TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
ELECTRICAL ENGINEERING | ELEKTROTECHNIKA

1-E/2016

DOI: 10.4467/2353737XCT.16.031.5293

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MANAGEMENT OF THE INNOVATION PROJECT IN THE AREA OF DESIGN AND IMPLEMENTATION OF MICROPROCESSOR SYSTEMS FOR THE RAILWAYS

ZARZĄDZANIE INNOWACYJNYMI PROJEKTAMI Z ZAKRESU PROJEKTOWANIA I IMPLEMENTACJI SYSTEMÓW MIKROPROCESOROWYCH NA KOLEI

A b s t r a c t

In the paper, the main elements of the management of product innovation projects in the field of microprocessor systems for the railway industry are identified. The advantages and drawbacks of methods, tools and techniques used for the management of innovation projects are discussed. Also, their influence on efficiency, quality, safety and effectiveness of the management of this kind of projects is described. Based on the available literature sources, contemporary tools and technology means enabling development of safe (from the functional point of view) microprocessor systems as well as the significance and influence of formal and legal factors on the way of projects execution are presented. The conducted analyses result in recommendations for necessary changes and improvements of the execution phase and identification of key success and threat factors in the management of innovation projects for the railways.

Keywords: Project Managment, Innovative Projects, Microprocessor Systems, Safety

S t r e s z c z e n i e

W artykule przedstawiono główne rozwiązania projektowe z zakresu systemów mikroprocesorowych stosowanych w przemyśle kolejowym. Omówiono główne wady i zalety technik stosowanych w zarządzaniu takich rozwiązań projektowych. Opisano również wpływ tych rozwiązań na bezpieczeństwo, wydajność oraz jakość. Na podstawie dostępnej literatury przedstawiono współczesne narzędzia i technologie umożliwiające rozwój bezpiecznych systemów mikroprocesorowych. Przeprowadzona analiza dotyczy niezbędnych zmian i ulepszeń na etapie realizacji oraz identyfikacji czynników powodujących sukces wraz z zagrożeniem przy stosowaniu innowacyjnych rozwiązań na kolei.

Słowa kluczowe: Zarządzanie Projektami, Projekty Innowacyjne, Systemy Mikroprocesorowe, Bezpieczeństwo

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Innovation projects are projects resulting from the realisation of industrially implemented new or improved products, new processes or services, or methods applicable in business practice, workplace organisation or relationships with environment [1].

In the recent years, a growing influence of innovation processes on the improvement of the efficiency of operation of companies and even of entire economies of several countries can be observed. All innovation enterprises are associated a larger uncertainty of outcomes because this kind of enterprises have a greater probability of failure than other projects, which follows from the lack of knowledge of many details of realisation. As a result, the process of risk management is nearly mandatory for those enterprises and it absorbs significant financial means, as well as human and technological resources. Because of the increased risk, the provision of funding alone is a big challenge for entrepreneurs, who sometimes delay the decision of starting the works or even withdraw from the project. The increased uncertainty associated with innovation projects is the reason they are deemed much more difficult to be managed. Knowing the particularity of such projects, also from other domains like, for instance, automation and industrial robotics, one may say that they should be managed in a different way than the typical R&D projects.

In the railway industry, wherever microprocessor controllers are used, two tendencies can be noticed – on the one hand, the eagerness to use any technological novelties, which allow gaining the competitive advantage is visible; on the other hand, very often, there is a requirement for the devices to comply with very rigorous SIL (Safety Integrity Level) functional safety standards following from the IEC61508 standard. Reconciliation of those two tendencies calls for the application of adequate means and techniques from the project management domain, and also for appropriate means and technical tools for the project to be led efficiently, while at the same time, satisfying high standards of reliability and safety.

According to the *PMBok Guide 4 Edition* [2], a project creates a unique product, service or outcome. J.P. Lewis [3] gives the definition of a project as “a multi-task job that has performance, cost, time and scope requirements and that is done only one time”. The project is an enterprise, which can be represented as having distinct phases – in Fig. 1, four phases are distinguished.

