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GENERAL ASSUMPTIONS FOR PROJECT MANAGEMENT IN INDUSTRY 4.0

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Purpose: Authors of the paper develop the main assumptions for project management in the Industry 4.0, and present them in the short form as basic knowledge, useful for managing smart manufacturing (SM) projects in companies.
Design/methodology/approach: the process of preparing SM (smart manufacturing) projects and their implementation, in the Fourth Industrial Revolution, have been changed, due to the importance of the issue of linking more and more intelligent machines, IT-computer programs and monitored processes into integrated technological systems of key importance for the construction of cyber-physical production systems (CPS). The paper applies a conceptual analysis of possible areas of change in project management (PM) when enterprises build the smart manufacturing (SM).
Findings/conclusions: companies building the smart environment must adapt their organization of project management to the new requirements and opportunities of Industry 4.0 (I 4.0) technologies.
Research limitations: the narrow scope of knowledge about the ongoing changes in SM project management is due to the short period of experience (the Industry 4.0 concept has been implemented since 2011), therefore the authors have only presented the framework of changes in organization of project management.
Practical implications: the authors' intention was to initiate a practical discussion about the changes in project management in the ongoing industrial revolution.
Originality/value: Since 2011, when the government of the Federal Republic of Germany recognized the concept of "Industrie 4.0" as the key strategy of innovative development, Industry 4.0 has become an important discussed topic among practitioners and researchers. The fourth industrial revolution is expected to result in a leap in the efficiency of companies operating in the intelligent technological environment. Key technologies or pillars of Industry 4.0 are implemented in manufacturing enterprises to build the smart manufacturing processes. Enterprises develop new projects and make investments in order to create Cyber-Physical Production Systems (CPPS).

Keywords: Industry 4.0 (I 4.0), project management (PM), integrated technologies and IT systems, digitalization, smart manufacturing (SM).

Category of the paper: Conceptual paper.

1. Introduction

The environment of business is becoming more and more revolutionary, the periods of use of industrial technologies are shorter, and enterprises are increasingly forced to develop and implement successive projects for new technological solutions. Companies prepare more and more projects and realize new investments for the modification of production means. These projects are: technological projects, reorganisation projects, software projects with computer support of processes, projects for new products and even the new structure of supply chains. Under the conditions of the ongoing the Fourth Industrial Revolution and the proposed disruptive technologies (pillars) of Industry 4.0, the investment needs of enterprises are ever greater and more revolutionary. The term "Industry 4.0" is strongly popularised in highly developed countries. In Industry 4.0, the aim is to fully automate processes and digitise industry, towards the transformation of existing production facilities into self-controlling and self-adapting Cyber Physical Systems (CPS), forming, over time, smart factories with smart values (Lasi et al., 2014). The Fourth Industrial Revolution, despite being only a general vision of industrial development, brings with it key changes in the area of production. This applies in particular to further investments or projects transforming the existing manufacturing system into a smarter one, which in turn requires the development of new assumptions for Project Management (PM). The purpose of this article is the conceptual analysis of the main changes in PM during the implementation of the Industry 4.0 concept in manufacturing companies.

The paper is based on a literature review with short synthesis. In the first part of the paper, the idea of the Industry 4.0 concept in the context of project management was presented. The main framework of changes in the project management in Industry 4.0 was in the second part of the paper. The paper concluded the summary.

2. About the background for project management in Industry 4.0

Industry 4.0 refers to the changes of the Fourth Industrial Revolution. The term 'Industry 4.0' was first used in 2011 by the German initiative group 'Industrie 4.0', made up of representatives from business, politics and academia, as the name of a concept for the development of smart and high industrial technologies (Kagermann et al., 2011). Industry 4.0 is the trend of the next industrial revolution. This trend is spreading across more and more companies in different industries, moving towards smart manufacturing with cyber-physical systems that are a combination of real and virtual worlds, Internet of Things (IoT) and Internet of Services (IoS), up to smart factories (Greengard, 2015; Gajdzik et al., 2019). In the Fourth Industrial Revolution, the aim is for intelligent manufacturing systems to be dynamic and flexible (adapting to change), clever and intelligent (self-organising and optimising).

