the autonomy to safeguard creativity and balance control to support flexibility. For this reason, an R&D manager should operate in close contact with R&D performers on the same hierarchical level as researchers of informal groups.

6.3.3. The duality of R&D manager duties

The duality of R&D manager duties could not be neglected, as the widely accepted managerial approach to any other field of activities could work as an obstacle for research management. The elements of discrepancies of duties of R&D managers are discussed in the following section.

Driving forces. Managers obtain a mandate that covers mediation between representatives of different cultures, the nature of which is driven by very opposite forces. A businessman is driven by financial benefit, while a researcher is driven primarily by personal curiosity.

Result orientation versus process orientation. Curiosity-driven targets determine the expression of results. A researcher is oriented to new knowledge, while both proving and disproving the suggested theory or the analytical approach is plausibly accepted. While for company, the acceptable R&D results are those that could be sold on the market and give real profit. More specifically, a researcher could sell the idea, while a company is selling goods with applicable practical value.

Time pressure. Global competition exerts pressure on R&D intensive companies to be mobile and catch up with new knowledge. Time pressure pushes companies to use tacit knowledge, as a consequence they tend to be as close to knowledge generation as possible, and use every knowledge spreading channel as a formal or informal network⁶⁴. At the same time, a public R&D organisation can operate in the self-defined time regime, which is determined by funding bodies.

Control level. The notion of soft management control is to be introduced when considering R&D project management. Scholars distinguish between manager role in research and development projects in terms of intensity

64 Kratzer, J., Gemunden, H.G., Lettl, Ch. (2008) Balancing creativity and time efficiency in multi-team R&D projects: the alignment of formal and informal networks. *R&D Management*, Vol 38 No.5, p. 538-549.

and frequency of interaction. In research projects, manager's role is limited by "soft" coordination to the exchange of views in order to safeguard the free spirit of scientific creativity, while development projects require more "intense interaction"⁶⁵ in every project phase, starting from the definition of project conception to project finalisation on time and within the budget.

Communication. The duality of the manager's duty lies in finding the language equally understandable by both researchers and other stakeholders from non-scientific world. Stakeholders represent a wide range of diverge parts of the society, which has its own working language, priorities and the ways of acting.

Leadership versus assistance. Manager and leadership are comprehended as complementary categories. It is proven that leadership style directly influences innovation, shapes activity outputs and works as a stimulus for team collaboration and identification⁶⁶. R&D autonomy is determined by less assistance required and more leadership present. It is not expected that a leader will assist. In such a case, instead of complementary categories, we transit to the opposed categories.

The duality of duties of a R&D project manager lies in the nature of R&D, which is characterised by high autonomy level which stimulates creativity, high risk and uncertainty at multidimensional environment. That effect directly impacts managerial attitude, where competition of objectives must be taken into consideration. The task for a manager is to be flexible, to secure knowledge-based creative environment and be strict in scheduling and seeking time efficiency. Coherent attention should be paid to the question of balancing the autonomy of R&D activities with strict managerial control.

Review questions:

1. Who is responsible for the project?
2. What does R&D project manager do?
3. What skills do project managers need?

65 Chiesa, V., Frattini, F., Lazzarotti, V. Manzini, R. (2009) Performance measurement of research and development activities, *European Journal of Innovation Management*, Vol. 12 No. 1, p. 25-61.

66 Paulsen, N.; Maldonado, D.; Callan, V. J.; Ayoko, O. (2009) Charismatic leadership, change and innovation in a R&D organization. *Journal of Organizational Change Management*, Vol. 22 No.5, p. 511-523.

Chapter 7.

R&D PROJECT COMMUNICATIONS

The main concepts⁶⁷

Result

An output from performing project management processes and activities. Results include outcomes (e.g., integrated systems, revised process, restructured organization, tests, trained personnel) and documents (e.g., policies, plans, studies, procedures, specifications, reports). Contrast with product and service.