Project management is the process of making decisions and their execution [2], in which the leader is responsible for planning and monitoring the tasks involved in the project, making appropriate allocation of resources to reach the appointed goal within the deadline,

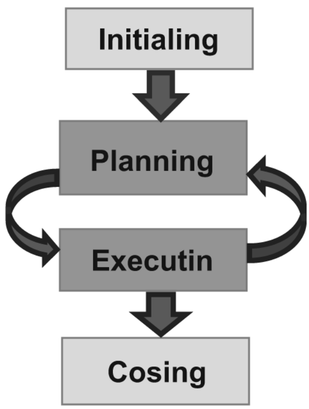

Fig. 1. A phase model of the project lifecycle

at defined costs, and ensuring the assumed quality. One of many organisations, which seek to define the minimum scope of knowledge necessary for effective project management, is the PMI (*Project Management Institute*), points to nine areas of this knowledge [2], that is, management of project integration, management of project scope, management of project time, management of project cost, management of project quality, management of project human resources, management of communication in the project, management of risk in the project, management of purchases in the project.

Besides the scope of knowledge necessary to lead the projects, particular significance is gained by concepts, such as skilful risk management, the social aspects, management of stakeholders of the project, and the institutional aspects [4]. The mentioned factors do not directly take part in the operational activities, but they are the processes and aspects, which often have significant influence on the project.

Risk management is the key process, especially in case of innovation projects. It runs in parallel to other operational activities during the whole duration of the project. All risks and possible event development scenarios, which are reactions to the identified threats, should be defined already at the project planning phase, and then they should be continuously monitored during execution. In general, risk is described as a probability of the occurrence of an event that will adversely affect the project. The probability of the occurrence of such events has a particular significance, especially in cases when some difficult to define elements are part of the project itself or its environment. This situation is characteristic for IT projects and innovation projects [5]. The risk is an inherent component of any project, which can, and should be controlled [5]. In the process of risk management, one may distinguish the following elements [6]:

- identification of threats,
- assessment of threats,
- description of feasible reactions to a threat,
- choice of reaction,
- planning of action and allocation of resources,
- monitoring and reporting.

For the sake of better efficiency of risk management planning, the risk is often divided into categories by its nature, e.g.: technical, financial, organisational, formal and legal, etc. [7], which makes it easier to identify the threats not noticed earlier. After the risks are identified, one should consider some tactics of how to proceed in case of their occurrence. The most typical countermeasures include [5]: threat elimination, threat mitigation, transfer of responsibility, and threat acceptation including a plan for actions to be taken in case of their occurrence.

During the decades, as a result of the realisation of diverse IT and engineering projects, which ended both with great successes and spectacular failures, certain concepts of project management have emerged, which take into account the use of limited resources, called project management methods. The first methods (classical methods) emerged from the general concepts of management. They evolved with increase of the significance of projects, thus engaging more and more refined tools and techniques. Every project boils down to solving problems and the execution of tasks in order to change the existing state into the desired state, thus creating the following cycle:

situation analysis → goals formulation → solution seeking → evaluation of solution options → choice of solution

Classical methods of project management are characterised by a sequential (linear) approach, where, initially, a detailed analysis of the problems is conducted in the effort to extract all relevant project elements. Next, a plan of realisation using the available resources (people, means, money) is developed, and then, operational works are started. Since that moment, the project management is mainly associated with monitoring the schedules and sequential and/or parallel execution of successive tasks, and in case of discrepancies, with appropriate reactions and updating of the base plans. The classical methods, the so-called waterfall or linear methods [8], are not very flexible and require diligent planning of all activities, well ahead of the beginning of the execution phase. Those methods are not suitable for projects where scope or aim cannot be well defined, which is the characteristic of innovation projects and the projects from the IT domain. They stem from the projects realised by corporations and large industrial plants.

