sciendo

PRODUCTION ENGINEERING ARCHIVES 2022, 28(1), 56-63

PRODUCTION ENGINEERING ARCHIVES

ISSN 2353-5156 (print)
ISSN2353-7779 (online)

Exists since 4th quarter 2013
Available online athttps://pea-journal.eu

Analysis of the use of artificial intelligence in the management of Industry 4.0 projects. The perspective of Polish industry

Bartosz Wachnik[1]

[1] Warsaw University of Technology, Plac Politechniki 1, 00-661 Warszawa, Poland
Correspondence: bartek@wachnik.eu; Tel.: + 48-660-404-291

Article history
Received 08.10.2021
Accepted 26.11.2021
Available online 07.02.2022

Keywords
AI
Industry 4.0
IT system
project management

Abstract
Artificial Intelligence (AI) supports project management in industry projects increasingly more often. The article documents research results regarding the use of AI in Industry 4.0 projects. The aim of the article is to define the range of AI use in Industry 4.0 projects throughout their entire life cycle and to indentify the main stages of AI development in project management. Additionally, the article indicates the main barriers to AI use in project management identified in the studied projects. In order to identify and systemise the range of AI use, the Conceptual Framework of Using AI in Project Management presented in literature is applied. Research results indicate that we are in the early stages of AI use in projects. The studied projects use AI mainly in project administration, i.e. to complete the following tasks: simple automation of routine activities, support, and, to a very limited extent, in the area of project management, i.e. in identifying anomalies and predicting the phenomena where the anomalies will occur. The research uses the case study method, where four projects were studied: an ERP system upgrade, an implementation of an IT system supporting high-bay warehouse management, an implementation of an IoT as a data-collection sensor platform and an E-learning platform implementation. The study was conducted between 2019 and 2021, and covered the entire project life cycle, including its three stages, i.e. preparation, implementation and operation.

DOI: 10.30657/pea.2022.28.07 JEL: L23, M11

1. Introduction

In Industry 4.0 projects, an important part is played by high-tech projects in the area of business process digitization (Lee, 2013). Cao and Zhang (Cao, Zhang, 2016) indicate that many of the currently used project completion methods will be replaced with new ones, which will provide for particular technological conditions, i.e. AI, agility requirement, a lower level of formality, especially in the area of communication and project documentation, information asymmetry between the supplier and the client, and the possibility of strong organizational turbulences, both internal and external. Confronting the above observations with Bukłaha and Juchniewicz (Bukłaha and Juchniewicz, 2019) and Spałek (Spałek, 2017), it can be seen that, currently, the important trends in project management are: supporting the work of project teams through solutions such as AI and VR, the development of international projects, the development of IT tools supporting the work of project managers, an increased importance of non-monetary motivation tools, an increasing importance of sustainable development and social responsibility in projects, the development of the Agile approach and an increase in the importance of the so-called megaprojects.

Industry 4.0 projects are naturally complex, both technologically and with regards to organization, which necessitates the use of flexible implementation methodologies.

These considerations allow us to predict that project management in Industry 4.0 will become increasingly more adaptive and will require the use of different, often contradictory methods, resulting in a combination of existing routines with a parallel use of hard skills, especially digital, including the use of AI. Currently, Industry 4.0 projects are completed in the conditions of uncertainty or deep uncertainty (Walker et al., 2010) in a highly turbulent environment. The existing external and internal conditions of Industry 4.0 project implementation stimulate the development of agile and adaptive

methods supported by tools using AI. The study indentifies two main aims of AI use in Industry 4.0 project completion:

1. Limiting risk factors and the conditions of uncertainty or deep uncertainty.
2. Limiting the cost linked to project management. The study has shown that the cost of project management in Stage 2, i.e. project implementation, equaled 10-15% of the total cost linked to the implementation work during that stage (Wachnik, 2016).

The article enriches the discussions on the use of AI in Industry 4.0 project management from the perspective of Polish industry. We need to stress that, according to Eurostat (European Commission, 2021), in March 2020 industrial production in Poland achieved an increase of 16.3% compared to March 2021, placing Poland on the third position after Italy and Slovakia. Although an increase this high results from the Covid-19 pandemic, it indicates that Polish industry is developing dynamically.