Performance Reports [Output/Input]

Documents and presentations that provide organized and summarized work performance information, earned value management parameters and calculations, and analyses of project work progress and status. Common formats for performance reports include bar charts, S-curves, histograms, tables, and project schedule network diagrams showing current schedule status.

A management process is not entirely managed, if communication issues are ignored. For R&D project management, both outer and inner communication is essential. We can list many advantages of communication for project success. The following tips can be listed:

- **Misunderstanding of complexity.**
- **Common understanding.**

⁶⁷ Washington State Department of Transportation (WSDOT). PROJECT MANAGEMENT GLOSSARY OF TERMS, SPRING 2005. <http://www.wsdot.wa.gov/nr/rdonlyres/3dde6d10-c5fb-4d45-8386-4180ce905bd0/0/wsdotpmglossary.pdf>. 25/08/2013.

- **Matching project proposal and project activities.** R&D projects usually are funded by external source of financing, thus a R&D project proposal is prepared as the list of wishes and promises that are plausible and could be achieved with adequate resources. From the perspective of project management, a proposal is a guideline for project activities. Thus communication has a role to ensure that project activities are guided as close as possible to the proposal and have a mission to align the promised activities with real practice.

“Communicating is about people, not media”⁶⁸, so that every form of communication that stimulates interaction between R&D project players is welcome. In terms of communication planning, first of all we should be familiar with the fundamental forms of communication and with the main players in communications.

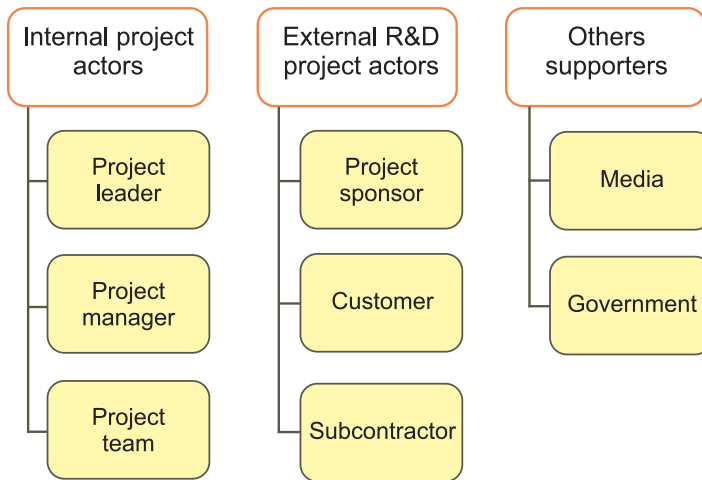


Figure 16. The type of communication players for R&D project communication

68 Ralph L. Kliem. 2007. *Effective Communications for Project Management*. Auerbach Publications, pages 1–24, ISBN: 978-1-4200-6246-5.

7.1. Communication forms:

1. Written communication.

2. Face to face communication. That form of communication is very important to ensure proper development of a project on the daily bases. We can draw the following main tasks that ensure adequate face to face communication:

1.1. To share tacit knowledge

1.2. To create consensual knowledge

1.3. To maintain sufficient interest and motivation

3. Communication via media. Thanks to information technologies project management and communication became less time-consuming and speeded up. Different forms of e-media enable managers to save time for sending mails and messages for different purposes: to provide project players with up-to-date information, to generate reminders and etc. However, communication via media could not substitute face to face meetings and should be used simultaneously.

3.1. Virtual meetings. This form of communication is widely used for international R&D projects when project team members are located in different countries hundreds or thousands kilometres away from each other. For that particular purpose, periodic face to face meetings are too expensive, thus some of them are substituted by periodical virtual meetings.

3.2. E-mailing. This type of communication is distinguished among any other forms of communication due to its written form that produces solid evidence for future discussions. This writing material works out as a support for words and creates additional motivation to start or finish a particular task, whether or not they were discussed in a face to face meeting or read in delegation notes.

3.3. Databases. Databases provide an interactive possibility to search for project results and data that could be used for reporting at any stage of project development. Database could be developed internally and externally, also when stakeholders can have a right to enter the data into a database.