The methods suitable for building a new knowledge base within the company and for introduction of innovative solutions, even if the project will be terminated at certain stage, are called adaptive methods of project management [8]. Their genesis is associated with the area of systems engineering and software engineering. Currently, one of the more popular adaptive methods is the AGILE methodology (*Agile Project Management*), which stems from the IT domain. As distinct from the traditional approach, in case of which any possible measures are taken to describe and define the project in the finest details since the very beginning, thus determining duration and cost of the project already at the business phase, the AGILE model assumes that the changes are unavoidable during realisation. It is assumed that the cost and duration have to remain constants, but within the defined budget and time one strives to deliver the highest value (functionality) of the scope appropriate to the current situation [9] (Fig. 2), available and known technology. In general, the Agile-type methodologies focus on providing the client with the highest value in the given budget and time.

Fig. 2. The project golden triangle

On the technical side, the projects in this model are conducted in successively defined stages, called sprints, which last from 1 to 4 weeks, depending on the scope. The aim of the sprint is to deliver the maximum possible product functionality to the client. Each sprint [10] consists of planning, execution, review of effects and retrospection. The retrospection is about gathering past experiences. Thanks to the sprints being short, it is possible to very quickly adapt to new environmental conditions and react to disturbances. The necessary condition for success of the projects realised by means of the agile methodologies is the client involvement. At the end of every sprint, the partial product is assessed by the client, suggestions and changes are proposed and the scope of further works is defined. For this reason, in the adaptive model, one of the largest threats is the lack of appropriate engagement from the business side [9]. Adaptive methods are successfully used in the industries like IT and telecom, where dynamic changes in technology are observed, and new trends in engineering or information technologies can pop up quite surprisingly. The traditional methods simply do not follow the changes because they treat the technology level as constant. This problem is neither new nor unknown, which is evidenced by numerous publications in web pages of agencies like, for instance, DARPA.

Figure 3 shows comparative statistics for projects carried out in the IT domain using the traditional and AGILE methodologies.

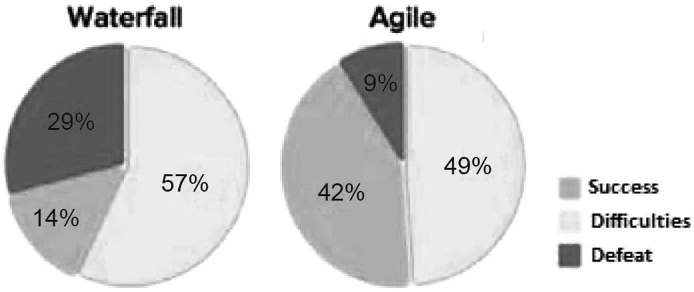

Fig. 3. Traditional and adaptive management methods for the IT projects
Source: The Chaos MAnifisto, The Standish Group, 2012

The adaptive methods perform well where clearly defined objectives exist with a simultaneous lack of the possibility of definition of the methods of realisation. Those methods guarantee quick reaching of project results by seeking optimal methods of realisation of project tasks [11].

Contemporary tendencies aim at joining the traditional and adaptive (like AGILE) project management methods together. The idea behind joining those methods is to allow mitigation of the main project problems: longer than assumed project duration and lower than assumed quality of the product [12]. Analysis of the available models of project management points to the possibility of their integration within a single project. The project models shown in Fig. 4 indicate that both the projects of a very large number of iterations and projects with unknown solutions become adaptive in their character.

The fundamental standard for functional safety – IEC 61508 – introduced as the mandatory model for management of a project whose outcome is to be the product of a very high level of reliability and safety integrity, the *V* model, known from contemporary corporations, by recognising it as satisfying the requirements of reliability of the device development process (Fig. 5). The process defined in the standard embraces the whole product lifecycle – since initialisation of the development (idea) to the moment of product withdrawal from the market.

The *V* model is based on classical linear methods of project management, enhanced with numerous iterations, which are the result of many years of evolution of the waterfall model. Working with this model allows to discover errors and defects of the product, also in the early stages of design, which reduces the risk of the occurrence of unforeseen events at the stages of system implementation and system use. Practically, since the project initialisation in the works must participate external certification unit, e.g. TUV, UL, EXIDA, SIRA, which is accredited in the project area. This approach is different from the traditional one, where the certification takes place at the end of the device development when fulfilment

