
Body of Management Competencies for Engineer 4.0 (BoMC4E4.0) – A Model Proposal

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Abstract:

Purpose: The purpose of this Article is to present a proposal for a model of managerial competence in the fourth industrial revolution, known as industry 4.0. The consequence of this revolution is the emergence of new requirements in terms of the competences of employees at every organizational level. The authors focused on the requirements of 4.0 engineers, in connection with the managerial competences expected of them.

Design/methodology/approach: In order to answer the research questions posed, a review of the literature and commercial reports presenting the results of research on the expected managerial competences and the profile of an engineer 4.0 was carried out.

Findings: The conducted research allowed for the development of the Body of management competencies for Engineer 4.0 model - BoMC4E4.0.

Practical Implications: Research results will help to identify the scope of managerial competences of an engineer in the era of Industry 4.0, which in practice may contribute to the creation of requirements for candidates applying for a job in a managerial position in manufacturing companies, educational entities to adjust training programs to contemporary requirements of industry and other researcher to undertake in-depth research in this field.

Originality value: The basic and original scientific contribution is the model Body of management competencies for Engineer 4.0 - BoMC4E4.0, developed based on literature research. This model considers three research perspectives: general for Industry 4.0, managerial and engineering. This approach is original and has not been analyzed and published before.

Keywords: Managerial competence, engineer 4.0, industry 4.0.

JEL codes: D2, O10, M54.

Paper Type: Research article.

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1. Introduction

Companies wishing to operate under the conditions of the fourth industrial revolution, implementing the new technologies necessary for this, are forced to retrain employees, adapt new work and organizational models, recruit in accordance with the needs of Industry 4.0 and engage in strategic planning in the area of employee development. The observed dynamics of the changes taking place are a consequence of the emergence of completely new technological areas that require the development of new skills.

Examples include the integration of cyber-physical systems, advanced production management systems, advanced robotization, complex production data analysis systems, or the application of artificial intelligence algorithms in the manufacturing space (ASTOR, 2017).

As a result of the fourth industrial revolution and the spread of the Industry 4.0 concept, the competencies expected of employees are changing. Since Industry 4.0 represents an industrial revolution, the change in the scope of competencies particularly affects engineers.

Industry 4.0 (Industry 4.0, Industrial 4.0 - IoT) was first used in 2011 at the Hannover Fair and referred to the German project "Das Zukunftsprojekt Industrie 4.0," which deals with the topic of technological strategies combined with the digitization of production processes (Cao *et al.*, 2015). The aim of the project was to define strategies for increasing the competitiveness of German manufacturing companies using modern technological solutions, including cyber-physical systems, the Internet of Things, and cloud computing (Kagermann *et al.*, 2013).

In October 2012 the Industry 4.0 Working Group presented a set of recommendations to the German federal government on implementing Industry 4.0. The recommendations focused on automation and data exchange in manufacturing technologies and processes, which include cyber-physical systems (CPS), Internet of Things (IoT), Industrial Internet of Things (IIOT), cloud computing, cognitive computing, and artificial intelligence.

The concept of Industry 4.0, also known as the fourth industrial revolution, is based on 9 pillars:

- autonomous robots,
- horizontal and vertical integration of systems,
- Internet of Things,
- cyber security,
- cloud computing,
- incremental manufacturing,
- augmented reality,

- Big Data
- Simulation,

which, in the opinion of the authors, affect the range of competencies placed on modern managers - engineers.

Competencies can be analyzed at different levels, including, individual, group, or from the company level (Korytkowski, 2017). In this article, we focus on individual competencies of employees. There are many definitions of competencies in the literature, as has been demonstrated by many researchers (Prift *et al.*, 2017). For the purposes of the study, we have assumed, following Becker *et al.* (2002), that competencies are knowledge, skills, abilities, or personality traits that directly affect the results of a person's work. On this basis, we define competence in detail, as a set of 3 components: knowledge, skills (soft skills and technical/hard skills) and attitude reflected in action, also called social competence.

The research presented here deals with managerial competence, which we define following Woodruff (1993), who states that a competent manager must meet three basic conditions in carrying out his tasks:

- have the knowledge, skills, and abilities necessary to perform the managerial function in a given organization,
- have the motivation to perform the managerial function and be willing to devote the necessary energy,
- have the ability to use his competencies in the business environment.