- 3.4. Telephone calls. Telephone calls could substitute the face to face meetings in the form of quick and interactive communication.
- 3.5. Project website. A project website is useful both to ensure communication between the project team and to facilitate information sharing and transferring within the wider project auditorium, by reaching those who at a particular moment of time do not recognise themselves as project stakeholders but might be interested in the project outputs.

7.2. Planning communications

- 1.1. To identify the project actors that need to be contacted and to screen up the list of those interested in project success the list of stakeholders will shape the next planning stage.
- 1.2. To set the targets for communication at every single project development phase. Possible communication targets: information distribution, information gathering, information sharing (intermediate research results, output development, activity constraints).
- 1.3. To select the best form of communication according to communication targets and stakeholder needs.
- 1.4. To state the methods and ways to collect, receive and retrieve information.
- 1.5. To schedule every communication.
- 1.6. It is very useful to produce a matrix to align stakeholders, forms of communication and indicate the responsible person. This additional document forms part of the planning process.

Table 8. Sample stakeholder and communication forms matching project communication. Adapted by Schwalbe⁶⁹

Stakeholder	Document type	Document format	Contact person	Due
Executive management	Monthly status report	Hard copy	Contact person	Indicate date
Sponsor	Annually status report	Hard copy	Contact person	Indicate date
Team	Deadline alert	e-mails	Contact person	Indicate date

Preferences for communication forms

While planning communication preferences of actors, the communication forms need to be taken into consideration. If executive management participates in goal setting, they do not need to be updated on a daily basis with all the details of project development. In that case, they prefer periodical information about progress and results achievable during a particular period of time. Written documents, such as short progress reports and oral communication are recommended. For other project teams more detailed communication is needed to ensure horizontal and vertical communication between all parties of stakeholders.

7.3. Partner communication

As R&D becomes more and more international than local or national, R&D project gain more benefits when international partners complete the project team. Together with many cases of successful international collaboration, international R&D project teams bring many intercultural challenges.

The success of R&D international partnership depends on the following managerial abilities:

- To be familiar with intercultural communication;
- To understand partner motivation;

69 Schwalbe, K. 2010. Information Technology Project Management, Cengage Learning; 6 Edition, p. 672.

- To get to know partners' expectation: different partners could have different drivers for participation in R&D project. SME seeks know-how, big companies knowledge and product prototype, research institutions cooperate for new R&D methodologies or publications.

7.4. Communication as Performance Reporting

Performance reporting as part of project management is also part of communications. The data retrieved during performance evaluation should be translated to the stakeholders and to the project team also with the purpose to inform all the stakeholders about the real progress of the project.

Periodic performance reporting needs to cover six interrelated issues⁷⁰:

- **Status reports.** What is the status of the project at the particular point in time
- **Progress reports.** What has been done during the reporting period and what activities are to be continued.
- **Forecasting.** Taking the progress report into account, will the project follow the time schedule and the budget? Whether additional resources are needed or not?
- **The aim.** How perfectly the project meets its aim.
- **Quality.** What is the status of quality, analysis and testing, if applicable, for the R&D project?
- **Risks.** What is the status of identified risks. Project planning stage and whether new risks were identified and the measures taken against the risks.

Methods and tools for performance reporting

1. Earned Value Analysis

Earned value analysis is a very wide spread method to analyse project performance measurement in economic terms. It reveals cost and time variance using simple mathematical formulas.

70 Heldman K. 2002. *PMP® Project Management Professional Study Guide*, second edition. 576 p. Sybex Inc, 0782141064

Earned Value (EV) is described as work that has been accomplished plus the allocated budget for the work that has been accomplished. We can list several methods to calculate the Earned Value for the project work. The most common method is the multiplication between the percentage of the work completed and the budget at completion (BAC).

$$\text{Earn value} = \text{percentage of the work completed} * \text{budget at completion}$$

Equation 9

Table 9. Earned Value Analysis example:

Problem	A project has a budget of EUR 100.000 and 20% of the work is completed
Problem solving	EV is $10000 * 0.2 = \text{EUR } 20.000$.

