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# UNDERSTANDING QUALITY FACTORS IN R&D ACTIVITIES: A NEW MODEL FOR QUALITY MANAGEMENT

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***Abstract:*** *Project quality management is one out of ten areas of project management defined by the Project Management Institute (PMI). According to definition, it includes the processes for incorporating the organization's quality policy as regards planning, managing, and controlling project and product quality requirements in order to meet stakeholders' objectives. The current paper focuses on R&D (research and development) projects, whose specificity and high-uncertainty of the results requires a specific approach to quality management. In view of the lack of research efforts in this area, the objective was to propose a new, multicriteria based model for R&D project quality management. The construction of this model was based on the review of the extant knowledge and interviews with certified R&D project managers. The model includes factors influencing both the quality of project activities and the quality of R&D results. As a next step, the model was tested based on multi-criteria evaluation of the relative importance of these factors. It has potential, inter alia, to support decision-makers in selection of the optimal project quality management strategy. Finally, relevant recommendations have been provided for researchers and practitioners.*

***Keywords:*** *project quality management, multicriteria evaluation, research and development, R&D*

## 1. Introduction

Research and development (further: R&D) projects serve as the cornerstone of innovation policy at both the macro level, involving the state, and the micro level, concerning the organization conducting the project. The successful execution of R&D projects is key in determining whether an organization is achieving full competitiveness. However, management of R&D projects takes place in constantly changing and extremely uncertain conditions. Thus, effectively managing R&D projects demands not only a high level of expertise, but also proficiency in advanced PM tools (Kisielnicki, 2014).

The concept of quality in R&D projects is a very complex problem, which requires incorporating different knowledge domains and approaches. They include, *inter alia*, quality management processes in project management, competencies of project managers (PMs) to implement these processes in the specific ecosystem of R&D activities (especially if they are carried out in SMEs), as well as different methods which help to operationalize quality management factors in such a complex environment. The system of quality assurance (QA) in R&D

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projects can be defined as the planned and systematic actions to verify whether R&D processes are conducted in a proper manner and the R&D results satisfy customers' requirements (Kim et al., 2013).

Project Management Institute, an international, US-based, non-profit organization associating project managers, defines project quality management as the processes for incorporating the organization's quality policy as regards planning, managing, and controlling project and product quality requirements in order to meet stakeholders' objectives (PMI, 2021).

Quality also constitutes the central (middle) element in the so-called Project Triangle (or: Iron Triangle, Triple Constraint Model). This is a key concept in project management, representing the relationship between four criteria (project constraints): budget (costs), scope, time (schedule) and quality (Pollack et al., 2018).

The aim of the current research is to bring together all the challenges and problems related to R&D project quality management into one, multicriteria-based model, and demonstrate how it may contribute to decision-making processes in enterprises carrying out R&D activities.

## 2. Key terms in management of R&D projects

Before we go further, it seems right to explain several important terms pertaining to R&D projects, such as the following: *innovation*, *technology readiness level* (*TRL*), *industrial research*, *experimental development*, and *commercialization*.

**Innovation**. The most widely used definition of innovation, and categorisation thereof, has been provided by OECD/Eurostat (2018). It defines *innovation* as "a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)", while *innovation activities* are defined as "all developmental, financial and commercial activities undertaken by a firm that are intended to result in an innovation for the firm" (p. 20). Further, it defines eight types of innovation activities, where R&D takes the first place on the list, followed by i.a. engineering, design and other creative work activities, intellectual property (IP) related activities and innovation management. It also classifies innovations into four categories, including product, process, organizational and marketing ones. The manual also emphasizes the role of *knowledge* in innovation processes.

**Technology Readiness Level (TRL)**. This is a concept introduced first by NASA (Sadin et al., 1989), which helps to classify the current state of technology maturity at one of the 9 levels: from "1" - beginning of fundamental research, where basic principles of a physical phenomenon were observed, to "9" - actual system tested and proven in operational environment, ready for implementation and use in real conditions.

