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COMPREHENSIVE APPROACH TO TRAINING SPECIALISTS IN THE AREA OF ENGINEERING EDUCATION

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Abstract. The article outlines advantages of applying a comprehensive approach to training specialists in the area of engineering education. Modern approaches to project management in production are analyzed, using the known experience of the European countries and the world. The basic tools of project management that are applied at all stages of implementation of engineering projects are described. Based on the analysis of known project management techniques, it has been established that effective engineering project management is possible by way of involving future professionals in the stages from developing the project idea, goals and objectives to obtaining the desired results and achieving the set goals. It is important to motivate students to think critically and encourage teamwork on a project. In the present article, the authors suggest to consider the process of training specialists in civil and industrial engineering through the prism of the next four phases of the project. The first phase is to prepare the project with elements of structuring. It addresses the issues of the project goals, tasks and results, risk management, project documentation, budgeting, formation and management of the project team. The second phase is project management, which includes drafting a project structural plan (PSP) and work packages, scheduling task completion, resources and costs planning, cost estimation, and time management tools. The third phase is the implementation of the project with control and monitoring. Here, future specialists are working on issues of the project control, financial monitoring, monitoring of resources, communication and interaction between teams, conflict management, change management and keeping necessary documentation. Completion of the project is the fourth stage, which is an integral element of project management. It provides for financial and analytical reporting, documentation for retention of experience, knowledge management, certification and feedback to the project team. Based on teaching practice and considerable practical experience in industry, the authors found out that the process of pedagogical training of future competitive specialists in various areas of civil and industrial engineering should be accompanied by practical and theoretical materials on modern tools for a holistic and integrated approach to project management. At the same time, taking account of

the dynamics of political and economic changes in Ukraine and integration with international standards, it is necessary to take a skilled approach to the issue of production change management in the project activity. The global experience reveals that only truly successful organizations anticipate and initiate changes. Thus, the organizations themselves, their goals, objectives and tools are undergoing changes. And the issue of change management itself is the subject for further research by the authors.

Keywords: engineering education, project management, planning, risk assessment, practical value.

Introduction

For a constantly growing company, which must be conscious of economic trends in the implementation of innovations and meeting the needs of increasingly demanding customers, it is not sufficient to update the technical and technological processes and equipment.

Every year, fulfilling the objectives of the contract, while maintaining customer satisfaction and staying within the budget requirements of the company, it is necessary to more efficiently and flexibly carry out project management, especially in projects of production, engineering, modelling and design of engineering systems. At the same time, experts in such profile engineering areas should understand the holistic approach in the project, and not only its separate technological element. Accordingly, in engineering education, it is necessary to study the modern tools and techniques in detail that future engineers will be able to apply in implementing real multi-faceted projects and cases.

Object and subject of research

The object of the research is the methodology of training specialists in the field of civil and industrial engineering. The subject of the study is a set of theoretical and practical recommendations that increase the activity of the acquisition of knowledge and skills during the training of specialists in the field of engineering project management.

Purpose and objectives of the study

Analyze modern project management techniques used in training and offer a set of recommendations that will increase the level of knowledge and practical skills of students, from developing a project idea, goals and objectives, to obtain the desired results and achieve goals.

The practical significance of the obtained results

Using the proposed set of theoretical and practical recommendations, you can improve the training program for future professionals in the field of industrial and civil engineering. Using the proposed approach, it is possible to develop in future students the necessary professional skills that will allow them to manage projects taking into account the dynamic social and economic changes, risks, challenges associated with Covid-19 and others. Students who will be "immersed" in the process of real projects will have a significant stock of theoretical knowledge and practical management skills in real time. The development and implementation of processes for the preparation, planning, implementation and completion of engineering projects will promote the development of students with the necessary competencies such as critical thinking, teamwork, change management, staff motivation and others.

Especially this baggage of knowledge that will facilitate faster adaptation to change and contribute to the successful economic activity of not only one enterprise but the industry as a whole.

Analysis of Literary Sources

The present day pace of implementing large and innovative projects in the area of civil and industrial engineering the need for highly skilled specialists and specialists, who understand the whole process of project implementation, from planning to successful completion. In general, it should be noted that the topic of quality project management has recently become a major issue in various engineering sectors, including instrument making and machine building in Ukraine. The worldwide prevalence of mega-

projects with the purpose to better utilize cutting-edge technological advances requires new or improved project management techniques for rapid development. Since the concept of a project is fundamentally different from day to day or routine operations, this means that a number of project management principles and concepts should also be distinct from those that are applied in the day-to-day management of operations [1].

