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# PROJECT MANAGEMENT IN RESEARCH AND DEVELOPMENT

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***Abstract:*** Implementation of R&D projects determines whether the organization is changing and becoming fully competitive. R&D projects are the basis for innovation policy at the macro level – the state – and the micro level – the organization. Management of R&D projects requires not only high level of skills, but knowledge of highly developed tools to support the development of the organization. In managing this type of project, methods such as management competence, talent and knowledge, knowledge of modern information, and communication technology, stand out. In this study the following issues are presented: analysis of decision-making processes of R&D projects, basic modeling methodology of R&D projects, and analysis of communication systems in project management. The final part of the article presents the problems of commercialization of results obtained from R&D projects.

***Keywords:*** R&D projects, decision in R&D projects, modeling of R&D projects, the system of communication in the project, the project managers, the commercialization of the project results.

## 1 Proposals for research – development, characterization, and importance

In management science, different periods of research proposal development can be distinguished. There are calm periods of evolution, but also turbulent periods of revolutionary change. Certainly, the present is situated in the latter. It consists of the fact that organizations that have, so far, been structured, orderly (managed, objective, and hierarchical), and transferred to a new type of flexible management. Such flexible management, focused on objectives and results, is called project management. R&D projects are in the family category of both the hardest and most significant projects in the development of organizations and society. Managing this type of project requires commitment and knowledge; an ambitious challenge for everyone involved in the project. For R&D, each project has its own area of research. Depending on the nature of the project as a whole, the research part will have a different contribution.

Implementation of R&D projects determines whether an organization is changing and becoming fully competitive. The state and its government, which does not attach importance to such projects, is not an attractive partner for other countries. Such a state is not innovative. R&D projects are, in fact, the basis for innovation policy at the macro level – the state – and the micro level – the organization.

Management of R&D projects requires not only high level of skills, but knowledge of highly developed tools to support the development of the organization. In managing this type of project, some methods stand out, such as management competence, talent and knowledge, knowledge of modern information, and communication technologies, as well as the ability to use both Management Information Systems (MIS) and Business Intelligence Systems (BIS).

R&D projects have a very broad meaning, including the business of creating new objects and changing the existing ones. The research carried out often ends up suggesting that the intended changes do not pay to be carried out. Procuring research projects tends to be too political, with parties who are interested in research because of public sentiment, especially after various decisions modifying economic life. Such research often results in a waste of public funds. Often parties implement projects as a first test of public sentiment, and only then take positions on the case. For example, a public opinion survey on the implementation of innovative projects, such as the construction of a nuclear power plant.

All organizations are interested in projects that will enable them to become competitive. Projects may include, among others, organizational change, technology, and marketing, including the introduction of new products or services. The result of the project is to obtain new products, e.g. different types of mobile phones or devices for copying documents. R&D projects can be as simple as writing a transition to college, or a Bachelor's or Master's thesis, but they can also be complex and require the cooperation of teams from many

countries (projects global), and the disposal of huge financial resources. One example is an R&D project, implemented in 2012: Flight to Mars, the purpose of which was to take pictures of the Red Planet.

We conclude that a project is a system of activities characterized by the following triad: project scope, deadlines (time), and resources (human, capital, material, technological, information needed for the project). Sometimes the aforementioned parameters characterizing new projects are added, such as criteria for quality, cost, or risk. In the literature it is written as the characteristics of the project, such as uniqueness, complexity, and traceability. These features in the case of R&D projects are always present. Just as it is said, 'do not enter a second time into the same river,' so a second identical R&D project is never implemented. Conditions change. The people are not the same. Sometimes these changes are large, sometimes small. The complexity of the problem is not unique.

Each project has a primary objective in the implementation and support of specific goals. The general terms of a project, however, are not always congruent with R&D projects. R&D projects are carried out in conditions where it is often difficult to determine whether a goal has been achieved. Therefore, there are frequent cases of disagreement between reviewers reporting on projects in various competitions. M. Trocki [45] notes that there are high-risk technical, organizational, and economic factors in projects. It is good if we can determine the probability of achieving the project, expenditures, and execution time. The consequences of the absence or scarcity of research in the procedures of the project make its costs grow, even to a very large extent, such that sometimes it will not be realized at all.

The task facing the implementers is often the analysis of the relationships in the selected area of reality. This is consistent with the principles of system analysis, according to which the R&D project is an open system of actions, in which we analyze all of its elements and the relationships between them. The overlapping relationships are diverse in nature. One of the most important is feedback. The project, by obtaining partial results, verifies earlier hypotheses that can be corrected in the next stages of work. During this procedure, hypotheses are put forward by other researchers. You can also transfer results obtained during the implementation of projects in the field of basic science into practice. The earlier you check the correctness of the results, the lower the potential costs in making the necessary adjustments.