Manufacturing systems in Industry 4.0 are formed by intelligent machines and devices and the IT and network systems that support them. The set of technological solutions constitutes a dynamic structure that constantly reconfigures itself depending on the changing needs of the customer and business conditions (Erro-Garces, 2021).

The implementation of Industry 4.0 projects in manufacturing enterprises brings about changes in all areas of the functioning of business. From the point of view of management sciences, the changes in organisation and project management are particularly momentous. In opinion of Spałek, the importance of project management in the Industry 4.0 is greater than before (Spałek, 2017). This situation is the acceleration of technological progress and the growing number of projects and their increasing scope for technological change. According to the idea of the Fourth Industrial Revolution, the technologies implemented should ensure the standardisation and modularisation of process solutions through interconnection and flexible modular combinations, as well as the integration of information and computer devices and systems, enabling the creation of identities of machine components and communication systems and creating conditions for the development of interconnection networks with computer optimisation and system virtualisation solutions, as well as ensuring the continuous development of technologies. Companies planning new investments or developing projects or modifying existing process solutions, must make a reliable diagnosis of the company's needs and select optimal variants of technological development from the vast set of possibilities brought by the fourth industrial revolution. In modern technological projects, companies must remember about the principle of integrating manufacturing technologies with IT systems by using IoT. According to the idea of Industry 4.0, integrated devices and IT systems are able to improve the management of business processes or factories and ensure nearly full control of the situation in a dynamically changing environment. Technological projects in the fourth industrial revolution are different from the previous industrial projects of companies, although they use some of their characteristics, which they process in their own way, that is, towards smarter solutions of manufacturing. In the current conditions, enterprises are oriented towards combining the digital and physical pespective. The former includes modern manufacturing systems, analytical systems, smart sensors, mobile interfaces, among others. The latter includes, among others, new materials, advanced robotisation, automated vehicles, intelligent products. The importance of IT and digital solutions is growing in new technological projects. Synchronization of biggest and biggest databases and compatibility of IT systems is the beginning of building projects of intelligent technologies of Industry 4.0. There are more and more projects in companies and the implemented installations are almost a common organism that can react to the business environment. The new project management plays an important role in the development of Industry 4.0. The PM is an appropriate tool for achieving the goals and activities of evolving smart technologies and operations (López-Robles et al., 2019). All project resources influencing project success must be integrated, with the aim of achieving smarter solutions than previously used, and must be equipped with self-organising and self-optimising process functions (Monostori et al., 2016).

3. Main challenges for project management in Industry 4.0

The term 'project' is defined as a construct involving budget, time and quality (Bryde, 2008; Fortune, 2011; Turner, 2009). According to the classical definition of a project, the project purpose is to find a solution to business problems, after an initial and precise definition of the them (Kerzner, 1989).

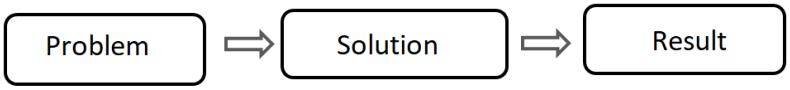

Figure 1. The concept of project based on classic definition of project management. Adapted from: "Zarządzanie projektami" by H. Brandenburg. 1999 by Publisher: Politechnika Śląska, Gliwice, p. 46.

In Industry 4.0, the projects aim to adapt the enterprise to the requirements posed to it in the Fourth Industrial Revolution, i.e. to create a cyber-physical production system (CPPSs) that enables the achievement of quality defined as the adaptation of production to personalized needs (individual orders), while at the same time the projects must ensure the optimization of the process and reduce energy consumption. The classic project management diagram shown in Figure 1 can be presented in a slightly different way according to the idea of Industry 4.0 (Figure 2).