2. Literature review

PMI[1] (Project Management Institute, 2008a) defines PM as: a set of proven principles, methods and techniques for the effective planning, scheduling, controlling and tracking of deliverable-oriented work (result) that help to establish a sound historical basis for the future planning of a project. Currently, an important subject of research is the use of artificial intelligence in project management.

Table 1. Conceptual Framework of Using AI in Project Management. Source: Auth et al, 2019.

Problem Solving	**Knowledge representation and deduction**	**Machine learning**
Algorithmic search Blind search Heuristic search Adversarial search Constraint satisfaction	Data/text mining Ontology Expert system (Multi-)agent system Bayes network Decision tree or forest	Learning with or w/o supervisor Support vector machines Neural network Deep learning Predictiveanalytics
Communication	**Perception&recognition**	**Robotics**
Natural language processing Translation Text generation Speech synthesis	Text recognition Image or audio classification Speech recognition 3D-world reconstruction	Locomotion Sensor elements Actuating elements

According to Russell and Norvig, "artificial intelligence supports the development of intelligent agents that can perceive their environment and perform derivative actions. Furthermore, such artificial systems have the ability to (1) act autonomously, (2) persist for longer, (3) adapt to changes, and (4) set and track objectives" (Russell and Norvig, 2010).

With regard to the effective implementation of projects, the so-called rational agents suggest a special potential: their extended capabilities enable them to strive for the best result in their actions or the most valued result under uncertainty (Auth et al., 2019).

In an application-oriented scientific context, AI uses interdisciplinary models and methods for mathematics, statistics / stochastics, computer science, psychology, and cognition and neuroscience (Auth et al., 2019; Rowley, 2007).

Auth, Jokisch and Dürk, using the concept and procedures by Russell and Norvig (Russell and Norvig, 2010), as well as AI taxonomy devised by Davis, Hoffert and Vanlandingham (Davis et al., 2016), designed the Conceptual Framework of Using AI in Project Management presented in Table 1. The study used this conceptual framework of AI application in project management to categorise the identified AI tools.

The basic idea behind data-driven project management (DdPM) is that the more relevant information about a decision problem is available, the more reliable the best decision alternative is (Sullivan III, 2016). DdPM initially focuses on the classic problem of planning projects with limited resources, and thus on the planning and control functions in terms of time, cost, risk and quality (Vanhoucke, 2012). The range of methods includes known mathematical-statistical methods such as program evaluation and review technique (PERT), critical path or chain, earned value management (EVM), analytical hierarchy process (AHP) and (Lean) Six Sigma (Auth et al., 2019). AI platforms for PM (Project Management) can be understood as a stage in the evolution of DdPM, aimed at unlocking new potential through artificial intelligence in the context of big data and analytics (Ruchi and Srinach, 2018). Due to the combination of heavy implementation effort for one company on the one hand, and high user expectations on the other, some vendors have developed cloud service platforms that deliver AI-based services (Auth et al., 2019).

The term Project Management Bots (PMB) was coined in 2017 by consulting firm Gartner in the Hype Cycle for Project and Portfolio Management (Schoen, 2017), meaning a class of intelligent software agents specialising in project management. In contrast to RPA bots, however, the focus on graphical user interfaces is missing. PMB are more likely to be equipped with speech or text interfaces for communicating with humans, and thus have features of chatbots (Gaton, 2017). Currently, chatbots (Nimavat and Champaneria, 2017) are used as interface of quasi-assistants (PM – Lahmann, 2018) or post-implementation support consultants (Wachnik, 2020a).

The development of AI tools, which support project management, is very dynamic. Currently, however, it is not possible to replace a human PM with artificial intelligence. AI tools used in project management help only to a limited extent in precisely defined areas. The development of AI tools in project management heads in two parallel directions, i.e. finding solutions to specific tasks and the development of interface between the AI and the human (Leviathan and Matias, 2018), e.g. Google Duplex.

3. Experimental

Research problems present in management sciences, indicating a considerable lack of knowledge or uncertainty linked to the available knowledge, should be solved using the existing research methods. At the same time, due to the stz`ong connection of management sciences with economic practice, solving such problems should have specific practical implications. One of the qualitative research methods is case study. It is a comprehensive description of the studied phenomenon, regarding any research discipline. However, in the context of management science, a case study is a detailed description of a usually real-life economic phenomenon, e.g. an organisation, a management process, its elements or the organisation's environment, in order to formulate conclusions regarding the causes and results of its course (Czakon, 2011).