Due to the nature of the work and the final result, R&D projects can be divided into:

1) Soft: those projects whose implementation is based on the presentation of reports, or semantic computer models, and other studies in the discovery of new relationships, patents, or improvement of techniques and technologies used. The result of these projects, according to the value chain, can be further researched.
2) Hard: projects in which the goal is defined as a product presented in the form of a pattern or the finished product. Here, too, there is a value chain, which results in an improved prototype in future projects.

The National Science Foundation (NSF) defines three types of R&D, namely: basic research, applied research, and R&D. Basic research is the primary aim of acquiring better knowledge and understanding, without a focus on practical application. According to the terminology adopted by the Central Statistical Office of Poland (http://definicja.net/definicja/Gus), R&D is considered to be systematically conducted creative work undertaken in order to increase the stock of knowledge, including knowledge of man, culture, and society.

According to the presented ideas, we assume that R&D projects are defined as the realization of a particular purpose, not always precisely worded, allowing new knowledge about the reality that surrounds us, to which end we have the necessary resources, including a highly qualified team of contractors. The project must be achieved at a given time, while being aware of the risk (sometimes high), and the assumed parameters. We are also aware that at the beginning of the project, all is not completely identified, and the parameters of the project will only be clarified during the work. Management of the project aims to develop the response posed by the initiator (sponsor). The objective is to increase the intellectual capital of individual researchers and teams, and the result is the development of theoretical and practical assumptions, plans to create a new product or service, as well as the development of principles of a new project. Often, the initiator is also the manager of the team performing the project. Often work organization is amorphous (i.e., sponsor, manager, and producer are the same person).

R&D projects have a good chance of achieving success, if they meet the following conditions:

- the project is relatively new (no one had realized such a project before),
- there is a very clear goal of what needs to be achieved,
- researchers with appropriate expertise and strong track record are involved in the project,
- the project is consistent with the strategic approaches developed, depending on the context: organization, region, state of the European Union, and the world economy.

If these conditions are not met, it is likely that it will be very difficult to achieve success in implementation.

## 2 Decisions in the implementation of R&D projects – the concept and typologies

In each phase of the research project, a number of decisions are taken. Some of them are more important from the point of view of the objectives, others less so. Activities in this field are supported by the decisions that are taken on their own, forced or taken by someone on our behalf. The concept of 'decision' (Latin *decisio*) has two basic meanings: result (narrow) and function (wide). Decision making is understood as the non-random selection of one of a set of possible options. The decision in the second, broader sense is understood as the process of deciding, which consists of: evaluation of information, decision-making problem identification, selection criterion decision, and determination and registration information for its execution.

A common platform for decision-making problems is derived from the work of the 1978 Nobel Prize winner, Herbert A. Simon [40]. This is sometimes called the Carnegie School approach from the name of the university where Simon worked. His concept of bounded rationality criticizes the concept of economic man (*homo economicus*), who decides only in his own interest. The approach of the 'homo economicus' decision maker is based on not having complete information about the problem of decision making, as all the possible options for solutions to the problem and the consequences of their application are not known. Its objective is to maximize the utility and ability to rank the options to be implemented according to the probability of success. H.A. Simon, like most of the people involved in decision-making theory, believed that the decisions are made by decision-makers with limited opportunities to formulate a set of possible alternatives, and the consequences of their discernment forms part of its adoption. Hence the action makers – project management here – are not fully rational. In practice, the first chosen course of action that meets the criteria and the expected results, are good enough for the decision maker. The decision is a derivative of the objectives pursued and the tools to reach it.

The decision-making process (DMP) can be divided into seven elements such as:

- decision-making situation (decision problem) – a situation in which an entity (decision maker) is faced with the need to select one of at least two possible options for action where appropriate decision making is a set of options or conditions affecting the pursuit of the decision,
- decision maker – individual or group of individuals who decides or selects the final variant of decisions,
- the reason for the decision – perceived by the decision maker as a threat or as an opportunity; general situation that requires a decision,
- the purpose – the desired state intended, which is achievable through the implementation of the decision,
- the subject of the decision – with what is the decision concerned, which spheres of activity,
- user decision – person(s) for whom the changes caused by a decision may be relevant.

The decision in R&D projects is to select one of a set of capabilities to achieve the objective, related to all phases of the project, which consist of at least two competing elements. This process of selection is called DMP. Decisions affect a variety of factors such as tradition, convenience, experience, State guarantees, etc.

From a formal point of view, the DMP in R&D can be represented by the following:

$$PD = \{P, S, W, H\}$$

where:

P = the decision-making body, which must decide on the establishment of the project and decisions regarding its implementation; decision-maker has the right to decide, bears the responsibility for it and is interested in its implementation,

S = a set of decision-making situations, i.e. a set of conditions; these are the conditions within the organization or in its surroundings, where a particular deci-

sion is taken by considering the so-called terms of decision-making in accordance with the principles of the golden triangle: scope, time, and budget,

W = a set of results, to be able to select and determine whether the right decision has been taken, we need to know how it will end; the results depend on both the company's decision-making, as well as certain conditions (the conditions),

H = a set of hypotheses about future situations involving both the terms of the project, as well as influencing decisions on its implementation.