Accordingly, graduates from specific areas, such as an engineer of design systems, or a specialist in the area of development and implementation of automated design of welding processes, must have comprehensive knowledge and skills to provide their customer with practical solutions to specific problems [2]. Taking account of the social and economic situation, such a decision should be not only technically fit for use, but also be cost-effective and time-specific.

Based upon the analysis of the previous presentations, we see that the existing challenges require in training engineers and design engineers of civil and industrial engineering focusing on an integrated approach to training specialists in this area, and in engineering in general, who can effectively initiate, plan, structure, implement and successfully complete engineering projects. At the same time, the management aimed at the implementation of the project should be as effective as possible with the time constraints, resources, as well as the quality of the final results of the project (the so-called "magic triangle"). In the modern world, a number of techniques and tools have been developed to help project managers manage these constraints (classical project management, also referred to as "waterfall model", Agile, Scrum, Lean, Kanban, Six Sigma, PRINCE2, etc.). It should be noted that the developed approaches (standards, tools, models, concepts, methods and frameworks) differ significantly from one another in the areas and fields of application, detailing, self-sufficiency and formalization.

There is no doubt that innovative and flexible project management approaches, such as the approaches of the Agile and Scrum family, have a competitive advantage over traditional ones, particularly in the IT area. Nevertheless, according to our belief, while training future competitive specialists in various areas of civil and industrial engineering, we must admit that the classic project management model does not lose relevance in the implementation of complex long-term projects.

Specifically, the detailed engineering process management process can be demonstrated based on the standard developed by the Project Management Institute (PMI) and accredited by the American National Standards Institute (ANSI), which standard is described in detail in "A Guide to the Project Management Body of Knowledge" (PMBOK® Guide) – Sixth Edition [3]. At the same time, it should be noted that the authors do not attempt to describe all phases and tools of project management in accordance with this standard, but only provide certain techniques and tools, which can be used by future engineers during project management at a specific place of production.

Results and Discussion

Qualitative and effective project management should be understood as a comprehensive approach from the development of the idea to obtaining the desired results. If it is a step-by-step approach, then, based on the experience, it is possible to define the following phases of the project in the course of the training of engineers for the project activity:

A. training with elements of structuring (including team building and involvement of experts);

B. planning;

C. implementation, including control and monitoring;

D. completion of the project.

Let us now focus in detail upon the first stage, briefly describing the other three and outline the main techniques and tools that should be taken into account in the training of information technology professionals.

Phase A: Preparation with elements of structuring.

The project, as a whole element, is characterized by many factors, among them: one-time conditions, which differs from everyday work; presence of a goal; time, budget, and other restrictions; a specific implementation process. According to the statistics, more than 37% of projects have not achieved their

ultimate goal due to the ambiguity of the set goals. Accordingly, at this stage, the training of engineers should thoroughly outline the basics of project goals.

A1. The project goals. There are many methods and tools, but before the goals have been worked out, it is necessary to clearly identify the answers to the key questions, including: what should be done in the process of project implementation?; what benefit should the project bring, etc.?

Meanwhile, it should be noted that the goals should be necessarily measurable, because only the results that can be measured will give us an expected and real success. In addition to the teamwork on the formulation of goals, we should remember what we must achieve, what funds and time frame we have for this, with and within which we must achieve the desired result. When all goals are formulated, they need to be analyzed and evaluated. In practice, there are many tools and techniques that should be selected in accordance with the scope of the future project. Based upon experience, one can apply the following methods of analysis of goals in the field of engineering:

– The SMART concept is a fairly well spread methodology that helps a project team to analyze goals whether they are Specific, i.e. what is to be achieved, Measurable, i.e. achievement of goals are expressly estimated using data, graphs or indicators, Achievable, Realistic, and Timely.

– The SWOT concept is an analysis that shows the Strengths and Weaknesses of the organization and its Opportunities and Threats from the exterior.