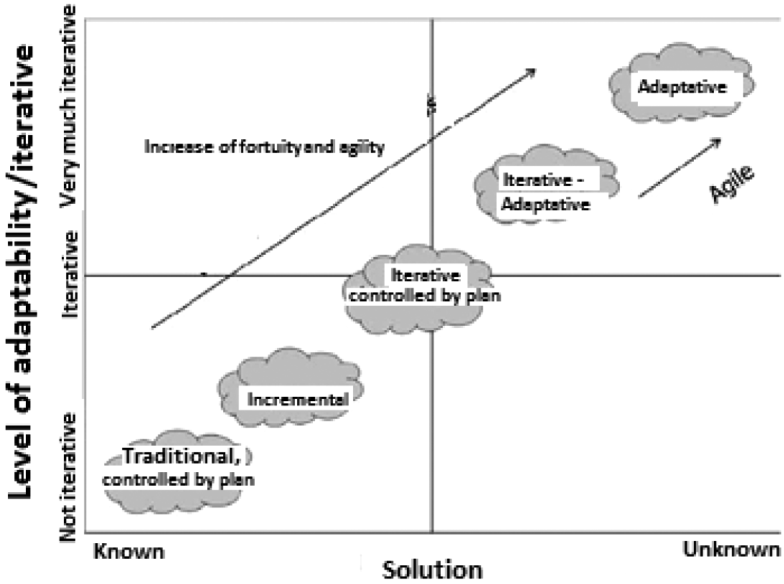

Fig. 4. Models of project management

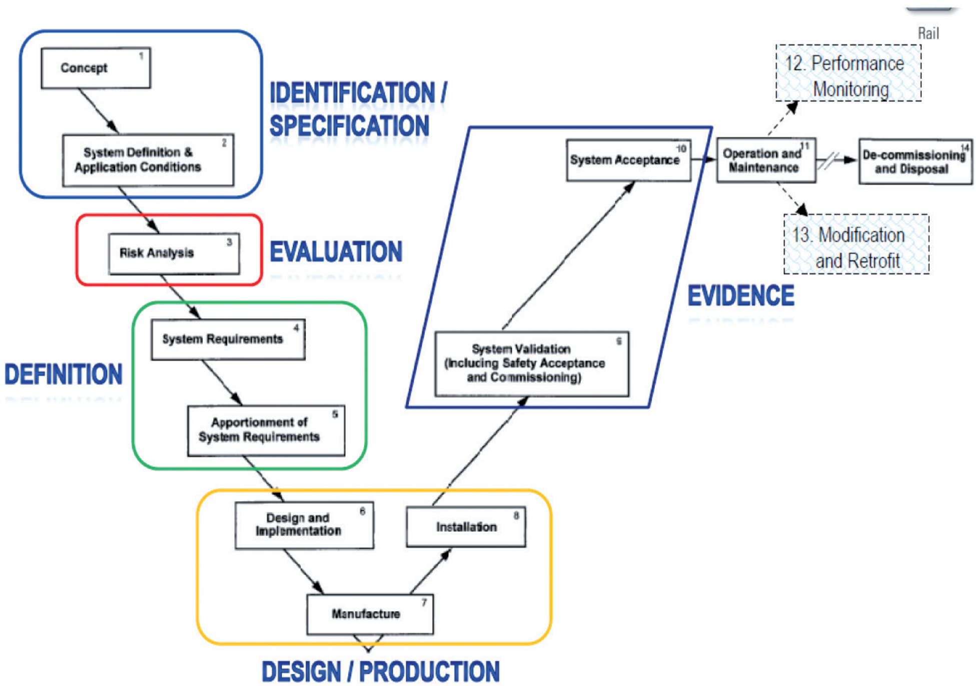

Fig. 5. The *V* model of project management proposed in the EN50126 standards

of the requirements stated in the relevant standards is tested. In the case of the equipment subject to requirements of the integrity of functional safety, the whole process of product development must be supervised. In case of development of a new product based on the previous solutions, they are also subject to assessment (defects, failures, design flaws and reliability of components). This methodology is also used in the IRIS railway standard.