In DMP, one should have knowledge not only of the existing conditions, but also about how they will shape the future. We can distinguish the following situations:

1) Decision making under conditions of uncertainty.
2) Decision making under risk. Risk for the condition is considered to be a situation in which the elements influencing the decision are known with a certain probability.
3) Decision making under uncertainty. This is very much the situation occurring in projects, especially if they relate to strategic issues.

In practice, this also concerns deterministic and stochastic situations in decision making. The last two situations mentioned above define a common term: stochastic decision. The decision must be remembered in the existence of competition. Competitive projects can be changed at any time, and the rival can modify its earlier decisions and try to anticipate the decisions to be made by his competitors.

The implementation of many R&D DMPs are evaluated, controlled, and supervised. Function is performed by the evaluators. The natural way is to become their sponsors (stakeholders).

Evaluators use different evaluation criteria. The variety of decisions often leads to groups, classified by identifying some common characteristics and conditions. With the separation of the different types of DMP, it is easier to manage the project, train and improve decision makers, build specific procedures to assist managers, and rank performers. The classification of a decision for a particular type allows a more effective search algorithm, or heuristics, as well as highlighting decision risks, errors or traps specific to the type. The extent of the impact of the decision can be: economic, technical, information, personnel, production, and organization.

Because of the seriousness of the case and place in the hierarchy of project management, decisions can be strategic, operational, and tactical. Traditional management functions are distinguished by planning decisions, organizational, coordination, order giving, control, and motivation. Decisions may be taken both by individuals as well as by groups of people. Their specificity, often called psychological and sociological considerations, can distinguish several types of decisions that could significantly affect the operation of the project management system. These are often described as balanced, impulsive, passive, risky, and cautious.

To take the best decision from a set of possibilities requires the use of a variety of tools. They have a different form. Some are complex, while others are quite simple, such as, the model of a garbage can. It is used to make decisions in a situation of high time pressure and high complexity. The model name suggests the disorder, the lack of clear rules, and randomness (chaos) refers to the principle of trash in physical terms. The author of the theory is M.D. Cohen [34].

A contemporary tool to assist DMP is Information and Communication Technology (ICT). The problem of tools to support decision making is a wider problem, influenced by the type of decisions for which they are to be useful. In the DMP in the course of the project we have to deal with the chain of decisions. In making the first decision, we should consistently take all subsequent related decisions.

The results obtained after the first decision affect the next. Such models are called decision-making dynamic models. In contrast, the studies of specific individual decisions include static models. DMP, in which all stages of the design are strictly defined, is called algorithmic, and the method of its implementation is defined as an algorithm.

Heuristics is defined as the discipline dealing with methods of solving problems under conditions of incomplete information. The heuristic approach is offset by the lack of information, intuition, and experience. The use of heuristic methods needs the ability to locate and detect the facts and relations between them. Most of the discoveries, inventions, and unconventional methods of operation are achieved by heuristic techniques to solve problems.

Table 1. Selected project management features supported by formal models

| Management Features | Mathematical Quantitative Models | | | | | |
|---|---|---|---|---|---|---|
| | Optimization | Simulation | Econometric | Predictive | Theory game | Theory graphs |
| Forecasting | X | X | X | X | X | |
| Programming | X | X | | | X | |
| Planning | X | X | X | X | X | X |
| Coordinating | | X | | | | X |
| Monitoring | | X | X | | | |

*Note*: X indicates that the function is particularly often assisted by quantitative methods

The general characteristics of the situation seem to be useful for programmable decisions only. Programmable decisions are taken in relation to projects with a clear structure, in which the problem is clearly defined. In practice, a hybrid approach is required, that incorporates both algorithmic and heuristic elements.

Mistakes, or the existence of new reasons, make it necessary to change the decision. If these are seen after the implementation of the project, then assume a much higher repair cost than shown in the initial steps. It is also assumed that the cost of repairing errors grows in an exponential manner depending on the time of their discovery.

## 3 Modeling of R&D projects – methodological basis

Decisions before they are implemented in the real world should be checked in the virtual world, i.e. modeled. What is the model? According to W. Findeisen [10], it is an ambiguous concept. Typically, the model is understood as a certain image or pattern. Sometimes the model is identified with a very broadly defined course of action. The project model and implementation process is a simplified picture of reality, because it focuses on what is most important. Its construction is based on system analysis, or a set of elements and relations between them. The costs of mistakes in the world of models are much lower than those in the real world. We take care of a particular class of models, namely models of managerial decision making. Decision models have different designs and are both mathematical models and structured. The specific practical situation requires modification of the base model and its adaptation to the real situation. It could be argued that, in practice, no two models are ever the same.