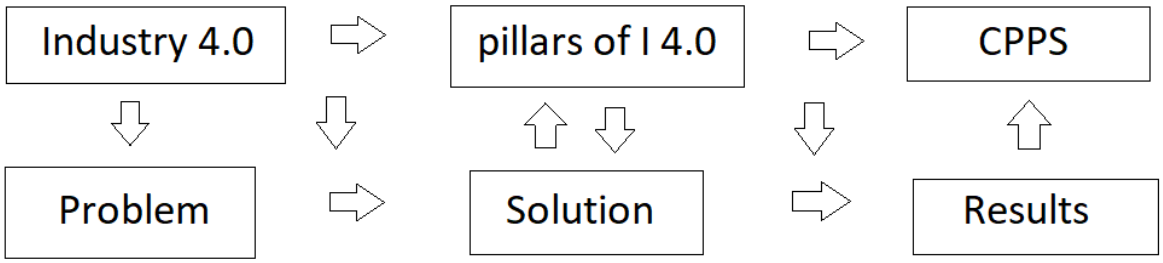

Figure 2. The concept of project management in Industry 4.0. Source: own elaboration.

Industry 4.0 refers to the key technologies or pillars of the fourth industrial revolution, which include: autonomous robots, simulation, system integration, Internet of Things (IoT), incremental manufacturing (3D printing), data processing, cloud computing, databases, augmented reality and cyber security (Kagermann et. al., 2011). The solutions that a company can implement are not as obvious in the Industry 4.0 as one would think, as the path leading a company to create the cyber-physical production systems is long and complex and consists of many projects (Gajdzik et. al., 2021). The new development projects in industrial enterprises are not simple projects due to the diversity and range of applications of Industry 4.0 pillars. The multiplicity and diversity of technological solutions in relation to other projects creates new relationships between individual machines and information systems in the field of flexibility based on cooperation between technologies. Each project involves further projects that must be completed to create an intelligent solution. S. Spałek (2012, pp. 172-188) notes, that the complexity and number of projects carried out by companies has increased in the modern century. The new projects (in Industry 4.0) are associated with greater risks than

projects of fragmentary technology modification. There is a greater technical risk resulting from the complex environment of implementing new technological solutions (intelligent machines with learning function, installations responding to emerging problems and able to adapt to changes) and completely new production engineering assumptions (intelligent optimisation). Lack of communication and cooperation between used technologies can be the main obstacle (barrier) to the success of projects. The basis of new projects is the integration of information systems and technologies without unnecessary operations in processes and re-entering data.

New projects are so innovative that designers may feel they are doing something beyond their capabilities and competence. Artificial intelligence (AI) will control entire production lines, ensuring product quality and improving the efficiency of processes. Algorithms can be used to predict many problems, but they must first be developed based on the company's specific process conditions. In the implemented projects, it is assumed that the applied technologies of Industry 4.0 should ensure resources (energy, materials etc.) savings. The concept of development of Industry 4.0 is based on the assumptions of sustainability (Gajdzik et al., 2020; Aghemo et al., 2014). Based on research by Vrchot et al. (2021), it was found that there is a relationship between the benefits of Industry 4.0 and the sustainability of projects. The research found that in companies that use project management, project managers believe more in Industry 4.0 to achieve sustainability. The analysis also showed that large companies see the benefits of Industry 4.0, especially in projects aimed at introducing new energy sources in the manufacturing processes. In Polish industry, the problem is still low diversification of energy sources. The success of many projects of domestic industrial companies in the long term is related to the diversification of energy sources. The energy economy of Polish industry is still based on coal and energy supplies from external commercial sources. Therefore, it happens quite often that when starting a new technological project, an enterprise must first create a new energy source in order to later optimise its energy economy or diversify its energy supply sources. In the technological projects of the fourth industrial revolution, the cheapest energy is considered to be the energy that the machine has not consumed and therefore has saved and can transfer to other devices. Companies can either adopt the strategy of making the investment on their own by investing in the energy management system (their own capital) and diversifying energy sources or use external companies that will design the technologies together with an energy saving service in the form of so-called "as a service" (Gendys, 2021).