2. Project variance

Project variance could be applied to project time (completion of activities), aim (how perfectly the achieved results fit the promised results), quality level, budget (cost). The procedure is based on comparison between actual experienced values and planned values. In the most common cases, variances are applicable to estimate the cost and time variance. All other issues, such as goal, quality, resources variance produce knowledge that could have effect on time and cost afterwards.

Project variances provide information for further strategic actions as follows⁷¹:

- Prevent future undesirable variances.
- Determine the root cause of variances.
- Determine how variance is evaluated: anomaly, flawed, whether it falls within the acceptable range or not.
- Determine the risk to expect variance in the future of the project.

Variances: every project manager is interested whether budget variance will emerge at the end of the project. It is calculated as follows:

71 Heldman, K. 2002. *PMP® Project Management Professional Study Guide*, second edition, p. 576. Sybex Inc., 0782141064.

Variance=Actual Cost-Budget at Completion

Equation 10

Variance could be calculated for any controlling criteria and means the differences between actual values and planned or expected values.

Table 10. **Project variance** example:

Problem:	Budget at completion = EUR 120.000. Total project completion at 30 %. Actual cost is EUR 40 000. Project completion month 12 = 50%
Problem solving:	Earned Value = %COMP X BAC= 120 000*0.3=EUR 36.000 Variance: 40000-36000=EUR 4000. The manager is interested in what the project will be worth at this point in the schedule”

2.1. Cost Variances

Cost Variance (CV) is the difference between the Earned Value and the Actual Costs (AC).

$$\text{Cost Variance} = \text{Earn Value} - \text{Actual Cost}$$

Equation 11

For example:

Problem	In a project with a budget of 250.000 € and a completion rate of 20% the prices have changed. However, the market prices increased and this affected the actual cost: EUR 55.000 were spent.
Problem solving	EV= 250000*0.2= 50.000 €. Cost Variance = 55000 – 50000 = 5.000 €.

2.2. Schedule Variances

A Schedule Variance (SV), similarly as in case of cost variance, is the difference between two date values: planned project date and actual dates.

Table 11. **Cost Variance** example:

Problem	A project has a budget of 400 000 € and is expected to last for three years. At the end of the first year, the project is supposed to be completed at 40%. However, at the end of the first year, the project is only 35% complete.
Problem solving	Planned value = $400\,000 \times 0.4 = 160\,000$ € Earn value = $400\,000 \times 0.35 = 140\,000$ € Schedule variance = $160\,000 - 140\,000 = 20\,000$ €

3. Cost Performance Index

Cost Performance Index (CPI) shows the amount of actual cost of the project in relation to the planned cost of the project. If CPI is less than 1, this means that the project spends more than it earns. If this index is higher than 1, this shows investment gains into project activities.

4. Completing Trend Analysis

Trend analysis produces information on the criteria with time series and is usually applicable for long-term project performance measurement. The project manager should pick up a value that was monitored along the project life time and analyse its changes over time. This method is able to make a prediction of value for the next project period – i.e. making a trend analysis. The prediction is based on past records, thinking that the future is the prolongation of the past, if no new arrangements take place.

Review questions:

- Who are the main players for R&D project communication?
- What are the main issues for communication as performance reporting?"

Chapter 8.

R&D PROJECT QUALITY

The main concepts⁷²

Project Quality Management [Knowledge Area]	A subset of project management that includes the processes required to ensure that the project will satisfy the needs for which it was undertaken. It consists of quality planning, quality assurance, and quality control.
Quality Assurance (QA)	All those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality.
Quality Assurance (QA) [Process]	The process of applying the planned, systematic quality activities (such as audits or peer reviews) to ensure that the project employs all processes needed to meet requirements.
Quality Control (QC) [Process]	The process of monitoring specific project results to determine whether they comply with relevant quality standards, and identifying ways to eliminate causes of unsatisfactory performance.