**Industrial research and experimental development**. These terms have been defined jointly by the Commision Regulation (EU) No 651/2014. *Industrial research* is the "planned research or critical investigation aimed at the acquisition of new knowledge and skills for developing new products, processes and services, and for bringing about significant improvements in existing products, processes and services. It (...) may include the construction of prototypes in a laboratory environment or in an environment with simulated interfaces (...)" (art. 85). Experimental development has been defined in the same Regulation as "acquiring, combining, shaping and using existing scientific, technological, business and other relevant knowledge and skills with the aim of developing new or improved products, processes or services" (art. 86) (Prusak, 2017). These are jointly called R&D activities, and they correspond to particular TRLs. Specifically:

- TRL 1: fundamental (basic)

research,
- TRL 2-6: industrial research,
- TRL 7-9: experimental development.

*Fundamental research* is “original experimental research or theoretical research undertaken primarily in order to acquire a new knowledge of the fundamentals of phenomena and observable facts, without intention of direct commercial use” (Act of January 15, 2015, amending the act of financing science in Poland).

**Commercialization**. Some authors associate commercialization as the market-facing stage of R&D activities (Godin, 2006). However, it has many definitions in the literature and can be generally described as the process of introducing a new product or production method into commerce, that is, making it available on the market and offering to customers (Sløk-Madsen et al., 2017).

**Financing R&D**. This is perhaps the most difficult aspect of R&D activities due to high costs and uncertainty of the final results, both in terms of technology and the market. These problems have been widely recognised by the EU authorities, who acknowledge the role of innovation in the global marketplace (European Parliament 2023). To stimulate private-sector innovation and motivate to undertake R&D activities, the EU provides a number of financial instruments to support entrepreneurs, such as the European Regional Development Fund or Horizon Europe 2021-2027 (European Commission: ec.europa.eu). These instruments are distributed to the European entrepreneurs through the calls for proposals, in which entrepreneurs may compete in gaining funds to finance their innovative projects. Such calls take place either at national and at the European level.

## 3. Project quality management in R&D projects

The term *project* has been defined by another project management organization, International Project Management Association, IPMA, as “a unique, temporary, multi-disciplinary and organized endeavor to realize agreed deliverables within predefined requirements and constraints” (IPMA, 2015). Interestingly, this organization recognised the existence of R&D projects as a distinct category of projects, and provided sub-certification for R&D project managers. As regards R&D projects specifically, they should follow similar principles of project management, but their management is much more demanding and requires specific skills. This is due to the fact that R&D are categorized as not only the hardest, but also most significant projects for both an organization and the whole society (Kisielnicki, 2014).

Project quality management addresses both the management and deliverables of the project. It was defined in PMBoK as one out of ten areas of PM, namely: integration, scope, time, costs, stakeholders, communication, resources, risk, procurement and quality. As regards the quality management, it consists of three groups of processes: Plan Quality Management, Manage Quality and Control Quality (PMI, 2021). *Plan QM* is “the process of identifying quality requirements and/or standards for the project and its deliverables, and documenting how the project will demonstrate compliance with quality requirements and/or standards”; it can be done through a properly applied expert judgment, data analysis and decision making; *Manage Quality* means “translating the quality management plan into executable quality activities”; and *Control Quality* is “the process of monitoring and recording the results of executing the quality management activities to assess performance and ensure the project outputs are complete, correct and meet customer expectations” (p. 271).

There are four main criteria that are key in project quality management (Locker & Gordon 2005):

- Maximizing satisfaction of stakeholders and other project output users, which requires proper communication systems at various stages of R&D projects.
- Ensuring proper implementation and completion of all planned activities.
- Achieving the quality of both the final products and project processes, using a proper monitoring system.
- Ensuring that the project management system constitutes a supportive environment to reach the adequate quality of project output.

As R&D activities are seen as a primary catalyst for innovation processes, and with more and more R&D being integrated into business models, they should become the focus for implementing the quality management systems into the projects (Mikulskiene, 2014).