Projects in Industry 4.0 are implemented under conditions of high uncertainty and volatility of the environment, which in turn enforces the use of agile methodologies at the stage of project management (Spałek, 2017). For example, the Scrum method is used in IT projects, which offers a general framework for proceeding with a set of desired behaviours. The pillars of Scrum are (Arczewski, Salwin, 2021, pp. 369-377, Wybraniak-Kujawa, Salwin, 2021, pp.423-430):

- transparency: all stakeholders in the project should receive understandable information and interpret it in the same way using the same standards and codes,
- inspection based on verification (audit) of the current level of progress of the project,
- adaptation by continuous improvement of the project to the current situation.

Besides the pillars, the basic determinants of Scrum are (Schwaber, Sutherland, 2017):

- the list of tasks,
- the list of operations,
- the analysis of results and increments.

The key Scrum characteristics are: mutual respect, openness to any challenges in the project, commitment to the goal, focus and courage to overcome difficulties (Asproni, 2006). In turn, Scrum events are: sprint, sprint planning, daily sprint, sprint review and sprint retrospective. More on Scrum in the document "The Scrum Guide". For illustrative purposes, the authors present an example of project activities: Development of an equipment health check system.

Table 1.
Project scope: development of a condition monitoring system

Sprint No.	Scope of activities	Results
1.	Determination of the scope and type of sensors to monitor the operating status of the machine "A"	Installation of temperature, pressure and level sensors on machine "A" and other machine parameters
2.	Generation of data from the operation of machine "A"	Transmission of data on the status of machine "A" to the decision-making system of the prevention centre
3.	Transformation/processing of data from monitoring the operation of the "A" machine	Applied visual system of data (tables, graphs, etc.) on the operation of the machine "A"
4.	System for preventive maintenance of the "A" machine (adaptation of the system to the needs of end users)	Condition monitoring of the "A" machine by systems with extensive analysis options and software for evaluating machine efficiency
5.	Accessing the operations of machine "A" and testing the control system called: Successful predictive maintenance of machine "A"	Active prediction system of the machine "A" with dynamically changing data presentation and analysis modules

Source: own elaboration based on: Wybraniak-Kujawa, and Salwin, 2021, pp. 423- 430.

Many manufacturing changes start with pilot projects, where data analysis is prepared and trends are simulated in order to assess the final effect. From the project to the undertaking, the time extends significantly due to the complexity of the Industry 4.0 concept. Apart from the already mentioned necessity to integrate IT systems, Industry 4.0 projects require considerable automation of activities, or even full automation. Industry 4.0 technologies, together with integrated IT systems and full automation, give only an insight into cycle time and the entire process. Determining the number of devices and places where they will be installed also requires the creation of visualisation systems, in which various disturbances must be taken into account, e.g. disturbances of learning algorithms in the work of mobile robots carrying out the process. The implementation of Industry 4.0 projects takes place in small steps, from individual workstations to entire production lines, up to factories and supply chains.

In Industry 4.0, project management methods are changing, from classic (cascade) ones, there is an increasing shift to variable methods, using the latest ICT developments and digital networking of industry (Marouska,Novotnego, 2016, pp. 80-85; Spałek, 2017). In the initial period of adaptation of project management methodologies, hybrid solutions are emerging, characterised on the one hand by the rigid framework imposed by traditional project management methods, and on the other hand by the integration of agile methodologies into the overall project management process. This approach is currently used with great success by companies located in Germany (Spałek, 2017 based on Komus et al., 2015).