A decision model is a concept in the theory and practice of management. It shows the mapping of the whole or part of the reality that synthetically describes the decision problem (see Table 1). Its task is to define a set of permissible decisions, evaluation criteria, and the conditions of implementation, to be able to select a set of optimal decisions, if such solutions exist. In practice, the project management of R&D strives to create models with the greatest possible participation of formal elements. Due to the interdisciplinary nature of the decision-making processes in the implementation of R&D projects, it happens that the applied models are statistical, econometric, economic, and semantic. There are also models that can be classified as psychological and philosophical.

Before we start to build the model, we need to formulate the decision problem. The conditions that were adopted in the formulation of this problem, also become the DMP assumptions. Sometimes, there are two types of DMP models, conventionally called classical and managerial. In the classical model, there is a belief in the possibility of optimizing the decision. It is believed that rational, reasoned, and systematic actions are conducive to finding relevant solutions to problems. The managerial model explains that it is practically impossible to make optimal decisions, but you must strive for such a solution. Therefore, the project manager and his team should seek to obtain full information about the decision situation and seek to minimize risk. Such activities need to have a broad set of information. This form of decision making uses the experience of the expert team and tools such as mind mapping and brainstorming.

The hard approach, which we call engineering, seeks to ensure the model is accurate and unambiguous. It is created using modeling languages and computer programming, as well as formal techniques. In practice, the packages used are computer-specific, such as, 'Statistica'.

The basis of the modern approach to project management, irrespective of its use, are mathematical or other models, which also seek formal analysis of the project at all stages, but they have a slightly different structure and other features. We call them structural models. The name of this type of model comes from a focus on the presentation of project structure, in order to present them according to the existing system approach. As a result of analyses, hierarchical or network structures are created, which are data elements, features, and the relationships between them. This approach is currently dominant in project management.

The construction of structural models uses a number of techniques detailed in the literature and recommended design methodologies. Often, their job is the most accurate presentation of the situation and the decision provided to the project. To serve this purpose, specific techniques are included, such as: block diagram data flow, entity relationship modeling, and UML models used in the approach of ARIS [11] and ADONIS [48].

To build the model, it is necessary to use a specific notation record. Just as the semantic model is written using a specific language, using a dictionary and correct grammar, structural models for the description of the project also use a variety of notations for their construction. The simplest and probably oldest model used in the presentation of the processes occurring in the implementation of R&D projects is a block diagram.

In practice, we use hybrid models. In these types of models, there are both formal and heuristic elements. Such models are used in advanced projects. Two examples are given below, each model having different uses and structure. Both can be assigned to the class of structural models.

In the first of them – Mind Mapping – principles of graph theory are applied, while the second uses a tool to support applied statistics and econometrics. Mind Mapping is used for a variety of work-related R&D projects, especially for creating documents in procedures and formulation of decision problems. The result of the application of the model is – according to its creators – to work together to increase the efficiency of the system and to improve communication among teams.

Another representative of hybrid models is the Technology Acceptance Model (TAM). This model has an advantage over quantitative quality tools. We use the TAM to investigate causal relationships that occur in the project. The author of the TAM is F.D. Davis [7]. This model is used in the explanation of technological solutions adopted in R&D projects. Theory and models have been developed based on the Theory of Reasoned Action (TRA) [3]. TRA assumes that the final user's behavior is the result of his beliefs, fears, and hopes. This means that the more a person is convinced of the rightness of the selection tools, and hopes that it will help them work better, faster, or with less effort, the easier it will be to accept new technologies for project management.

In the process of analysis models used in projects, we would like to draw attention to the models used in the management of selected stages of this type of project. One of the most important steps is to define the R&D project. Two of the most useful models used in this stage of project management are the Work Breakdown Structure (WBS) and the logical framework. The use of this type of model is required in the majority of R&D projects, whose creators seek funding from the European Union.

The stage of the project can recommend the implementation of these models to support the implementation schedules, determine the critical path, designate milestones, and allow for resource management, as well as optimize the duration of the project.

Scheduling is a common tool for project management support. Basic information contained in the schedule shows the relationship between the activities carried out in the project. Schedules for R&D projects have their own specifications. The applications can be distinguished as follows:

- static models, such as an illustration of a graph (model) using a Gantt chart, is a graphic representation of the steps of planning and control of the project, often referred to as a technique of beam diagrams,
- dynamic models, also called network diagrams; the term covers models such as Program Evaluation and Review Technique (PERT) and the Critical Path

Method (CPM), developed by the company DuPont for control of large and complex industrial projects.

Regardless of the model presented previously, business models have a special place. In fact, in the business model, analysis should begin with the presentation of the selected item within the sequence of models used in the management of R&D projects. Implementation of the project always requires resources, and thus, we need to look at the R&D of the business side. This is an important but difficult problem.

We agree with D.J. Teece [43, p. 175], who says that 'good design is the art of business models.' The popular definition of the business model proposed by A. Afuaha and C.L. Tucci [2, p. 20] is that the 'business model is adopted by the method of zooming in and use of resources in order to provide customers with products and services whose value exceeds the offer of competitors and while ensuring the profitability of the company.' In simple terms, we can say that the business model describes the way in which R&D projects are to make money or be financed.