– Analysis of the Porter's five forces, which is a model for analyzing goals and industries, as well as the development of a business strategy, which was developed by Michael Porter of Harvard Business School in 1979. Five Porter's forces include: analysis of the threat of the emergence of substitute products; analysis of the threat of the emergence of new players; analysis of the market power of suppliers; analysis of the market power of consumers and analysis of the level of competition. It is an analysis that involves the evaluating of the products and services of competitors in terms of the importance of certain product or service criteria for a customer or a buyer. This analysis is proposed by the authors of the Blue Ocean Strategy [4]. The strategy is a simultaneous desire for a high product differentiation and a low cost, which makes competition irrelevant. In order to identify the elastic blue ocean, Kim and Mauborgne recommend that enterprises consider what they call "The Structure of Four Actions to restore the value elements of the buyer, when developing a new curve of values. The analysis approach consists of four key questions: increase - what factors should be significantly higher than the industry level?; reduction - what factors were the result of competition with other industries and can be reduced?; to eliminate - what factors, for which the industry has long competed, should be eliminated?; to create - what factors should be created, which industry has never offered? This exercise forces companies to explore each competition factor, inviting the leaders to identify the assumptions they unconsciously make during the competition. Then they can look for blue oceans in their fields and make changes.

– Analysis of the interested parties and other types of analysis.

A2. Evaluation of the project budget. After the identification of the goals and tasks of the project, one of the key issues remains the evaluation of expenses, which will be carried by the enterprise to achieve the goals. This assessment is broad enough and is carried out in accordance with certain standards and requirements [5].

A3. Risk Analysis and Development of the Risk Management Strategy. At the initial stage of decision making concerning the project implementation, a risk analysis should be carried out, on the basis of which a principal decision can be made as to the possibility of starting or suspending the project. In project management, the following can be identified among the basic principles of risk management: prevention (it is much easier to be prepared and prevent risks, than to react at the moment, when the risk has occurred); openness (for effective risk management, the team should openly talk about them) and continuity (risk management is carried out throughout the life cycle of the project).

In practice, the four-step model of risk management is well-known: *identification of risks* (identifying internal and external risks, grouping risks according to the project phases, etc.); *analysis and risk assessment* (qualitative and quantitative analysis is performed, and tools such as brainstorming, SWOT-analysis, assessment of probability and consequences of risks, FMEA-analysis [6], assessment of

previous projects, interviews with experts, assessment of trends, etc., can be applied here); *development of risk response strategies* (such response strategies, as risk reduction or risk transfer and risk management logging can be used); *monitoring and control of risks* (such monitoring is carried out throughout the project and involves audit, periodic analysis and identification of new risks, documenting risks, planning additional activities, etc.).

A4. Preparation of the project application. After having completed previous steps and applying other well-known tools and techniques, the project team must prepare a project application that should include a list of goals and tasks of the project, justification of the proposed project decision with detailed steps, advanced risk analysis, investment and financial analysis of the project design and recommendations for the implementation of the project.

A5. Selection of the organizational structure of the project. Most projects are part of the enterprise's usual activities, but the implementation of a separate project requires the determination of a separate organizational structure. There are several such structures and each has its own peculiarities. From experience, it should be noted that, compared with the linear and headquarters structure of project management, the matrix organizational structure is most effective and flexible. This is primarily due to the following advantages: operational creation of a team of the necessary specialists from different departments of the organization; effective coordination of the work; joint responsibility for the success of the project and its results; decisions are made in the project team. It should be noted that at this stage, it is necessary to develop such elements as: a matrix of competencies; model of the organization of the work process; the matrix "task - authority – responsibility" for each member of the team, and so on. From the experience, it should be noted that the matrix of competencies is an effective tool for the project personnel management and their participation in the project. It allows identify responsibilities and competencies among the workers of the organization and the personnel of the project. The matrix sets clear goals, powers and responsibilities for each member of the project team, as well as provides guidance and actions for the implementation of a particular phase of the project. In general, the matrix of competencies reflects each position in the project and the level of knowledge / participation or competencies that one needs to have when working in a particular position.

A6. Preparation of legal and project documentation of the project. Practically all projects must contain appropriate permits and other legal documents, which may include contracts with executors of works and services, design estimates documentation, a log of division of responsibilities, quality management documents for products or services. It is the quality management issue that is extremely broad and one of the priorities in the project activity. It must be worked out in detail using known approaches and tools [7].