At the stage of project development, the method (matrix) Smart Manufacturing Kaizen Level (SMKL) in the corporation Mitsubishi Electric. To develop a project, the current place (state diagnosis) is marked, as well as the place to which the company is aiming. According to the four levels of maturity, the company checks whether it collects data, if not then it begins this stage, if so, the data collected from the machine must be visualised and the results from this particular machine must be provided to managers and/or designers for analysis, who make the decision. Once you have optimised one station, you can move on to the next, until you reach the entire production line (visit the Mitsubishi Electric website, and see the ARC 2020 document, p. 5, IAF document, 2020, 4/1, p. 6). Of course, in accordance with project management, at each stage of the project implementation it is necessary to provide adequate resources and analyse the return on investment. In this article, the authors do not undertake a discussion of financial issues, but only draw attention to the availability of the so-called financial navigator of investment projects, as a tool to facilitate the financial analysis of the digital transformation of the enterprise. Smart Manufacturing projects are created in accordance with Japanese concept of Kaizen applied in Lean Manufacturing. Kaizen consists of continuous operational improvement in small steps. In the conditions of the Fourth Industrial Revolution, the level of Kaizen refers to the level of influence or effectiveness on the enterprise of the modern technologies and projects of digitisation of the enterprise. The concept of Industry 4.0 is very useful for achieving significant process efficiency. Bottom-up projects with low costs help many companies to implement smart technologies. By developing projects, the company establishes a starting point and outlines the direction of the projects (enterprise) to achieve Smart Manufacturing. Getting to Smart Manufacturing requires the development and implementation of many projects. Companies start their journey to the smart manufacturing from simple projects with low costs to increasingly complex ventures and investments (Gajdzik et al., 2021). In enterprises with the Smart Manufacturing direction, many different projects are realized. The number of projects is increasing as the availability of Industry 4.0 technologies increase. Each activity within the individual pillars of Industry 4.0 can be a separate project built from multiple activities, e.g. installing sensors on machines, developing AI algorithms for operating objects, designing a visualisation system for a machine control station.

At the stage of project development and implementation, companies very often use the services of specialised external IT companies. In Industry 4.0 projects implemented in specific enterprises, the importance of internal IT and R&D departments, which participate in the development and implementation of projects, is also growing. In the new technological solutions of Industry 4.0, moreover, the cooperation of humans and robots in the Systems of Human Cyber-Physical Systems (H CPS) is realized (Romero et al., 2015).

The members of the project teams are strongly differentiated and selected in terms of having the necessary competences for each stages of project management. The teams are open, i.e. they are constantly being expanded with additional individuals or companies, contractors or stakeholders. The members of the project teams include numerous computer scientists and programmers, as well as technologists, mechanics, material scientists, power engineers, laboratory workers, electro-mechanics, electronics engineers, planners, economists, etc. Each project team must be characterised by a high degree of flexibility in the actions taken, due to the fact that the project developed and implemented should be fully system-integrated and the technological solutions used should identify, react and adapt to changes (Cerezo-Narváez et al., 2017; Gajdzik, 2021). The project team members and their managers need to use new digital technologies and physical systems to communicate (Cakmakci, 2019). The three knowledge domains, i.e. technical knowledge, engineering knowledge and IT knowledge, must strongly complement each other in Industry 4.0 projects (Figure 3).

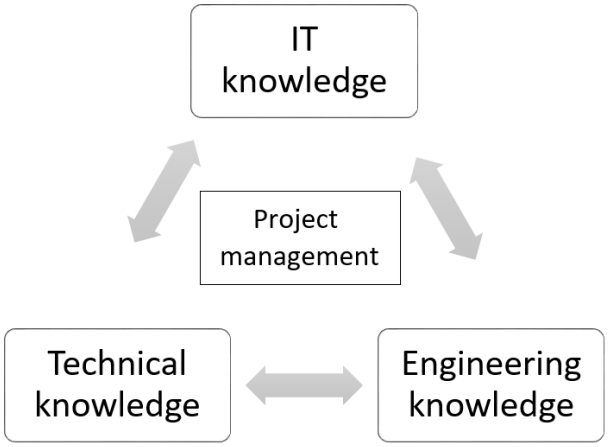

Figure 3. The knowledge triad in the project management. Source: own elaboration.