2. Material and Methods

2.1 Scope of Research and Conceptual Model

The subject of the study is the managerial competencies of Engineer 4.0. The conceptual model of the study is presented in Figure 1.

In the research, we posed 4 research questions:

RQ1: What are the competencies for Industry 4.0?

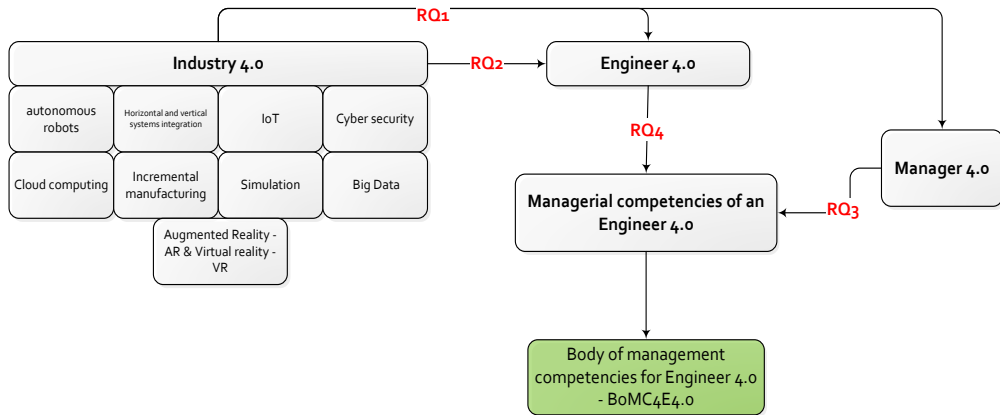
RQ2: What competencies are required of an Engineer 4.0?

RQ3: What managerial competencies are desired in the era of Industry 4.0?

RQ4: What managerial competencies are required of an Engineer 4.0?

The answers to the presented research questions made it possible to develop a proposal for a model Body of management competencies for Engineer 4.0 - BoMC4E4.0.

Figure 1. Conceptual model



Source: Own creation.

2.2 Data for the Answers to Research Questions

To answer the research questions posed, a preliminary review of the literature and commercial reports on competencies for Industry 4.0 was conducted. On this basis, the model Body of management competencies for Engineer 4.0 - BoMC4E4.0 - was developed.

2.2.1 Competence for Industry 4.0

Competencies for Industry 4.0, in recent times, have become the focus of interest of many researchers, as a result of the spread of the Industry 4.0 concept and research conducted in this area

Table 1. Competence for industry 4.0

competitive component	ID	Industrial competence 4.0 (CI4.0)
knowledge	CI4.0 _{K1}	knowledge of modern management models
	CI4.0 _{K2}	IT knowledge
	CI4.0 _{K3}	knowledge about AI
	CI4.0 _{K4}	knowledge about cyber security
	CI4.0 _{K5}	Knowledge of digital solutions
	CI4.0 _{K5}	interdisciplinary knowledge
skills	CI4.0 _{S1}	decision-making
	CI4.0 _{S2}	communication
	CI4.0 _{S3}	teamwork
	CI4.0 _{S4}	knowledge transfer
	CI4.0 _{S5}	leadership
	CI4.0 _{S6}	conflict resolution
	CI4.0 _{S7}	problem solving
	CI4.0 _{S8}	research skills
	CI4.0 _{S9}	strategic management
	CI4.0 _{S10}	team management
	CI4.0 _{S11}	time management
	CI4.0 _{S12}	process management
	CI4.0 _{S13}	project management
	CI4.0 _{S14}	entrepreneurship

attitude	CE4.0 _{A1}	willingness to learn
	CE4.0 _{A2}	knowledge sharing
	CE4.0 _{A3}	efficiency
	CE4.0 _{A4}	innovation
	CE4.0 _{A5}	creativity
	CE4.0 _{A6}	abstract thinking
	CE4.0 _{A7}	process thinking
	CE4.0 _{A8}	systems thinking
	CE4.0 _{A9}	openness to change
	CE4.0 _{A10}	working in interdisciplinary and multicultural teams
	CE4.0 _{A11}	independence
	CE4.0 _{A12}	tolerance

Source: Own study.