This article poses the following research questions:

Q1: To what extent is AI used in Industry 4.0 project managementduring the entire project life cycle?

Q2: What are the forecast development stages of AI use in project management?

In the presented research, the first goal of the case study will be to define the practical ways of AI use in Industry 4.0 project management during the entire project life cycle. Thus formulated goal is mainly aimed at understanding to what extent AI is being used in the selected group of industry projects. The case study contains a catalogue of AI use as part of the conceptualisation presented in Table 1. The second goal of the case study will be to define the stages of AI development in project management. Literature describes case-study building based on seven stages (Skorek et al., 2010). This study has been based on the following sequence of seven stages:

Table 2. The structure of case study completion plan. Source: Own study.

No.	Stage name	Stage description
1	Establishing the subject matter and the aims of the case study	The case study subject concerns the use of AI in the management of a selected group of Industry 4.0 projects. The aim of the study is defining the range of AI use in the project management process.
2	Defining the object of the case study	The case study object will be Industry 4.0 projects. The study will concern the entire project life cycle, consisting of three stages.
3	Making contact with the case study object	Contact was made with enterprises that took part in project implementations as clients. Close cooperation was struck with project managers, who became study respondents. During initiation talks with the enterprises, visit dates for case study research and the form of information collection were agreed upon.
4	Defining the case study structure	In this stage, it was established what actions should constitute the case study, what information will be included in its individual sections and what type of information will be collected. The organisation of a case study assumes one meeting between the researcher and the respondent in Stage 1, two meetings in Stage 2 and one meeting in Stage 3.
5	Collecting information to compile the case study	The information was collected through interviews with project managers, observations of their actions during the three stages, and participatory observations, i.e. where the person collecting the information participated in the described phenomenon or situation.
6	Verification and evaluation of the collected research material	The collected material was ordered and divided according to the meaning of the described situations. Additionally, it was verified whether the data included in the research material was complete and up to date.
7	Case study description	The study results were described and visualised.

The presented case study has an applied and descriptive character, presenting the range of AI use in project management. The research was conducted between 2019 and 2021, covering the entire project life cycle, i.e. preparation, implementation and operation. The study can be used as a basis for managerial decisions in conditions similar to the ones presented.

4. Results and discussion

4.1. General information on the use of AI in project management

Table 3 presents the structure of the studied Industry 4.0 projects, using the case study method. All the studied projects were characterised by implementations of modern information technologies making part of digital transformation (Fitzgerald et al., 2013) of the enterprises. "In the general sense, the DT can be de-fined as the modification (or adaptation) of business models, resulting from the dynamic pace of technological progress and innovation that trigger changes in consumer and social behaviours" (Kotarba, 2018). It is important to note that this definition is only one of the many approaches proposed by both academic and business communities. The research was completed between 2019 and 2021 and it covered the entire project life cycle, consisting of three stages, i.e. preparation, implementation and operation. The projects were completed using both Agile and Waterfall methodologies. The projects were medium-sized, i.e. with between 25 to 50 end users of the implemented system. In each studied project, a project group was formed in Stage 1, consisting of the steering committee, project management, key users and end users. In each of the projects, the users used AI to manage the implementation. The range of AI use was described using the Conceptual Framework of Using AI in Project Management (Auth et al., 2019).

Table 3. The structure of completed case studies. Source: Own study

	Project A	Project B	Project C	Project D
Project description	ERP system upgrade – transfer to cloud storage	MIS supporting high-bay warehouse management	Implementation of a work automation system on a large farm	An e-learning platform implementation
Number of project group members	25	50	20	40
Project range	ERP system modules: financial-accounting, logistics, production management	System modules: Warehouse Management Systems, RFID	An IT system analysing soil parameters using sensors. Information based on Microsoft Azure is relayed to a hub analysing data from the entire farming area	Implementation of an e-learning platform, allowing for creation & distribution of trainings in distributed architecture
Project completion methodology	Waterfall	Waterfall	Agile	Agile
Range of AI use in project management	**1.** Translation **2.** Text recognition – Introducing purchase invoices into the accounting system **3.** Actuating elements – Robotic Process Automation in the area of data introduction into the system	**1.** Translation **2.** Text recognition – Introducing purchase invoices into the accounting system **3.** Actuating elements – Robotic Process Automation in the area of data introduction into the system **4.** (Multi-)agent system – chatbot	**1.** Translation **2.** Text recognition – Introducing purchase invoices into the accounting system **3.** Sensor elements – identification of anomalies in the physical-chemical parameters of the soil	**1.** Translation **2.** (Multi)agent system – chatbot