In Industry 4.0 there is not one but several project controllers due to the complexity of the implemented technological solutions according to tasks of projects. The decision-making centre is at the strategic level of enterprises. In large projects managers control and make decisions centrally. In many smaller projects decisions are decentralised (Hofmann, Rüsch, 2017). The specifics of decentralised and centralised management are shown in Table 2. In addition, the authors introduced a hybrid approach consisted from decentralized and centralized management of projects. Organization of projects should be task or matrix. Such forms are used when new and complex technologies are implemented in enterprises (Brandenburg, p. 63).

These forms are characterised by high flexibility and extended scope of supervision (double supervision principle). In these forms both project managers and engineering and IT staff are heavily involved in project tasks. Both the project manager and the engineering or IT manager have supervisory and coordinating roles. However, one of the key differences between them is their responsibilities, which means that they differ in terms of the scope and span of project management. A project manager oversees the progress of a specific company project. A project can be very short or long term, lasting several months or even years. The scale of the project can be small or large, but once the project is completed the project manager moves on to the next project. An engineering manager is usually an engineer who supervises a group of other engineers, acting as the head of a team, department or programme. The engineering manager is responsible for employees (process works). The manager has the authority to coordinate directly with the projects' human resources department. An engineering manager may also oversee research and development or a specific project, but unlike a project manager, their position is permanent. While the project manager may come from a non-technical background the engineering manager must be an engineer and have technical knowledge and IT (industrial computing) expertise (White et al., 2019). Engineers and IT specialists are heavily involved in the development of projects at the operational level of the company, first on specific jobs and over time in the development of production lines and building smarter manufacturing with CPS.

Table 2.
Types of project management in Industry 4.0

Centralised	Decentralised	Hybrid
Projects are strongly embedded at the strategic level of the company	Projects are strongly embedded at the operational level of the company	Project framework developed at central level (top management) but problem solving carried out at functional groups (processes level)
Aims and topics of projects are fixed by the top management	Problems are identified by operational services and employees during process improvement	Aims and topics of projects are fixed by the top management based on the synthesis and final drafting of the operational services (engineering teams)
Projects are coordinated by a project centre team located at the top level of management	Projects are coordinated by process managers according to organization of management systems	Projects are coordinated by a team comprising a representative of the management and the bottom-up auditors and machine operators or process managers
Top management is strongly committed to the projects	Overseeing the implementation of projects by the top management as agreeing to projects and providing resources	Projects are embedded in strategic management in the strategic business units
Projects are strongly linked to the corporate strategy	Strategic business units organise their sub-projects according to the corporate strategy	Main assumptions of project result from the strategic objectives (corporate strategy) but the objectives and tasks are strongly connected with the specificity of the unit implementing the project (it fits into the framework of the strategic, main project)
Key (strategic) version of the realized project is proposed by top management	Strategic business units carry out internal projects	Strong project diversification, projects strongly adapted to the needs and capacities of each operational level

Adapted from: "Zarządzanie projektami" by H. Brandenburg. 1999 by Publisher: Politechnika Śląska, Gliwice p. 46.

4. Summary

The considerations undertaken on the basis of the literature review were the introduction to the broad topic of project management in Industry 4.0. In the Fourth Industrial Revolution, the development of project management in companies is more focused on the flexibility of activities and the continuous improvement of processes. Expected results of the project management are the cyber-physical production systems in companies. New conditions are changing the current methods and organization of project management. There are changes in the structures and ways of working of project teams, and consist in a constant adaptation of projects to changes occurring in the turbulent digital environment of Industry 4.0. Project management has a fundamental impact on the development of Industry 4.0. There is a research gap about the project management in Industry 4.0. Many success factors affect the success of projects. Research about the impact of Industry 4.0 technologies on project management is a new research area that will be developed in the near future.

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