A7. Detailed analysis of the project costs and benefits. At this stage, the project team carries out a thorough and qualified financial analysis for investment decisions. Here you can apply well-known techniques and evaluations, but beyond all others, it is necessary to pay attention to such tools, as an assessment of ergonomics for the user, an analysis of the practical value of selected design decisions, a comparative estimation of financial costs, decision-making balances and the decision tree. Applying these and other relevant tools, the project team will more accurately evaluate the financial success of the project and its benefits for consumers.

A8. Kick-off meeting. The goals of the Kick-off Meeting are to provide a detailed explanation to project participants about the nature, goals and expected results of the project itself. The goals of the kick-off meeting for an example of a project for the development of elements for control systems can include but not limited to: presentation of the project itself; its goals, tasks and expected results; definition of the project phases and the timing of their implementation; indication of expected risks and ways of their minimization, etc.

Note that this step completes the preparation phase with the elements of structuring, however, the project team, depending on the specific goals and tasks of the project, can further examine particular elements of the project, and thus attract third-party experts for an expert analysis of project decisions.

Phase B: Project Planning.

Project planning, taking account of modern techniques, such as Agile and Scrum, needs to be carried out consciously, since flexible project management has its advantages. However, with the implementation of projects in the field of manufacturing, modelling and designing micro-electromechanical systems, conscious and goal-oriented planning will ensure the future success of the project and foresee alternative steps and probable risks. In this article, we shall not deal in detail with the planning process applying detailed tools. At the same time, for future specialists in the area of information systems and automated design, it is necessary, however, to take account of the following:

– Project Structure Plan (PSP), which involves splitting the project into separate units, measures, phases and actions with a clear numbering of each operation or action. Structural plans can be object-oriented, function-oriented or mixed-plans.

– Work packages, which are an important result of structural planning and allow formulating the workload, increase the responsibility of employees and provide transparency in the project task implementation.

– A Mind-Mapping allows synthesizing well-known ideas and developing new ones.

Planning of terms and progress of the project works. By using developed work packages, plan of works is formed and priorities are defined; an example may be the construction of Gantt's chart or a grid graph.

– Planning costs and resources, including human costs and resources, technical means, materials, equipment, and others. As an example, the result of such a plan can be a table of employee participation with the distribution of payments by months of work.

– Budget planning, financial plan and cost estimation. Here, such tools as a method of analogy, expert evaluation and method of indicators can be used.

– Time management, which involves the forecasting of time-saving, the influence of external factors upon the time of the project implementation, the analysis of the possibilities of reducing the time of execution of certain operations and managing personal time.

Thus, the planning stage can be completed, however, it should not be excluded that third-party experts can be recruited for the correction of this plan.

Phase C: Implementation, Control and Monitoring.

The key to this stage of the project implementation is control, which is based on the possibility of operative collection of information, its analysis, comparison with expected indicators and making strategic decisions in order to achieve positive changes. The project control system includes: development of a plan; analysis of actual status; comparative plan / fact analysis; adoption of measures; if necessary, adjustment of the plan. At this phase, such analysis methods as Earned Value Analysis, MTA Analysis, EVA Analysis, Force Field Analysis, and others can be applied.

Another no less important element here is the process of managing changes during the project implementation. In almost all projects there are changes that at the stage of preparation or planning could not be expected, but in the process of project implementation they are necessary. Accordingly, they must be considered and managed. There are a number of effective techniques and tools, and for clarity, the process of effective change management can be shown in the block diagram [8].

These three steps (see the figure 1) are primarily managed using a change-request form, which has three parts: the request for a change that includes an explanation of why the change is needed (the justification section, step 1), an analysis of the impact of the change on the project (impact analysis section, step 2), and a section for approvals (approval section, step 3) [8].

Phase D: Completion of the project.

Completion of the project is no less important phase of the project activity, than other phases. Here, the design team should be especially careful to perform the set tasks, since the success of the whole project can depend on the final steps. Accordingly, in training future engineers, in particular, specialists in the field of programming, automated design and development of complex systems, attention should be paid to the following issues: preservation of experience (including the descriptive report, analysis, project team

dissolution procedure, equipment transfer, cost analysis, documentation, etc.), knowledge management (using Data Warehouse, Groupware, etc.) and project personnel attestation. This list of issues is not complete and depends on the specifics and subjects of the project.