72 Washington State Department of Transportation (WSDOT). PROJECT MANAGEMENT GLOSSARY OF TERMS, SPRING 2005. <http://www.wsdot.wa.gov/nr/rdonlyres/3dde6d10-c5fb-4d45-8386-4180ce905bd0/0/wsdotpmglossary.pdf>. 25/08/2013.

Quality Management Plan [Output/Input]

The quality management plan describes how the project management team will implement the performing organization's quality policy. The quality management plan is a component or a subsidiary plan of the project management plan. The quality management plan may be formal or informal, highly detailed, or broadly framed, based on the requirements of the project.

8.1. The concept of project quality

Quality as a concept for project management enables assess project success and reach the desirable results when the project is completed.

According to Lockyer and Gordon⁷³, four main criteria are important while discussing quality:

1. **he maximum satisfaction of stakeholders and other project output users.** The tasks and activities and the project results afterwards should be oriented to meet the requirements of end users and stakeholders. That is why the project team and the contractor pay considerable attention and efforts to understand the needs of stakeholders and end-users in advance. It is important to ensure that a proper communication system is established during all project development and implementation phases.
2. **The completion of all planned activities are properly implemented and finished.** The management process is under control and all functions, such as planning, coordination, resource management and material supply, monitoring and control are accomplished.
3. **The quality of products and process is achieved.** The quality of project process and the quality of the final output of project are interrelated subjects. This could be achieved in case the monitoring and control system is loaded and operated properly. A monitoring system is based on the criteria settled by end users. According to those criteria, the quality of final output will be evaluated.

⁷³ Locker, K.; Gordon, J. *Project Management and Project Network Techniques*. Prentice Hall, 2005.

4. **The project management system ensures the supportive environment to reach the adequate quality of project output.** In order to ensure the appropriate quality of R&D project output, a quality target needs to be established. Measurable quality goals go hand in hand with a flexible and clear organisational structure, quality evaluation system and criteria, supportive and dedicated project team with adequate competencies and motivation to reach the qualitative output within the available system.

8.2. Standardisation for R&D projects

R&D activities as a main driver for innovation processes could be the target for the introduction of quality management systems within projects. More and more R&D activities are deeply integrated into business models, furthermore, R&D ensures long-term competitiveness. Customers usually set quality targets and push companies to seek for processes complying with the principles of ISO 9001 standard.

From the perspective of companies other than R&D-oriented companies, the usefulness of ISO standards for the success of the company is widely proven. Increase in the market share, stability of production, customer satisfaction, stable and attainable product quality, and finally a supportive working environment are the main advantages that companies gain together with quality management systems⁷⁴. At the same time, despite many good practices and positive achievements, quality management standards are criticised for negative aspects, such as formality and strict regulation of a single procedure that limits projects flexibility. As noted above, R&D project flexibility is vital for project success and innovative outputs. Together with the quality management system, bureaucratic red tape and researchers overloaded with paperwork disturb creative workers.

Taking into account the above, pros and cons of introducing a quality management system into R&D organisation need to be considered.

Up to now, ISO 9001 is the most common standard for R&D project organisation and makes it possible to track the dynamics and help ensure the balance between efficiency and creative flexibility.

74 Colurcio, M. 1998. ISO 9000 quality system and product innovation: new evidence from shoe manufacturing factories. Proceedings of the 6th EISAM International Product Development Management Conference.

The following aspects become the target points for standardisation within R&D project management⁷⁵:

1. Management limits.

Once quality policy is defined, the responsibility is shared between the hierarchies of organisation. ISO becomes a management measure to ensure that the company's goals are reached and adequate resources are allocated.

2. Quality system, documentation, control feedback.

To implement quality policy, the quality management system with detailed description of procedures is prepared. This documentation element is the most criticised one, since many uncertainties and dynamics in R&D could be hardly described in advance. Nevertheless, documentation as the strongest advantage for quality management creates a challenge for managers.