In most of the analyzed types of projects, maintenance problems occur in the initial stage, then depending on the result, come issues of commercialization of the results. The issue of commercialization will be the subject of the last section.

## 4 The project managers and their role in the project

Building a team to carry out an R&D project, we create (cf. [22]) human capital organization or intellectual capital, which are basically the same thing. If we used morphology success factors of projects, in the first place we would find a man. Therefore, it is reasonable to say that one of the most important factors affecting the success of any project is the human factor. Human resources policy depends on whether the project will be implemented in an efficient and economical way. In the literature, there are many books and monographs on social potential management, management of social capital, and intellectual resources of the organization. All management schools devote a special place to this problem.

The specificity of the action of project management happens in a constantly changing environment, where decisions are risky. Human Resources management policy in research and development should follow some basic rules:

- volatility of the situation and the need for permanent modification of assumptions and behaviors,
- work in specific time intervals (or stable employment dilemma to some extent uncertain),
- special role of the project manager – often the creator – in the project.

Management of and work to implement projects carry a wide variety of challenges. Many contemporary projects have been created in a multicultural environment. Traditional procedures, such as management, recruitment, selection, conflict resolution, and talent management require a slightly different perspective than is given in the traditional monographs in this field.

The work of the project manager has many features in common with the typical work of the team leader in the traditional functioning of the organization. His work, however, differs from that of the traditional head of the organization in several key aspects. First of all, the work of the project manager is to implement a unique project, involving a temporary working group. Employees are recruited from an organization that is interested in the results of the project, or from other organizations, often through the activities of recruitment of cells of different organizations. The aim of the project is to create something new, unique, and therefore, to achieve these objectives requires very good cooperation between the principal, the contractor, and the beneficiary of the project. Thus, the project manager should be both a politician and negotiator.

J. Szaban [42] and R.A. Webber divide the power as:

- legitimate: derived from the belief that to hold power you just have to listen, because the manager has the legitimacy to exercise authority and has the appropriate qualifications,
- traditional: resulting from customs not always stored in the work regulations and other legal acts,
- expert: listening to someone because of their knowledge and the skills by which they exercise authority over others; this type of power is the most desirable for the project manager,
- charismatic: resulting from the specific qualities of a person having authority, such as having a vision and ideas.

The head of a R&D project should have all of these types of powers, but the most important is expert and charismatic authority. Charismatic leaders are sometimes referred to as transformational leaders.

These leaders should also have such features as: intelligence, social skills, persuasiveness, prone to dominance, ambition, and aggressiveness. Use of the term 'transformational leader' highlights the role of the project manager in inspiring, marking out new ambitious goals, motivating people to their implementation, and leadership.

Each R&D project is an 'unknown'; its implementation requires courage. The project manager is the person who is aware that not everything can be foreseen and that project management is associated with the risk of losing a professional position, embarrassment, and sometimes even their own lives. Ideally, it is demonstrated in experimental projects, which could include those aimed at the study of new types of aircraft, parachutes, or nuclear reactors.

The project manager is trained for times of crisis, because they have a chance to show their charisma and skills. R.K. Merton [24] made the following distinction among project managers:

- people who have an impact on the team at the moment, and their social position are fixed,
- people potentially affected (rising stars, climbing up the social ladder),
- people whose influence gradually disappears (after reaching the summit, they descend the social ladder),
- people whose influence is 'hidden' (the person exerting influence has objective qualities, but does not use them).

Using this typology, we can conclude that the project manager of R&D is from one of the first two groups of people. He is head of the project team. According to H. Schelle [39], the project manager is the person responsible for the project; organizing the team, and for the management, planning, and monitoring of the project. His task is to create the conditions to achieve the goal or goals.

Tasks and services performed by the project manager are different from those carried out by other members of the project team. The project manager directs the work of others. They also perform the tasks as instructed, teach, or give directions. In this way, they develop the skills of employees. The manager-staff relationship is basically that of a coach, where the manager shares his experience with the person to be trained.

H. Mintzberg [47] developed a system that, even after many years, is still termed 'according to Mintzberg's managerial roles.' Under this system, all managers implementing the project have a triple role, namely:

- interpersonal,
- informational, and
- decision making.

The project manager works in an ever-changing situation, both internal and external. Theories of management science are termed scientific management, behavioral management, including the psychology of work, and system management. The use of all approaches to solve a particular problem is defined as integrated management.

The project manager must be sensitive to this, in order to create favorable conditions in which the project is carried out as efficiently as possible. In most cases, the worker is working in order to meet specific needs. W. Kieżun [13] states that the minimum management skills needed are: intelligence, mental strength, a certain level of morality, as well as a predisposition syndrome called managerial talent and sense of organization.

As pointed out by M. Romanowska [37], the manager shapes a new profile. The complexity of management causes a significant increase of demands on him. This new situation creates increasing difficulties, requiring an increase in the skills and competencies of managers and non-traditional systems to fulfill their leadership roles.