Table 1 summarizes the competencies for Industry 4.0 presented in the scientific publications we selected (Prifti *et al.*, 2017; Simic and Nedelko, 2019; Fitsilis *et al.*, 2018; Hevyakova *et al.*, 2021; Bermúdez and Juárez, 2017; Grzybowska and Łupicka, 2017; Grzelczak *et al.*, 2018; Dzwigol *et al.*, 2020; Hecklau *et al.*, 2016).

Based on these, a set of Competencies for Industry 4.0 (CI4.0) was developed, presented in Table 1. The set is a list of the most frequently recurring competencies identified in the publications, divided into knowledge (CI4.0K), skills (CI4.0S) and attitude-attitudes (CI4.0A). The summary in Table 1, is a response to RQ1. Based on it, we can conclude that competencies for Industry 4.0 primarily include specialized engineering knowledge, especially IT and interdisciplinary knowledge, as well as a set of appropriate skills and attitudes.

2.2.2 Requirements for Engineers 4.0

In a report compiled in 2017 by ASTOR (ASTOR, 2017), the requirements for Engineers 4.0 were outlined. An Industry 4.0 engineer is a person who moves seamlessly between two planes: "cyber" and "physical." For this reason, Engineers 4.0 will need to combine knowledge of a specific manufacturing process, such as working with robots or tuning a machine, with IT skills ranging from basic (e.g., using spreadsheets and operating interfaces) to advanced, such as advanced programming and analysis skills (ASTOR, 2017).

Due to the digitization of production lines, Industry 4.0 technologies will require engineers to integrate the IT department with the company's operations department more closely than before. Programmers need to have a very good understanding of how and why manufacturing uses IT solutions, and production operators should have a full understanding of how IT solutions affect production (ASTOR, 2017).

Based on ASTOR's report, titled. "Industry 4.0 Engineers," it is possible to identify the following set of requirements for Engineers 4.0 (ASTOR, 2017):

openness to change, continuous learning, assimilation of knowledge from other disciplines, process and analyze large amounts of data from multiple sources,

evaluate the validity of this information, its reliability and accurately infer from it, understanding of concepts and ideas from other fields, work in a team, highly developed interpersonal skills, i.e., effective communication, ability to convince, motivate others, explain difficult and unpopular decisions, attitude, value system and respect for the other person.

Due to the change in the knowledge, skills, ja-competencies required of workers in the era of Industry 4.0, the Executive Agency for Small and Medium-sized Enterprises - EASME, at the European Commission has developed a document entitled "Skills for Industry 4.0. "Skills for the Software Industry for Industry 4.0: Future-proofing Education and Training for Manufacturing in Europe." The goal of the study was to address the challenges of Industry 4.0 for workers and employers by developing Programming Industry 4.0 Guidelines, offering education and training providers a structured overview of new ways to organize the learning experiences of individuals and groups for Industry 4.0.

The study also presents a target profile for Industry 4.0 Engineers. The target profile for Industry 4.0 Engineers consists of 5 components:

- 1) Basic expertise in the engineering discipline,
- 2) Methodological skills, especially process and systems thinking,
- 3) Multidisciplinary knowledge, such as mechanical, electrical and electronic engineering in computer science and data science, and basic knowledge of mechanical, electrical and electronic engineering and computer science for data science, respectively,
- 4) Contextual knowledge, i.e., knowledge of conditions, requirements and perspectives in other departments and disciplines,
- 5) Interdisciplinary skills, especially teamwork, self-sufficiency, motivation, problem-solving skills, learning and adaptability, openness and communication skills (EASME, 2020).

The profile is largely based on specialized requirements in various engineering disciplines, with new additions being skills in computer science, data science and data security (EASME, 2020).

The literature also discusses new qualification requirements in the era of Industry 4.0. A critical literature study in this area was conducted by Jelonek, Nitkiewicz and Koomsap (Jelonek *et al.*, 2020).