3. Contract review and control.

By this ISO element, stakeholders and customers are involved in the product development indirectly. Periodical review of contract gives a chance to align the project output to the real customer needs, sometimes shifting with time. If any changes occur, all of the new developments are confirmed in the contract and approved by all parties to the project. This element ensures the need for R&D project flexibility, when changes are accepted, approved and become legally implemented. With this quality element, the planning phase materialises the commitments of customers and investors in of the eyes of R&D project developers and fixes the project content.

4. Purchases.

All the details, such as goods or services or R&D know-how and other intellectual property, especially that developed in advance, before the start of the project and to be used to reach project goals should be described carefully and responsibly in the ISO documentation. It helps providing the supply in a timely manner and ensure further development of new knowledge. It also helps smoothing the knowledge flow and generation when pre-

75 Jayawarna, D. Pearson A.W. 2001. The role of ISO 9001 in managing the quality of R&D activities. *TQM Magazine* 13,2, p. 120-128.

knowledge or know-how is purchased on time, if any is available. The purchasing plan also prevents future risk concerning new intellectual property sharing after project completion.

5. Process control.

ISO standards require describing every stage of the process in detail. The specificity of the process becomes a guide for the details. The guide of project phases is accompanied by a communication plan, the description of a monitoring system, personnel employment strategy, and the R&D output documentation plan.

6. Infrastructure and equipment maintenance, testing and checking.

According to ISO 9001, testing and checking is not included directly. Standard description anticipates such testing at the end of the project, while the match between project result and specification of results at the project planning phase is tested. For a R&D project such testing is insufficient. For R&D outputs, there is a need both to be sure that a product or service meets the requirements and to know the reliability and precision of the results. For that purpose, periodical testing of equipment is included in the ISO standard. This section has a crucial role to play for the outsourced part of the project. In that case a subcontractor is obliged to provide the procedures for the periodical testing of the equipment used.

7. Internal quality audit.

A quality monitoring system is an integral part of ISO 9001. It is implemented via an internal audit programme. This programme contributes to self-learning, good practice sharing and incorporation of new improvements into the ongoing project phases.

8. Preventing performance and corrections.

The procedure for behaving in case of any changes and for coping with any new and unexpected project development direction needs to be incorporated into the standard. The list of prevention actions and the guidelines for reacting to uncertainties helps managing project success.

9. Training.

Standard procedures operate and impact project success in case everyone is familiar with them, they understand their added

value for their everyday practice. To facilitate the process of acknowledgment of procedures, periodical personnel training is needed and is incorporated into the quality management system. As usual for a quality management system, training programmes, achievements of trainees should be documented and used for determining the future demands of staff training.

10. Statistical checking and validation.

Statistical information is used periodically as an information source with the purpose to improve the existing situation. The way it is collected and used for further decision-making needs to be regulated. Although statistical output is not necessarily generated during R&D activities, managers need to input some efforts to create and analyse it.

Review questions:

1. When is stakeholder analysis performed?
2. What are the constraints of application of quality management to a R&D project?
3. What is the added value of contract review for R&D project management?
4. How R&D project flexibility is ensured by applying quality management standards?

Appendix 1. Research Funding schemes, 2013

International Programmes:

The Seventh Framework Programme

Duration: 2007-2013

Budget: EUR 53272 million;

Purposes:

Collaboration between scientists in different areas and countries, cooperation of private and public sectors;

Promote fundamental, new and innovative researches in unexplored areas;

Development of human resources;

Enlargement of current instruments, methods and innovations;

Participants:

Universities, research institutes, colleges, high schools and other educational institutions;

Small or medium-sized companies;

Public authority institutions;

Young and experienced scientists;

International organisations;

Civil society organisations.