## 4. Model and method

### 4.1. Model

Based on the above mentioned processes of quality management and the review of relevant literature, supported by interviews with two R&D project managers employed in a technology start-up in Poland, the following key QM challenges have been identified.

In order to operationalize the above challenges, a model was built combining the above three project quality management processes and quality factors (criteria) in innovative, R&D projects.

**Plan QM**. Defining requirements for output technology, taking into account the unknown factors inherent in highly innovative ideas; the higher level of innovation, the higher risk of failure. The possibility of output parameters' simulation using professional engineering software is very important, but not enough to ensure final quality of the project. Such parameters may include technology features such as eg. resistance to temperature and humidity, which often require testing in real conditions. Defining what may possibly go wrong and affect the quality is also very important.

**Manage Quality**. Reacting to the rapidly changing marketplace and scarcity of resources required to maintain the planned level of quality of products and processes. It refers to both material and human resources (eg. specialized and poorly available components, highly trained and qualified R&D personnel). In addition, R&D staff often used to work in a remote way and/or with irregular work hours, a fact which generates significant communication problems affecting the quality of work and final product.

**Control Quality**. As R&D processes often require an iterative approach, it takes time to go through all TRLs up to commercialization. Thus, R&D projects are often long-lasting (taking more than 4 years), which makes the quality control processes difficult and often ends up in control of only the final output.

In order to operationalize the above challenges, a model was built combining the above project quality management processes and the respective criteria, specific for R&D projects (Table 1).

**Table 1.** Criteria for quality management in R&D projects

| Process | Criteria affecting quality |
|---|---|
| Plan (P) | Output parameters to satisfy market needs and expectations (P1)<br>Output parameters to be simulated (P2)<br>Output parameters to go wrong (P3)<br>Availability of resources to be predicted (P4) |
| Manage (M) | R&D work quality to be measured (M1)<br>Quality of materials to be measured (M2)<br>Quality of final product to be measured (M3) |
| Control (C) | R&D work quality to be executed (C1)<br>Quality of materials to be executed (C2)<br>Quality of final product to be executed (C3) |

### 4.2. Method

In the next step, we discuss how the above general schema can be applied to support quality management in R&D projects. The aforementioned challenges can be translated into a hierarchical structure consisting of the main goal ("Highly demanding project in terms of quality"), processes ("Plan", "Manage", "Control"), their relevant criteria (factors), and possibly the R&D projects as decision variants at the bottom of the hierarchy. Thus, the analytic hierarchy process (AHP) can be applied to get the following answers: 1) which criterion is the most important in R&D project quality management, and 2) which alternative is most demanding in terms of quality management and needs particular attention.

The AHP is one of the most frequently used MCDM (*multiple criteria decision method*), described and explained by numerous researchers. Besides the manual of its creator, T. L. Saaty (Saaty, 2000), publications such as Prusak and Stefanów (2014) or Kułakowski (2020) explain step-by-step how to use this procedure. It involves the following steps: 1) building hierarchy; 2) evaluating hierarchy using fundamental, 9-point pairwise comparison (PC) scale; 3) constructing PC matrices (PCM); 4) calculating local priorities (weights) using one of a dozen prioritization methods; 5) calculating consistency of judgments based on Consistency Ratio (*CR*); 6) calculating global priorities; 7) in group decisions, aggregating priorities into common ranking vectors.

## 5. Results and discussion

The application of AHP to evaluate quality management factors in R&D projects is demonstrated based on the expert comparisons provided by two R&D project managers. Table 2 shows their aggregated judgments - priorities (weights) for processes (P, M, C), and their respective criteria (P1 - C3). "Local priorities" are those which reflect the importance of a given element with respect to its parent element (one level above in the hierarchical model), while "global priorities" reflect the importance of a given element in the whole system. Thus, global priorities are calculated by multiplication of the process priority by local weight of the particular criterion.