## 5 The system of communication in the project

The basic task of every project manager is to answer the question: How do you organize teams performing R&D to create the conditions for strengthening effects of working together, to allow full flow of information and knowledge within the team? Successes and failures of many projects depend on various factors. The most important is communication. It has a very large impact on the final effects.

One also has to deal with the mutual relations between internal and external communication systems. The advantage of the research presented in the literature concerns the analysis of external communication systems, usually the design team's relationships with the environment.

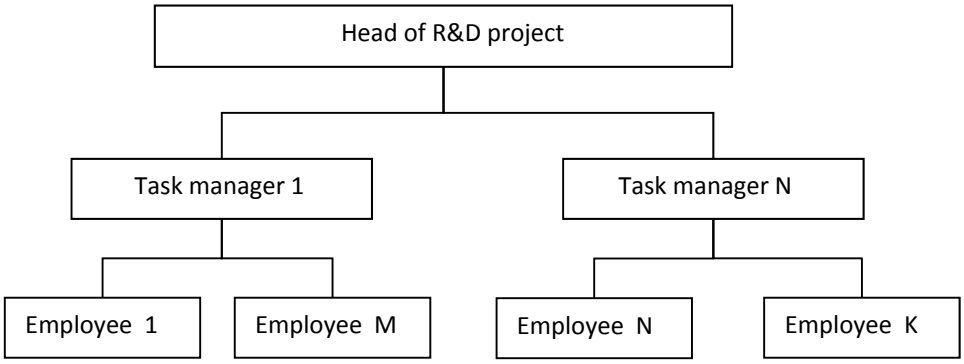



Figure 1. Hierarchical communication system

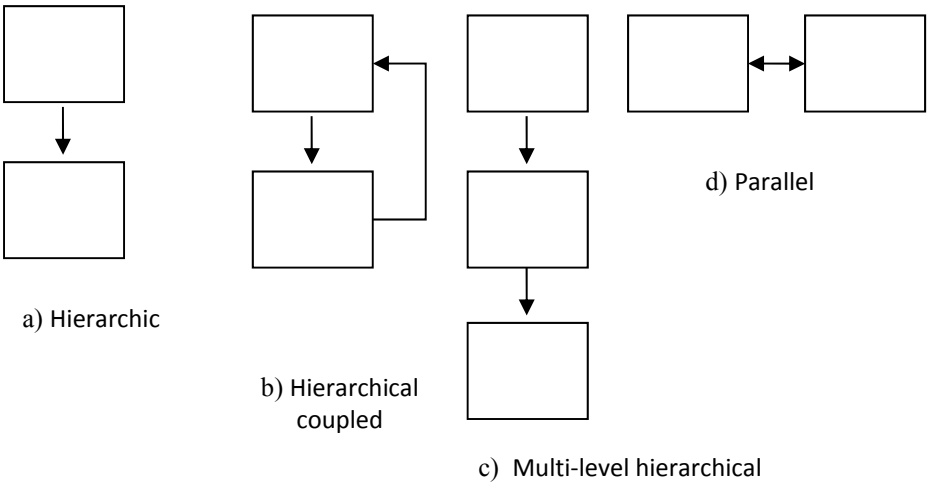



Figure 2. Relationship between individual employees in the project team

An analysis of publications in the field of building design and effective systems deserve special attention, since tests involve the analysis of the basic contradictions inherent in project teams (O. Stawnicz, K. Kurbel [41], D. Wehrenfennig [46]). L. Mullins [26] points out that the leaders of project groups of employees require both willingness to compromise and subordination, as well as high level of individualism and creativity. J. Chaffe [6] says that most people in the course of their work lose creativity and individualism in favor of conformity and mediocrity. Therefore, you will notice the tendency to form teams made up only of young workers, despite the absence of their professional experience. Consequently, you should reconcile to these contradictory tendencies and choose the most competent employees in order to minimize the risk of failure.

J. Adair [1] points to the three criteria that should be taken into account when selecting the design team: competence, motivation to work, and personal attributes. More specifically, before the task of organizing the communication system, the following question should be asked: What conditions should be created for the functioning of project teams to:

- minimize the negative effects of working in a team,
- strengthen the positives of this cooperation.

In fulfillment of tasks by project teams, different styles of management can be applied, and within them different systems of delegation of tasks and assessment methods for their implementation. Many project teams have used a traditional, hierarchical communication system as shown in Fig. 1. The communication system in the project team is made up of different types of 'bricks' or work stations. Basic types of connections are shown in Fig. 2.

Information System efficiency is dependent on the operation of the bricks, as well as the deformation associated with the operation of various types of noise in an information channel.