Scientific research areas:

Health;

Industry of food and farming;

All types of technology innovation;

Energetics, logistics and environment;

Social sciences and economy;

Priorities:

Research activities in unexplored areas;

Initial training of researchers;

Scientist skills promotion and career development;

Partnership between industry and academic institutions;
International collaboration programmes;
Scientist awards for academic achievements;
Development of infrastructure of researches in broader society context;
Support to scientific policy development;

Countries (all countries can participate based on the belonging to one of the three categories):

Member States of the European Union;
Associated countries under an international agreement;
International Cooperation Partner Countries.

Horizon 2020

Duration: 2014-2020;

Budget/Funding: EUR 70 billion;

Purposes:

Creating new growth and jobs in Europe;

Funding research and innovation currently provided through the Framework Programmes for Research and Technological Development, the innovation-related activities of the Competitiveness and Innovation Framework Programme;

Filling the gap between research and the market;

Breaking down barriers to create a genuine single market for knowledge, research and innovation

Participants:

Private and public companies;

Research and education centres;

Consortium of partners (institutions and scientists)

Scientific research areas:

All research areas according to programme priorities.

Priorities:

“Excellent science”, “industrial leadership”, “societal challenges”;

Strengthening the position of the EU in science;

Promoting industrial leadership in innovation;

Promoting development of sustainable transport and mobility;
Making renewable energy more affordable;
Ensuring food safety and security;
Coping with the challenge of an ageing population;
Promoting international cooperation;
Creating partnerships with the private sector and Member States to bring together the resources needed.

Countries:

European Union countries;
Associated countries.

EUREKA – European Research, Development and Cooperation Programme

Through EUREKA enterprises, large industry, universities and research institutes are introducing new products, processes and services to the market, helping make Europe economically strong and socially sound. EUREKA is orientated to creating significant public-private partnerships in any domain of research and development.

Duration: depends on project

Budget/Funding: by national authorities, average EUR 1-2.5 million of public and private sources for one project;

Purposes:

Involve at least two partners from different EUREKA countries;
Secure a significant technological advance in the product, process or service concerned;
Aim at applications in the civilian sector.

Participants:

Research institutions;
Public companies;
Private companies;

Scientific researches areas:

Electronics, IT and technologies of telecommunications;
Industrial production, material and transport;

Other industrial technologies;
Technologies of energy;
Chemistry, biology and physical science;
Agriculture and marine resources;
Technologies of food;
Measures and standards;
Protecting technologies of people and environment;

Priorities:

Funding of market-orientated research and development of technologies;
Increasing the competitiveness of European countries;
Quality improvement of products, processes and services;
Strengthening of international collaboration between companies and research institutions.

Countries:

There are currently 40 EUREKA member states: Austria, Belgium, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Latvia, Lithuania, Luxembourg, Monaco, the Netherlands, Norway, Poland, Portugal, Romania, Russia, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, Republic of Macedonia (FYROM), Malta, Bulgaria, Korea (South).

EUROSTARS – Programme of European Innovation

EUROSTARS is the first programme of European Innovation. It aims to finance small and medium-sized companies of researches in the field of technologies.

Duration: 2007-2013

Budget/Funding: EUR 800 million;

Purposes:

Promote the development of technologies;
Strengthening collaboration between research centres and companies.

Participants:

Science and education institutions;

Research centres;

Companies;

Other legal entities;

Scientific Research areas:

Biotechnical science;

Industry;

Energy;

Environment;

Innovative technologies.

Priorities:

Funding and support to research-performing companies;

Develop innovative products, processes and services, to gain competitive advantage;

Promote innovative business ideas;

Find new expertise and attract private investors to small and medium-sized companies;

Open new global markets and promote greater business success.

Countries:

Austria, Belgium, Czech Republic, Denmark, Estonia, Greece, Iceland, Ireland, Italy, Israel, the United Kingdom, Cyprus, Latvia, Lithuania, Luxembourg, Norway, Netherlands, Portugal, Romania, Slovakia, Slovenia, Finland Switzerland, Sweden, Turkey, Hungary, Germany.

COST – European Cooperation Programme in the Field of Scientific and Technical Research

This is one of the oldest and most highly developed scientific cooperation networks in Europe.