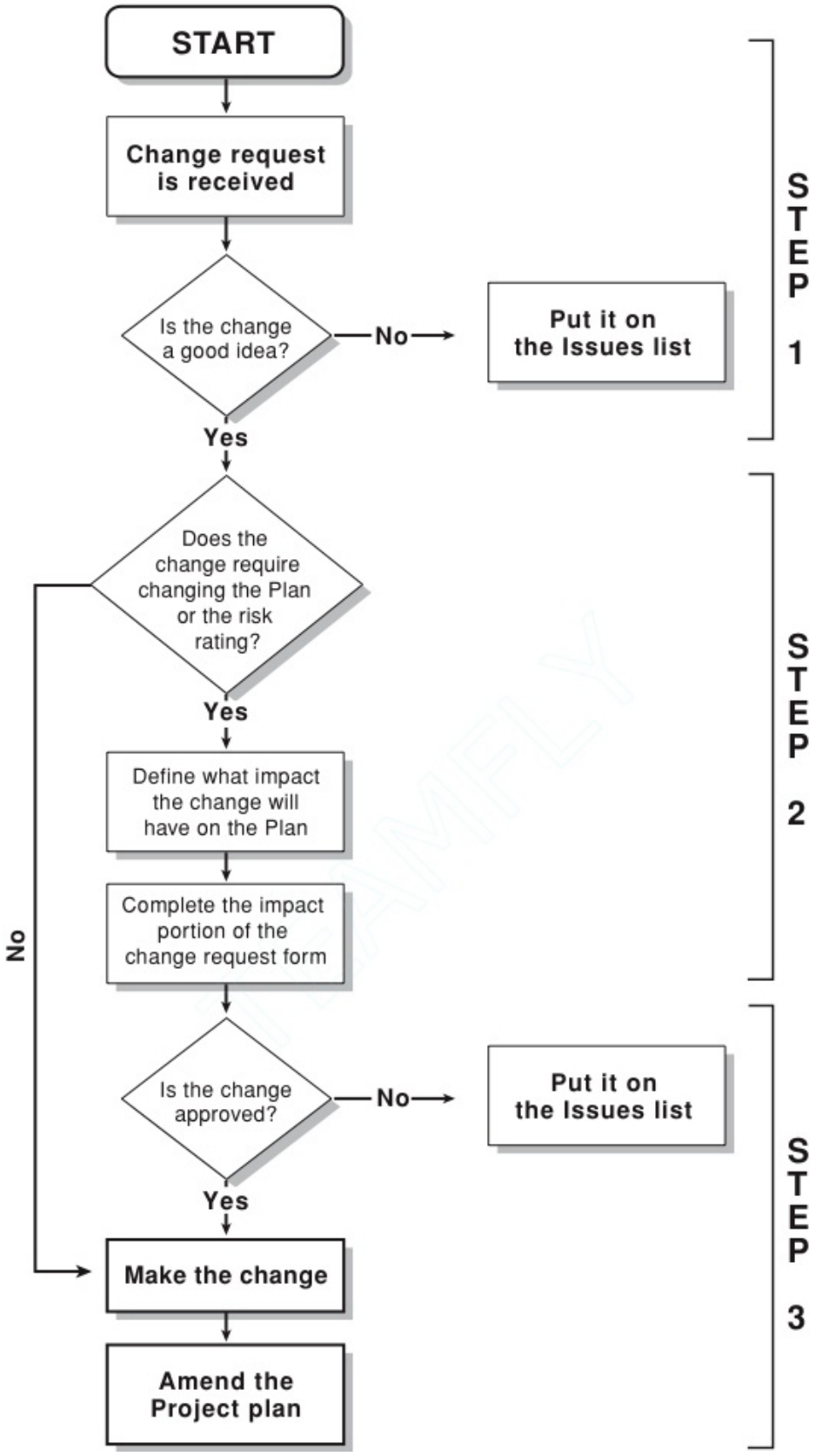

Fig. 1. Project change management process [8]

Conclusions

Thus, we analyzed some of the elements of the project planning and implementation in the context of the training of future specialists. We have a clear vision that in training of future competitive specialists in various areas of civil and industrial engineering, it is necessary to apply modern theoretical and practical tools for a holistic and comprehensive approach to the project management.

All in all, nowadays, engineer industry is functioning in complicated economical and political environment, which is developing and developing. This way, certain organizations have to change - correct their goals, tasks and working cases. Economical stability of organization is ability to be always ready for time issues and change without forgetting their goals and achievements. The following theoretical and practical research will be devoted to the problems of change management in the field of industrial and civil engineering.

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