The study has shown that the most popular AI tool was translation, which was used in all the studied projects. The translation tool was mainly used for translating correspondence and project documentation. From the users' perspective, it was the most frequently used tool supporting a project employing AI. The second most popular solution was text recognition, used in the digitisation of documents, i.e. purchase invoices, time-sheets and other reports. The aim of this tool is to process scanned documents into a digital format, and then to introduce them into ERP and DM systems. The next most common tool was the use of Robotic Process Automation (Actuating elements), which is responsible for automatic identification of divergence of the cost from the planned budget, and then an automated flow of information to the decision-makers for acceptance. The above tools using AI in project management belong to the group of tools automating simple tasks. "Automation can be defined as the technology by which a process or procedure is performed with a minimum of human assistance" (Groover, 2008). Another AI-employing tool is chatbot (multi-agent system), which supports end users in the helpdesk area, in post-implementation service – SLA (Auksztol, 2008) of the IT system. The end users who have questions about system functionalities can ask the chatbot a specific question, resulting in an instant transfer of knowledge and information from the trained base using AI to the user. This part of tool belongs to Project Management Bots which was coined in 2017 by consulting firm Gartner in the Hype Cycle for Project and Portfolio Management (Schoen, 2017), meaning a class of intelligent software agents specialising in project management. In comparison to RPA bots, however, the focus on graphical user interfaces is missing. PMB are more likely to be equipped with speech or text interfaces for communicating with humans, and thus have features of chatbots (Gaton, 2017). While a bot externally presents itself as one actor through one or more central communication interfaces, in the case of bots with extended capabilities, it is mostly multi-agent systems (Auth et al., 2019). These are characterised by the fact that the associated agents interact with each other in order to achieve a common goal (Olfati-Saber et al., 2007). The last tool, the least commonly used, is using IoT for studying chemical-psychical parameters of soil on large farms (using sensor elements). The aim of this solution is to automate the collection of data from more than a dozen diagnostic devices, which transfer the data to cloud through IoT, where the data is then analysed. To sum up, all the tools employing AI in project management in the studied projects were used for process automation, which decreases transaction project costs in project management.

4.2. The use of AI in the entire project life cycle

AI was used to a different extent throughout the entire project life cycle. In order to analyse the use of AI, a generalised project life cycle was defined. An analysis of methodologies used by Microsoft i.e. Sure Step and SAP i.e. ASAP , software producers, discussed in literature (Bradley, 2002; Esteves and Bohorquez, 2007; Esteves and Pastor, 2006; Chang, 2004; Nguyen et al., 2007), as well as other project completion standards, such as PMI (SAP, 2021), PRINCE 2 (Best Practice Solutions, 2021) and best-practice models in the area of information services management – ITIL (ITIL, 2021), has allowed

for a generalisation of an IT project life cycle, consisting of three stages, where AI was used.

Stage one, the preparation stage, consists of two phases.

1. Pre-implementation analysis – covers the creation of the problem domain model, user needs analysis and definition of the system's functional requirements, analysis of the organisation's IT infrastructure, project group definition, identification of significant risk factors, ex-ante economic analysis of the investment and preliminary definition of the implementation project.
2. System and supplier selection phase – this phase covers the preparation of a potential suppliers' list, creation of RFP forms, analysis and evaluation of offers according to established criteria, substantive and trade negotiations and contract formulation.

Stage two, the completion of an IT implementation project, consists of five phases.

1. Initiation phase – covers the following project tasks: implementation planning session as an initiation meeting and a technological project consisting in the installation and configuration of components in the hardware layer, system software and application software layer.
2. Analysis phase – covers the following project tasks: training for key users and functional analysis including analytical workshops and designing a theoretical prototype.
3. Design phase – covers the customization project task.
4. Implementation phase – covers a preliminary data migration, acceptance testing for the completed customisation along with tuning, developing workplace instructions and training for end users.
5.Go-live phase – covers system go-live and post-go-live support during the system stabilisation phase.