Duration: 2009-2020;

Budget/Funding: the programme is funded by the European Union Framework Programmes; funding from the European Science Foundation contract with the European Commission.

Purposes:

Development of technologies in various fields of science;

Cooperation of researchers from different fields;

Participants:

Researchers and scientists;

Government Organisations, except Intergovernmental Organisations;

Universities and Associated Organisations;

Business Enterprises (ranging from SMEs to multinationals);

Private Non-Profit Organisations/NGOs (even if international);

Standards Organisations (even if international);

Scientific Research areas:

Biomedicine and molecular biosciences;

Chemistry and molecular sciences and technologies;

Earth system science and environmental management;

Food and agriculture;

Individuals, society, culture and health;

Forests, their Products and Services;

Information and communication technology;

Materials, physical and nanosciences;

Transport and Urban Development.

Priorities:

Credentials, conferences, seminars, meetings, short term scientific visits of scientists;

Exchanges of researchers;

Researchers training;

Publishing of researches results;

Building capacity by connecting high-quality scientific communities throughout Europe and worldwide;

Providing networking opportunities for early career investigators;

Increasing the impact of research on policy makers, regulatory bodies and national decision makers as well as the private sector.

Countries:

Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Latvia, Lithuania,

Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom.

BONUS – Joint Baltic Sea Research and Development Programme

Duration: 2007-2016;

Budget/Funding: EUR 38 million;

Purposes:

Combining researches of the Baltic Sea of separate countries;

Promoting international collaboration;

Creating interdisciplinary, long-term, integrated program for sustainable development in the region of Baltic Sea countries;

Understanding the complexity of the Baltic Sea ecosystem structure and functioning;

Meeting the multifaceted challenges in linking the Baltic Sea with its coast and catchment area;

Enhancing sustainable use of coastal and marine goods and services of the Baltic Sea;

Improving the capabilities of the society to respond to the current and future challenges directed to the Baltic Sea region; developing improved and innovative observation and data management systems, tools and methodologies for marine information needs in the Baltic Sea region.

Participants:

Small and medium-sized companies;

Legal researchers teams.

Scientific research areas:

Marine innovations and technologies;

All uninvestigated areas related to the topics of the Baltic Sea.

Priorities:

Promoting high-level international and interdisciplinary researches;

Creating technologies and innovations to help protect the Baltic Sea resources;

Funding researches of uninvestigated areas of the Baltic Sea;

Successful coping with challenges related to the Baltic Sea (for example, pollution);

Creating ecosystem-based approach in the Baltic Sea management.

Countries:

Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Sweden and Russia.

National Programmes (business-oriented)

High Technology Development Programme for 2011-2013

Duration: 2011-2013

Budget/Funding: LTL 3.61 million (for 2013);

Purposes:

To help develop worldwide perspective hi-tech trends with scientific potential, which makes it possible to create new products competitive in a global market.

To promote collaboration between scientists and economic operators;

Participants:

Legal persons registered in Lithuania;

Higher education and research institutions and economic operators.

Scientific research areas:

Biotechnology;

Mechatronics;

Laser technology;

Information technology;

Nanotechnology and Electronics.

Priorities:

Developing five technology trends research and development works;

Increasing hi-tech production;

Promoting investment into high technologies;

Making a possibility to create new jobs;

Promoting science and business cooperation.

Industrial biotechnology development programme for Lithuania for 2011-2013

Duration: 2011-2013;

Budget/Funding: LTL 1.2 million;

Purposes:

To accelerate biotechnology industry development in Lithuania.

Participants:

Legal persons registered in Lithuania;

Higher education and research institutions and economic operators.

Scientific research areas:

Biotechnologies in different fields;

Priorities:

Create materials and products from renewable raw materials using biotechnological methods;

Create bio-plastics and materials to produce it from renewable raw materials using biotechnological methods;

Create new biocatalysts and develop their application technologies;

Create pharmaceutical and veterinary products.

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