$$w_g = w \times w_l$$

For example:

$$w_g(P1) = w(P) \times w_l(P1)$$

$$w_g(P1) = 0{,}3971 \times 0{,}2097 = 0{,}0833$$

**Table 2.** Priorities for processes and criteria

| Process | *w* | Criteria | *w* local | *w* global |
|---|---|---|---|---|
| P | 0,3971 | P1 | 0,2097 | 0,0833 |
| | | P2 | 0,1145 | 0,0455 |
| | | P3 | 0,5837 | 0,2318 |
| | | P4 | 0,0920 | 0,0365 |
| M | 0,2734 | M1 | 0,0827 | 0,0226 |
| | | M2 | 0,1635 | 0,0447 |
| | | M3 | 0,7538 | 0,2061 |
| C | 0,3295 | C1 | 0,0827 | 0,0273 |
| | | C2 | 0,1635 | 0,0539 |
| | | C3 | 0,7538 | 0,2484 |

The ranking vector of global priorities is shown in the barchart (Figure 1). It indicates that the priorities of three criteria (C3, P4 and P1) exceed 20%, and they all together account for nearly 70% of importance in the quality management of R&D projects.

As it was expected, the most important factor in R&D project quality management is execution of the quality of the final product (*w(C3)=0,2484*). The next quality criterion in terms of the importance is planning the availability of resources (*w(P4)=0,2318*). It demonstrates the contribution of resources (both human and material ones) to R&D quality management. It was especially evident during Covid-19 pandemic, and it continues due to the war in Ukraine. For example, shortages in worldwide supply of electronic components, resulting from stopping production in Chinese factories, forced many R&D project managers to lower the quality parameters of their innovative results. The interviewed experts stated that they had to redesign the product to be able to meet the deadlines and functionality, but it happened at the expense of quality. Moreover, low availability of R&D personnel was also a major problem affecting the quality of products and processes. It resulted from both the Covid-19 restrictions and rapid growth of inflation rate. The latter fact caused many entrepreneurs not being able to afford the wage requirements of their highly qualified and experienced research staff.

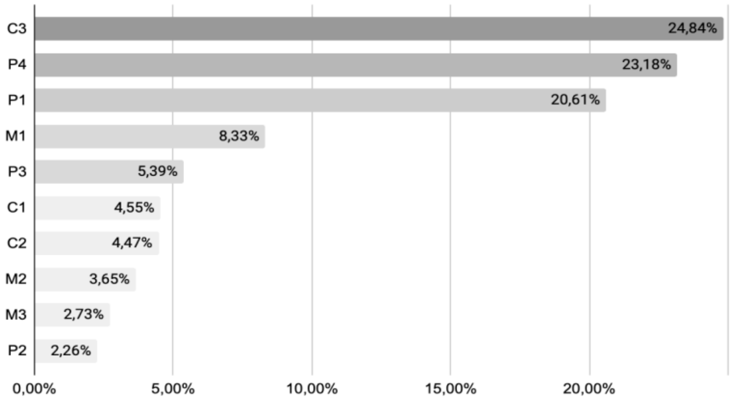


**Figure 1**. Global priorities of the criteria of quality management in R&D projects

The third significant criterion is to plan result parameters which satisfy market needs and expectations (*w(P1)=0,2061*). High score assigned to this criterion indicates the importance of the commercialization phase following R&D activities. It also demonstrates the significance of the planning processes in R&D quality management, which received nearly 40% priority (*w(P)=0,3971*).

In addition to setting the ranking of the quality criteria, the AHP can be applied to indicate which R&D project has the highest quality requirements. This would require taking into account project variants in the hierarchical model, and analyze them based on pairwise comparison against each criterion. It is also possible to establish the ranking of the specific parameters which can be modeled as sub-criteria of the relevant criterion. However, we do not present it here due to character limits, but it is a problem worth further scientific considerations.

## 6. Conclusions

The problem discussed in this paper, a multicriteria-based modeling of challenges related to R&D project quality management, is currently very important in Poland. This country is the largest beneficiary of the EU funds devoted to innovative, R&D projects, carried out in the private sector (especially by the SMEs). It is reflected in the enormous number of R&D projects co-financed from the EU funds. For example, the National Centre for Research and Development, the Polish largest agency responsible for distributing the EU funds, provided a list of nearly 14000 beneficiaries of the Operational Program Smart Growth 2014-2020, aimed at fostering R&D activities in enterprises. It raises questions about the quality of both the R&D processes carried out, as well as the quality of their innovative results. Thus, more exploration is needed in this area, and the research effort reported in this paper is one of them.