Stage three, IT system operation, consists of two phases.

1. Post-implementation analysis and identification of operational needs – covers tasks linked to an ex post analysis of the completed IT project and an identification of needs linked to system operation.
2. Selection of an appropriate supplier of post-implementation services linked to system operation – covers preparing a list of potential suppliers, creation of RFP forms, analysis and evaluation of offers according to established criteria, substantive and trade negotiations and creation of an SLA (Auksztol, 2008).

Table 4, included in Appendix A, presents the range of AI use in project management throughout the entire project cycle.

The translation tool was used throughout the entire project life cycle. The text recognition tool was used in Stage 2, where implementation tasks aimed at digitising the documents received from the enterprise environment were completed. The Actuating Elements tool – Robotic Process Automation was used to analyse reports linked to project implementation. The last tool was Sensor Elements, used in tasks linked to data migration and acceptance testing in Phase 6.

The studied projects were predominantly characterised by a selective and limited use of project management tools. This means that the majority of tools use solutions of specific tasks and activities, but do not support the entire project management process in a holistic manner.

4.3. Identified stages of AI development in project management

As part of the study, the respondents indicated the potential development of AI in project management. The study participants forecast the development of AI in project management in six stages, which have been presented in Table 5, included in Appendix A.

The analysed projects can be placed within the following AI development stages in project management: mainly simple automation of routine tasks along with elements of assistance, identification of anomalies and predicting the phenomena where anomalies occur. The study respondents believed that AI is used in project management to a very limited extent, additionally pointing out that autonomous and intelligent project management will require creating appropriate reference databases that will be the basis for information gap reduction (Wachnik, 2020b) and multi-agent systems (Andrews et al., 2005; Ziółkowski and Orłowski, 2007) allowing each agent (Maes, 1995), i.e. project group member at a given level (specialist, project manager, member of the steering committee), to infer and take correct decisions.

The respondents indicated the following challenges to AI development in the area of project management:

1. The need to create databases that would contain structured descriptions of completed projects from a given industry. This type of base would contain reference data and allow for detecting anomalies in projects and information gap management, which as a result would support autonomous decision-making.
2. The lack of trust amongst project group members regarding the use of AI in project management.
3. The limited knowledge of project group members regarding the use of AI in project management.
4. The cost of AI use in project management, which still remains high and is not competitive compared to the cost of task completion by project managers or other project group members in project implemented in Poland.

The author would like to point out two important limitations of the research: 1. A qualitative approach that allows to analyse a limited number of projects. 2. An analysis of projects implemented in Poland.

To sum up, the studied projects used AI mainly in project administration, i.e. to complete tasks such as simple automation of routine activities, assistance, and, to a very limited extent, in the area of identifying anomalies and predicting the phenomena where they occur.

5. Summary and conclusion

The answer to the first research question indicates that currently the management of Industry 4.0 projects may be supported by AI within a basic scope, mainly in the area of simple automation of routine tasks, assistance and, to a very limited extent, the identification of anomalies. My research indicates that in this moment, the expectations of project managers exceed the available MIS software using AI. The answer to the second research question identifies six AI development stages

in project management, i.e. simple automation of routine activities, assistance, the identification of anomalies, predicting the phenomena where anomalies occur, concluding from the phenomena affected by anomalies, and intelligent and autonomous project management.

Answers to the posed research questions indicate that current project management in Industry 4.0 can be supported by AI on a basic level, mainly in the area of simple automation of routine tasks, assistance and, to a very limited extent, identifying anomalies. The variety and diversity of Industry 4.0 projects stimulate the development of tools using AI that support project management. One of the main expectations of management personnel towards this type of tools is limiting transaction costs resulting from project management and limiting risk factors and conditions of uncertainty or deep uncertainty. Currently, the expectations exceed the available AI tools, which can support project management process. In order to close the gap between the expectations towards and the availability of tools, it would be advisable to carry out research and application work in the area of:

1.The use of AI tools in project management.

2. Building trust towards AI tools through transparency (Larsson and Heintz, 2020) of AI algorithm use for end users, legal responsibility (Daly et al., 2019), information ethics (Metzinger, 2019), (Bendel, 2016), as well as global legal and economic solutions (Jobin et al., 2019).