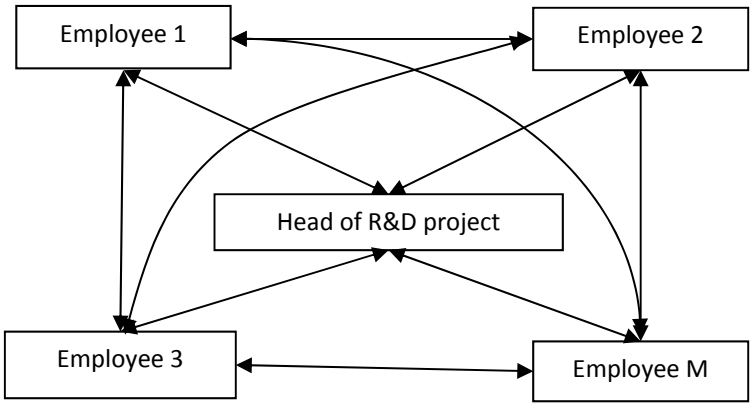



Figure 3. Network communication system in small teams carrying out research and development projects

The deformation is caused by factors such as:

- technical or computer, where existing infrastructure is unable to cope with the form and content of the transmitted information,
- semantic, that is when our recipient, usually with inadequate qualifications, cannot read or interpret the transmitted information,
- pragmatic, when the information received does not give anything new to him, and the recipient has lost time and resources to its acquisition.

Inefficient systems, shown in Fig. 2c, are characterized by long-term communication and the relatively large losses in the channels of information. Also, a system in which the employee receives only commands without feedback, illustrated in Fig. 2a, is not to be recommended. Such a situation does not occur in practice. There is always a feedback loop in which the subordinate employee provides information on the progress of the resulting task. However, as shown in previous works by J. Kisielnicki [14, 15], the relationship of dependency makes it difficult to absorb knowledge.

The employee is usually very reluctant to transmit knowledge to his leader. We can say that the employee considers it his duty to provide information only, rather than transfer his knowledge of the project. G. Morgan [25] writes that, in the organization, hierarchy is a source of various types of competition between workers. The game is played on the position of workers in the organizational structure. Based on surveys (J. Kisielnicki [14, 15]), it can be stated that the situation is different if employees work together, and the evaluation of their work is related to the evaluation of completed tasks together. Cooperation in such circumstances becomes a necessity. Between employees there may be a significant transfer of knowledge (J. Kisielnicki [16]).

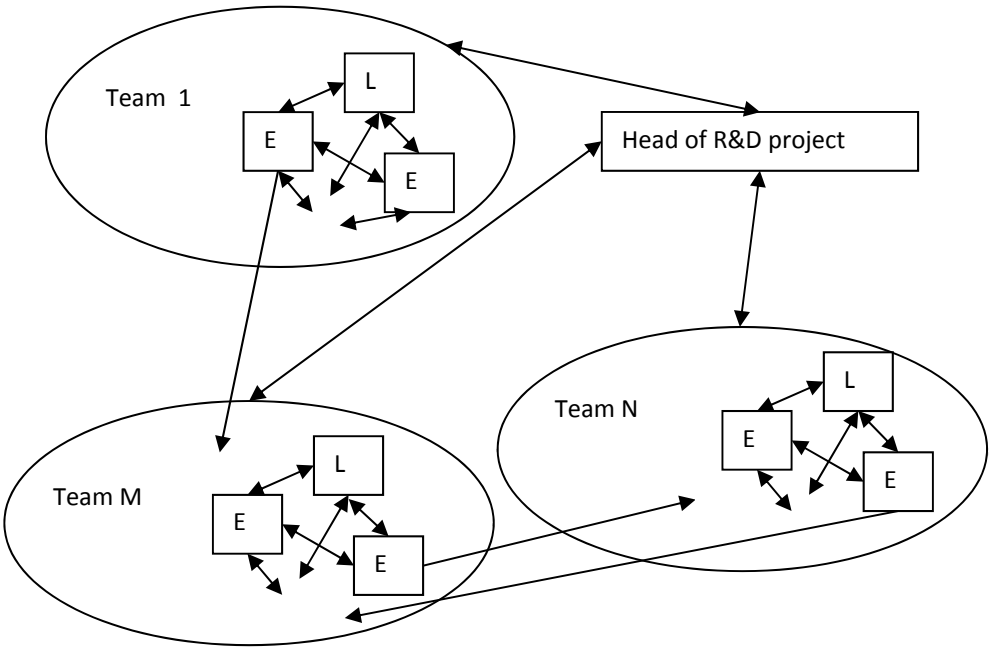
Tasks that occur in projects can be divided into two categories:

1) The implementation of tasks on technology purchased or installed software needed for research, as, for example, Statistica Data Warehouse. The most important is the strict implementation of so-called 'good' procedures. As practice shows, there is variability in business processes and project environments. This requires research projects to modify existing applications or existing processes to fit the reality.
2) Research tasks that require working in new and unique conditions, in which we have to use creativity and knowledge.

Therefore, keeping in mind the mentioned limitations, a network communication system is effective when it is determined by the performance of each point of the procedure

A network communication system is a system in which the relationships between the design team participants are direct. In such a situation, the role of the project manager is to build the system of information and knowledge, as well as the construction of a system of mutual trust between team members.