Currently, key significance is had by the scientific and R&D works, which enable the application of elaborated knowledge and its introduction in the form of innovation to the production, implementation of a new process or service. It means that knowledge, intellectual work and information become the critical factors of the development of organisations, and for this reason, all innovation processes gain importance. According to A. Pomykalski, innovation is the process embracing all operations associated with creating the idea, development of invention, and then industrial implementation of the invention – a new product, process [13]. Introduction or popularisation of the innovation in any form is a non-typical enterprise – the enterprise the organisation deals with for the first time ever.

A. Pomykalski points out that the key significance for all contemporary world economies is had by product innovations, which can be divided in the following way [13]:

- a new product in a new market – 10% of all product innovations,
- a new product in an old market, complementing the offer for the given market – 80% of all product innovations,
- an improved existing product – 10% of all innovations in the market.

Innovation projects are well characterised by the phase-wise process of innovation [14], defined by the four successive phases:

- fundamental research (1st phase),
- applied research (2nd phase),
- development works (3rd phase),
- industrial implementation works (4th phase).

Because of the types of innovation and the sources of their occurrence, not always all four phases are present, for example, in the process of product innovation of the type “new for the company, old for the customer”, the fundamental research usually does not take place. The characteristic trait of product innovations is the existence of the 4th phase (industrial implementation). It is the most important, and simultaneously the most difficult element of the innovation processes related to products, and it requires coordinated actions of different organisational units of the company as well as a continuous and active involvement of the client.

The phase-wise model of product innovation represents its development as a series of related processes and decision points. One can indicate the iterative models of project management, and use of adaptive methods of project management with sufficiently frequent flexible decision points, as the most adequate for the character of the product innovation processes. It is associated with a high level of uncertainty regarding the final product design in the sense of adopted concepts and solutions. Particular elements of the project undergo not only the elementary evaluation carried out based on the conclusions from previous stages, but also the enhanced one, caused by technology development and turbulent changes in the environment.

From the above observations results the important feature of the innovation projects – they are burdened with higher risk, which is caused by elements like, e.g. market tendency change, flexible decision points, unpredictable development of technology, formal or legal obstacles, lack of routine in operations, uncertainty of the outcome.

In the railways industry, in the case of a products whose function is associated with maintaining the appropriate level of safety of use, the particular significance is gained by formal and law aspects because it is the area subject to strict regulations, which is not in favour of innovation enterprises. Below are presented the formal and law factors and standards following from European and national regulations, which affect the project. Already, at the stage of the railway project initialisation, all those factors have to be taken into account. This results in railway industry projects being specific enterprises, which require significant financial means already in the initial phases to carry out the analysis of all elements related to the formal and law factors and to the standards.

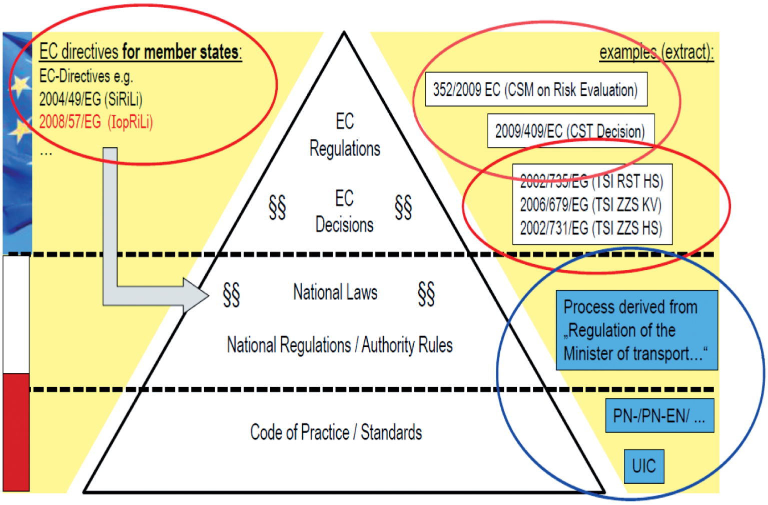

Fig. 6. Formal and law regulations in the area of the railways market

Similarly as in the case of the IEC 61508 standard, the EN 50126, EN 50128, EN 50129 and EN 50159 railway standards require, at each level of integrity of functional safety, the execution of the project in the supervision regime. They are harmonised with the IEC 61508 standard (the reference), but they slightly relax the statements of the reference by permitting the internal supervision at the lowest SIL0 and SIL1 levels. Higher SIL levels require participation of an external supervisory institution in the project.