3. Creating industry data bases (Big Data) characterising the completed projects. This would allow for defining reference data enabling the identification of anomalies in the managed project, reduction of the information gap, and finally autonomous decision-making.

4. Integration of AI tools in project management with implemented Industry 4.0 applications, which can also use AI. In this situation, AI algorithms in MIS would collaborate with AI algorithms in the implemented applications.

To sum up, the use of AI in project management can be compared to the development of autonomous cars. The current AI tools used in project management are not unlike an intelligent tempomat, active cabin soundproofing or a quasi-autopilot in a car, however, in practice, tools allowing to use AI in project management of Tesla's autonomous car, are not yet available.

References

Andrews, C.J., Baptista, A.I., Patton, S.L.W., 2005. Grounded theory and multi-agent simulation for a small firm. (in) Agent-Based Simulation: From Modelling Methodologies to Real-World Applications, Terano T., Kita H., Kaneda T., Arai K., Deguchi H., eds., Springer, Tokio, Japan.

Auksztol, J., 2008. Outsourcing Informatyczny w Teorii i Praktyce Zarządzania. Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk, Poland.

Auth, G., Jokisch, O., Dürk, Ch., 2019. Revisiting automated project management in the digital age – a survey of AI approaches. eJournal of Applied Knowledge Management, 7(1), DOI: 10.36965/OJAKM.2019.7(1)27-39

Bendel, O., 2016. 300 Keywords Informationsethik: Grundwissen aus Computer-, Netz- und Neue-Medien-Ethik sowie Maschinenethik. Springer Gabler, Wiesbaden, Germany.

Best Practice Solutions, https://www.axelos.com/best-practice-solutions/prince2 (accessed 16.04.2021).

Bradley, K., 2002. Podstawy Metodyki PRINCE II CRM S.A. Centrum Rozwiązań Menadżerskich, Warszawa, Poland.

Bukłaha, E., Juchniewicz, M., 2019. Kluczowe wyzwania i bariery oraz trendy w zarządzaniu projektami z punktu widzenia projektów realizowanych w Polsce. Przegląd Organizacji, 3 (950), 14-20.

Cao, J.Q., Zhang, S.H., 2016. ITIL Incident Management Process Reengineering in Industry 4.0 Environments. Proceedings of the 2nd International Conference on Advances in Mechanical Engineering and Industrial Informatics (AMEII 2016), 73, 1011-1016.

Chang, S.I., 2004. ERP Life Cycle Implementation, Management and Support. Implications for Practice and Research, Proceedings of the 37th Annual Hawaii International Conference on System Sciences, Hawaii, USA.

Czakon, W. (ed.), 2011. Podstawy Metodologii Badań w Naukach o Zarządzaniu, Oficyna Wolters Kluwer Business, Warszawa, Poland.

Daly, A. et al., 2019. Artificial Intelligence, governance and ethics: global perspectives, The Chinese University of Hong Kong, Faculty of Law Research, 2019(15), Hong Kong, China, DOI: 10.2139/ssrn.3414805

Davis, J., Hoffert, J., Vanlandingham, E., 2016. A taxonomy of artificial intelligence approaches for adaptive distributed real-time embedded systems. Proceedings of the 2016 IEEE International Conference on Electro Information Technology (EIT), DOI: 10.1109/EIT.2016.7535246

Esteves J., Bohorquez V., 2007. An updated ERP systems annotated bibliography 2001–2005. Communications of the Association for Information Systems, 19(1), 1-59, DOI: 10.17705/1CAIS.01918

Esteves, J., Pastor, J., 2006. Organizational and technological critical success factors behavior along 35 the ERP implementation phases, (in) 36 Enterprise Information Systems VI. Seruca, I., Cordeiro, J., Hammoudi, S., Felipe, J. (eds), Springer, Netherlands.

European Commission, https://ec.europa.eu (accessed 05.03.2021).

Fitzgerald, M., Kruschwitz, N., Bonnet, D., Welch, M., 2013. Embracing digital technology: a new strategic imperative. MIT Sloan Management Review, https://sloanreview.mit.edu/projects/embracing-digital-technology/ (accessed 28.03.2019).