In practice, as shown in Fig. 3, network communication systems are used in a more complex form. Such situations are possible in small, five to seven person systems design.




The team implementing a specific task design

L — Head of the team performing a specific task design

E — Team member performing a specific task design

Relationship information and organizational subordination

The share of the employee performing the tasks in the Team M in the work of another team, for example, the Team N

Figure 4. Organizational structure and communication scheme in an organized network-large project team

This system was tested by the study author in the implementation of several complex R&D projects in the Information Technology (IT) industry. It has been well received by the persons carrying out the project, and what is most important, it has proved to be effective and efficient.

Organizational structure of network communication, as shown in Fig. 4, can be characterized as follows:

1) Division into task forces that change dynamically during the execution of the research project.
2) The only person coordinating the whole process is the project manager (Fig. 4). Persons acting as individual task managers have a dual role: being the task manager and the designer (clerical).

The projects examined by the author (J. Kisielnicki [18, 19]) changes in rotational job as a manager of the project, if the situation was announced at the beginning of the construction team and met with understanding. Financial rules have also been fixed so that the position of the head of the project was treated as a kind of duty, with rewards, but not as an additional source of income. Decisions about team changes were difficult due to two reasons: differences in the implementation of individual tasks and the time of formation of interpersonal relationships between employees. Getting used to work in a stable team is treated as an important element in promoting communication systems within the task force.

## 6 The commercialization of the project results

R&D projects should be applied in practice and benefit both the sponsors and the implementers. For this purpose, we use existing business models. Some projects bring economic or social benefits directly to others over time, some projects may produce patents, and others professional empowerment of the manager and project participants, through degrees or promotions.

Of course, getting degrees does not preclude advancement and often strengthens the competitive position of the project team and its members. Therefore, we need to consider this, as the results transform into money, or commercialization.A milestone in the commercialization of research was the Bayh-Dole Act, adopted on December 12, 1980 by the US Congress. This Act gave universities intellectual property rights to inventions and discoveries. (N. Kirov, A. Kuśmierz, [49]).

Commercialization is defined as all activities related to the transfer of technical or organizational knowledge and related know-how to economic practice. So, it can be defined as the process of market power of new technologies (in our results of R&D projects). Often, commercialization is deferred over time, because to commercialize, the project must first be implemented. In this part we deal with the problem of commercialization more, because we want to show the proposed arrangements for financing the implementation of R&D projects. The starting point of the commercialization process is usually an invention or produced results. This opens up new technical possibilities and research, by itself, has no market value. E. Rasmussen believes that the approach to the commercialization of research can be divided into two types: the American and Canadian-European. The difference between them lies not in legal regulations, but on the specific national markets.

In the US, there are some great companies interested in the results of research projects carried out in universities, but in Canada and Europe, this demand is not there. As a result, in these countries, scientific and research entities establish spin-off companies, thus creating a company to create and finance such projects. Spin-off companies are created in order to develop and commercialize the results of creative works, with the right to acquire and use of intellectual property and its protection among public universities. The capital of such a company often comes from different sources.

There are three basic ways to commercialize the results of research and development:

- direct sales results of R&D, which is the simplest, but also the least profitable form of marketing,
- license sharing of the results obtained, which is a more advanced method of commercialization and requires more effort due to the long-term nature of the relationship between the licensor and the licensee,
- bringing the results of R&D to the company, which is the most advanced form of commercialization; bringing the results of the project to contributions in kind which may be held in an existing company, as well as the newly formed, spin-off company (Pietrusiński R., Zawalonka-Cegielska J. [32]).

As the Ministry of Science and Higher Education notes in its documents, the sale of R&D is the least labor-intensive and least risky method of commercialization. It is also the method with the least potential to generate revenue. At the other end of the spectrum is a method that involves the input of a test facility to the company commercializing the results of R&D (or the establishment of the company). This is the most laborious and risky method, but has the greatest potential to generate long-term benefits.

The key problem is to decide on the legal form of organization, which is to commercialize the results. The form chosen should be linked to:

- determination of the number of entities involved in the project commercialization, such as state universities and private research institutes and research centers, and other similar type,
- choice of sources and funding model to implement the project,
- adoption of the most favorable tax arrangements for the activity in question,
- determination of the subject and form of management implementation process.

Selected legal forms should correspond to the assumptions and parameters of the target business model. Limiting the options of possible solutions of the many legal forms, we present the following forms: a government agency (state), a research unit, a foundation, or a company (joint-stock).

The aforementioned E. Rasmunssen [36] distinguishes two periods of commercialization of research in Europe. The first – the start of the 1990s – was the so-called development of technology parks. The second period, which continues to this day, was the creation of spin-off companies, the sale of patents and licenses, and the involvement of students. In some Polish universities, for example, in the University of Warsaw, Warsaw University of Technology, Medical University of Warsaw, there are spin-off companies. A description of some of the types of companies as well as the problems they create together with the literature are given by J. Kisielnicki [19].

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