## References

Act of January 15, 2015, amending the act of financing science in Poland. *Polish Journal of Law 2015*, item 241

Commision Regulation (EU) No 615/2014 of 17 June 2014 declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty, Official Journal of the European Union

European Parliament (2023). Fact Sheets on the European Union. Innovation Policy: https://www.europarl.europa.eu/factsheets/en/sheet/67/innovation-policy [accessed 30.04.2023]

European Commission, European Regional Development Fund: https://ec.europa.eu/regional_policy/funding/erdf_en [accessed 30.04.2023

European Commission, Horizon Europe: https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en [accessed 30.04.2023]

Godin, B. 2006. The Linear Model of Innovation: The Historical Construction of an Analytical Framework. Sc*ience, Technology, and Human Values*, 31(6), 639-667. doi: 10.1177/016224390629186

IPMA International Project Management Association (2015). *Polskie Wytyczne Kompetencji Indywidualnych ICB 4.0*. [*Polish Individual Competence Baseline ICB 4.0*].

Kim, D.-H. Kang, M.-S., Ji, D.-H., & Choi, S.-J. (2013). R&D Quality Assurance: General Types and Key Quality Elements. *Journal of the Korean society for quality management*, *41*(4), 581-599. doi:10.7469/JKSQM.2013.41.4.581

Kisielnicki, J. (2014). Project management in research and development. *Foundations of Management*, *6*(3), 57-70, doi: 10.1515/fman-2015-0018

Kułakowski, K. (2020). Understanding the Analytic Hierarchy Process. *Series in Operations Research*. CRC Press, Taylor & Francis Group, A Chapman & Hall Book. doi: 10.1201/9781315392226-8

Locker, K., & Gordon, J. (2005). *Project Management and Project Network Technique*s. Prentice Hall.

Mikulskiene, B. (2014). *Research and development project management. Study book*. Mykolo Romerio Universitetas, Vilnius. ISBN 978-9955-19-637-2

OECD/Eurostat (2018). Oslo Manual 2018: *Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition, The Measurement of Scientific, Technological and Innovation Activities*. OECD Publishing, Paris/Eurostat, Luxembourg. doi: 10.1787/9789264304604-en

PMI Project Management Institute (2021) *A Guide to the Project Management Body of Knowledge PMBoK 7th Edition*.

Pollack, J., Helm, J., & Adler, D. (2018). What is the Iron Triangle, and how has it changed? *International Journal of Managing Projects in Business*, *11*(2), 527-547. doi: 10.1108/IJMPB-09-2017-0107

Prusak, A., & Stefanów, P. (2014). *AHP - Analytic Hierarchy Process. A step-by-step construction and analysis of decision models* (In Polish: *AHP - analityczny proces hierarchiczny. Budowa i analiza modeli decyzyjnych krok po kroku*). Beck, Warsaw.

Prusak, A. (2017). Development of new technologies in the context of the EU funded projects in Poland. *Conference Manual of the 2nd International Conference on Quality of Life*, 8-10 June 2017, Center for Quality, Faculty of Engineering, University of Kragujevac, 407-415

Saaty, T. L. (2000). Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process. Analytic Hierarchy Process Series, 6. RWS Publications, First Edition.

Sadin S. R., Frederick P. P., & Rosen, R. (1989). The NASA technology puts forward future space mission systems. *Acta Astronautica*, *20*, 73-77. doi: 10.1016/0094-5765(89)90054-4

Sløk-Madsen, S. K., Ritter, T., & Sornn-Friese, H. (2017). Commercialization in Innovation Management: Defining the Concept and a Research Agenda. *Paper presented at 77th Annual meeting of the Academy of Management,* Atlanta, Georgia, United States.

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