Gaton, J., 2017. Rise of the project bots, Microsoft Project User Group (MPUG). https://www.mpug.com/articles/rise-project-bots/

Groover, M.P., 2008. Automation, Production Systems, and Computer Integrated Manufacturing, third ed., Pearson Prentice-Hall, Upper Saddle River, New Jersey, USA.

ITIL, https://www.itlibrary.org/ (accessed 16.04.2021).

Jobin, A., Ienca, M., Vayena, E., 2019. The Global Landscape of AI Ethics Guidelines, Nature Machine Intelligence, 1, 389-399, DOI: 10.1038/s42256-019-0088-2

Kotarba, M., 2018. Digital transformation of business models, Foundations of Management, 10, DOI: 10.2478/fman-2018-0011

Lahmann, M., 2018. AI will transform project management. Are you ready? PwC, https://www.pwc.ch/en/insights/risk/ai-will-transform-project-management-are-you-ready.html (accessed 13.09.2021)

Larsson, S., Heintz, F., 2020. Transparency in Artificial Intelligence. Internet Policy Review, 9 (2), 1-16, DOI: 10.14763/2020.2.1469

Lee, J., 2013. Industry 4.0 in Big Data environment. German Harting Magazine, 26, 8-10.

Leviathan, Y., Matias, Y., 2018. Google Duplex: an AI system for accomplishing real-world tasks over the phone. https://ai.googleblog.com/2018/05/duplex-ai-system-for-natural-conversation.html (accessed 13.09.2021).

Maes, P., 1994. Agents that reduce work and information overload. Communications of the ACM, 37(7), 31-40.

Metzinger, T., 2019. Ethics washing made in Europe. Der Tagesspiegel, https://www.tagesspiegel.de/politik/eu-guidelines-ethics-washing-made-in-europe/24195496.html (accessed 15.09.2020).

Microsoft, https://www.microsoft.com (accessed 13.09.2021).

Nguyen, T.H., Sherif, J.S., Newby, M. 2007. Strategies for successful CRM implementation. Information Management & Computer Security, 15(2), 102-115, DOI: 10.1108/09685220710748001

Nimavat, K., Champaneria, T., 2017. Chatbots: an overview. Types, architecture, tools and future possibilities. IJSRD – International Journal for Scientific Research & Development, 5(7), 1019-1024.

Olfati-Saber, R., Fax, J. A., Murray, R.M., 2007. Consensus and cooperation in networked multi-agent systems, Proceedings of the IEEE, 95(1), 215-233.

Project Management Institute, 2008. A Guide to the Project Management Body of Knowledge (PMBOK® Guide) – Fourth edition, Newtown Square.

Rowley, J., 2007. The wisdom hierarchy: Representations of the DIKW hierarchy. Journal of Information Science, 33(2), 163-180.

Ruchi, S., Srinath, P., 2018. Big Data Platform for Enterprise Project Management Digitization Using Machine Learning. Proceedings of the 2nd International Conference on Electronics, Communication and Aerospace Technology (ICECA), Coimbatore, India.
Russell, S. J., Norvig, P., 2010. Artificial intelligence – A Modern Approach. third ed., Prentice Hall, Upper Saddle River, New Jersey, USA.
SAP, http://www.sap.com, (accessed 13.09.2021).
Schoen, M., 2017. Hype cycle for project and portfolio management, https://www.gartner.com/doc/3772090/hype-cycle-project-portfolio-management, (accessed 13.09.2021).
Skorek, N., Trojanowski, M., Wilczak, A., 2010. Studium przypadku w nauczaniu marketingu. (in) Marketing w Realiach Współczesnego Rynku. Strategie i Działania Marketingowe, PWE, Warszawa, Poland, 549-556.
Spałek S., 2017, Zarządzanie projektami w erze przemysłu 4.0. Ekonomika i Organizacja Przedsiębiorstwa, 9, 106-112.
Sullivan III, M., 2016. Statistics: Informed Decisions Using Data, fifth ed., Person, Harlow, England, ISBN-10: 0134135377.
Vanhoucke, M., 2012. Project Management with Dynamic Scheduling: Baseline Scheduling. Risk Analysis and Project Control, second ed., Springer, Berlin, Germany.
Wachnik, B., 2016. Wdrażanie Systemów Informatycznych Wspomagających Zarządzanie, PWE, Warszawa, Poland.
Wachnik, B. 2020a. Możliwość wykorzystywania botów zintergrowanych z Dynamics 365 BC/NAV, Alna, https://alna.pl/pl/blog/mozliwosc-wykorzystania-botow-zintegrowanych-z-dynamics-365-bc-nav (accessed 13.09.2021).
Wachnik, B., 2020b. Luka Informacyjna w Przedsięwzięciach Informatycznych. Problemy i Rozwiązania, PWE, Warszawa, Poland.
Walker, W.E., Marchau, V.A.W.J., Swanson, D., 2010. Addressing deep uncertainty using adaptive policies: Introduction to section 2. Technological Forecasting & Social Change, Elsevier, 77, 917-923.
Ziółkowski A., Orłowski C., 2007, Concept of the agent system for the information technology evaluation. Information systems architecture and technology: information systems and computer communication networks, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław, Poland, 61-69.