The IEC 61508 standard, fist published in 2000, was updated in 2010. It covers both the process of development and implementation of a new product in terms of hardware and software solutions, and introduces several recommendations associated with hardware and software implementation. Some of the statements concerned with higher levels of integrity of safety, SIL3 and SIL4, are so rigorous that most of the contemporary processors and microcontrollers do not satisfy them. One thing to make life easier is additivity of the SIL levels – two SIL2 level devices working in parallel form the SIL4 level device. In the case of serial connection of devices, the resultant SIL level corresponds to the device of the lowest SIL level. In numerous publications, a belief is accepted that, by means of a single processor, it is not possible to obtain a higher level than SIL2 because of the required check of the correctness of the data flowing through the microcontroller internal buses. Recently, companies, such as Texas Instruments (Hercules – ARM Cortex R4F, R5 [24]), Freescale (Quorivva 8643L – Power [22]) and Infineon (AURIX – TriCore [20]), expanded their offer with microcontrollers dedicated for systems subject to certification. The STM company introduces to production the derivative of the Freescale processor – SPC56. The characteristic feature of those designs, apart from the check of correctness of the data flow between the CPU and the remaining microcontroller elements, is the introduction of the second core, executing the same program code for the same input data with a programmable phase shift of 0.5 to 3 CPU clock cycles. Detection of the discrepancies of the results of operations of both cores results in triggering hardware safety mechanisms and bringing the system to the safe state (reset). Neglecting the subtle differences in the naming of this solution used by manufacturers, the technique is called "lockstep". It is known from previous designs, but the new thing is its application in a single chip, together with the remaining mechanisms essential for reaching the appropriate functional safety integrity level. The mentioned processor families obtained SIL3 and ASIL D certification, which also covers the process of manufacturing of those systems. A supplementary element are "Safety Manuals" [21, 23] supplied by the manufacturer and approved during certification. In all standards associated with the functional safety, the significance of immunity to electromagnetic disturbances introduced by the system environment is also emphasised – the allowable limits were visibly raised. It is widely accepted that the currently manufactured equipment can be the source of random errors and not the systematic errors. In the opposite way is seen the process of design and the final software itself, in case of which no one talks about random errors, but only about the systematic errors (design or implementation flaws). For this reason, the standards subject the whole process of software production to rigorous checks requiring the application of formal methods like, e.g., temporal logic for design and validation of code. Use of the certified software, e.g. compilers and linkers, is required. Formally, there is no requirement that the software must be the certified commercial software, which is currently available; however, one should be able to demonstrate to the supervising organisation that the used utility software is free of errors and is reliable. There is also no formal requirement for the use of certified real-time operating systems, the cost of which is many times higher than ordinary versions. Moreover, the updates are rare because they are subject to expensive and time-consuming certification. On the other hand, in case of the in-house solution, one has to demonstrate to the supervising organisation the correct support for all internal microcontroller components, which in any way affect processing of information related to the safety functions.

The innovation process is the process, which integrates different areas of knowledge and different organisational units of companies, and the basis for creation of innovation attitudes is a well developed information system in the company. The innovation project management is, first of all, the management of higher-risk projects, where institutional and social aspects are very important. In the area of industrial implementation of microprocessor systems for the railways, the difficulties are increased by formal and law factors, including international standards, which recommend the adoption of particular solutions in order to reach the required level of reliability and functional safety of the final system. The characteristic features of innovation projects are frequent iterations, which suggest the use of adaptive methods of project management, where output data of a certain stage become the input data for the next one. In the area of railways solutions, the use of the AGILE methodology is made at least difficult, and because of natural contradiction with the requirements of the IEC 61508 type standards, even impossible. Despite the formal restrictions, one may use this model during selected stages of design, for example, for checking the processor functionalities, input/output modules, etc. Joining the V model with the adaptive models seems to be the optimal solution, especially that even the rigorous functional safety standards leave certain freedom, by requiring only for the process to be accepted by the certification organisation.

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