Appendix A

Table 4. The range of AI use in project management throughout the entire project cycle. Source: Own Study

Stage 1		**Stage 2**					**Stage 3**	
Phase 1	**Phase 2**	**Phase 3**	**Phase 4**	**Phase 5**	**Phase 6**	**Phase 7**	**Phase 8**	**Phase 9**
Translation	Translation	Translation	Translation	Translation	Translation	Translation	Translation	Translation
		Text recognition	Text recognition	Text recognition	(Multi) Agent System – Chatbot	(Multi) Agent System – Chatbot	(Multi) Agent System – Chatbot	(Multi) Agent System – Chatbot
		Actuating elements – Robotic Process Automation	Actuating elements – Robotic Process Automation	Actuating elements – Robotic Process Automation	Text recognition Actuating elements – Robotic Process Automation Sensor element	Text recognition Actuating elements – Robotic Process Automation	Actuating elements – Robotic Process Automation	Actuating elements – Robotic Process Automation

Table 5. AI development in project management. Source: Own Study.

Stages	**Simple automation of routine tasks**	**Assistance**	**Identification of anomalies**	**Predicting the phenomena where anomalies occur**	**Inference based on the phenomena where anomalies occur**	**Intelligent and autonomous project management**
No.	1	2	3	4	5	6
Tasks	Elimination of simple and time-consuming tasks	Facilitating human-computer communication, using databases created by the AI through bots	Identification of anomalies	Predicting structured phenomena and trends, "What-If" sensitivity analysis based on Big Data	Identification of anomalies & inference, e.g. in controlling; image identification and inference based on the detected anomalies, control and inference of routine activities, analysis: reference model – real-life data	Task automation, data analysis, prediction, identification of information gaps, inference, detecting anomalies, identification of risk factors, decision recommendation, monitoring &control of decision implementation, identification of information gaps& taking autonomous actions aimed at reducing the information gap
Examples	Sending messages, writing and translating emails	Schedule modification, communication between project group members	Identification of defects in the image	Predicting resource utilization and cash-flow	Identification & inference of divergence between the planned date & the real-life data	Autonomous recommendation for schedule change based on risk factors

人工智能在工业 4.0 项目管理中的应用分析。波兰工业的前景

關鍵詞
人工智能
工业 4.0
信息化系统
项目管理

摘要
人工智能 (AI) 越来越频繁地支持行业项目中的项目管理。文章记录了有关在工业 4.0 项目中使用 AI 的研究结果。本文旨在定义工业 4.0 项目在整个生命周期中的 AI 使用范围，并确定项目管理中 AI 开发的主要阶段。此外，本文还指出了在研究项目中确定的项目管理中使用人工智能的主要障碍。为了识别和系统化人工智能的使用范围，应用了文献中提出的在项目管理中使用人工智能的概念框架。研究结果表明，我们正处于项目中人工智能使用的早期阶段。所研究的项目主要在项目管理中使用人工智能，即完成以下任务：日常活动的简单自动化、支持，以及在非常有限的范围内，在项目管理领域，即识别异常和预测现象哪里会发生异常。该研究使用案例研究方法，研究了四个项目：ERP 系统升级、支持高架仓库管理的 IT 系统的实施、物联网作为数据收集传感器平台的实施和 E-学习平台实施。该研究于 2019 年至 2021 年间进行，涵盖了整个项目生命周期，包括准备、实施和运营三个阶段。