Based on the reports and research presented, a set of Competencies of the Engineer 4.0 (CE4.0) was developed and presented in Table 2. The set is a list of the most frequently recurring competencies indicated in the publications mentioned above, divided into knowledge (CE4.0K), skills (CE4.0S) and attitude - attitudes (CE4.0A).

Table 2. Engineer Competencies 4.0

competitive component	ID	Engineer 4.0 Competencies (CE4.0)
knowledge	CE4.0 _{K1}	IT knowledge
	CE4.0 _{K2}	engineering knowledge
	CE4.0 _{K3}	basic mechanical engineering knowledge
	CE4.0 _{K4}	contextual knowledge
	CE4.0 _{K5}	interdisciplinary knowledge
skills	CE4.0 _{S1}	communication
	CE4.0 _{S2}	problem solving
	CE4.0 _{S3}	teamwork
	CE4.0 _{S4}	teamwork
attitude	CE4.0 _{A1}	openness to change
	CE4.0 _{A1}	creativity
	CE4.0 _{A2}	independence
	CE4.0 _{A3}	willingness to learn
	CE4.0 _{A4}	systems thinking
	CE4.0 _{A5}	abstract thinking
	CE4.0 _{A6}	process thinking

Source: Own study.

The summary in Table 2, is a response to RQ2. Based on it, it can be concluded that the Engineer 4.0 is primarily required to have knowledge and attitude, not much in the way of skills.

2.2.3 Powers of the Manager 4.0

As the literature analysis shows, in terms of managerial competencies, there is a close relationship between the chosen models of the HR function (or trends dominating management) and the required managerial competencies.

According to the PARP (2020) report, the Manager of the Future (Manager 4.0), is characterized by being a facilitator, partnering with colleagues, team building skills, conflict resolution, communication, group decision-making, conflict resolution, leading in a culturally diverse environment, including a diverse workforce, developing an organizational culture conducive to knowledge acquisition, and sharing.

Manager 4.0 enables employees to maintain a balance between work and personal life and can manage change in the organization.

Based on the report presented and the analysis of the literature (Kazak, 2017; Gracell, Makowiecki, 2017), a set of Manager 4.0 (CM4.0) Competencies presented in Table 3 was developed. The set is a list of the most frequently recurring competencies indicated in the publications, divided into knowledge (CM4.0K), skills (CM4.0S) and attitude - attitudes (CM4.0A).

Table 3. Manager Competencies 4.0

competitive component	ID	Manager 4.0 Competencies (CM4.0)
knowledge	CM4.0 _{K1}	knowledge of different cultures
	CM4.0 _{K2}	knowledge of modern management models
	CM4.0 _{K3}	interdisciplinary knowledge
skills	CM4.0 _{S1}	problem solving
	CM4.0 _{S2}	team building
	CM4.0 _{S3}	managing a culturally diverse team
	CM4.0 _{S4}	communication
	CM4.0 _{S5}	time management
	CM4.0 _{S6}	group decision making
	CM4.0 _{S7}	teamwork
attitude	CM4.0 _{A1}	cooperation
	CM4.0 _{A1}	openness to change
	CM4.0 _{A2}	development of organizational culture
	CM4.0 _{A3}	knowledge acquisition and sharing
	CM4.0 _{A4}	respect
	CM4.0 _{A5}	life balance
	CM4.0 _{A6}	partnership

Source: Own study.

The summary contained in Table 3, is a response to RQ3. Based on it, it can be concluded that Manager 4.0 is primarily required to have skills and attitude, with little knowledge.

3. Research Results

The performed literature analysis of the competencies of Engineer 4.0, managerial competencies of Engineer 4.0 is the starting point for the development of the Body of management competencies for Engineer 4.0 - (BoMC4E4.0). In the intention of the Authors, the model is the resultant (common part) of 3 collections:

- Competencies for Industry 4.0 - CI4.0, (Table 1),
- Competencies of the Engineer 4.0 - CE4.0, (Table 2)
- Managerial Competencies 4.0 - CM4.0, (Table 3),

which can be written with the formula (1):

$$\text{BoMC4E4.0} \in \text{CI4.0} \cap \text{CE4.0} \cap \text{CM4.0} \quad (1)$$

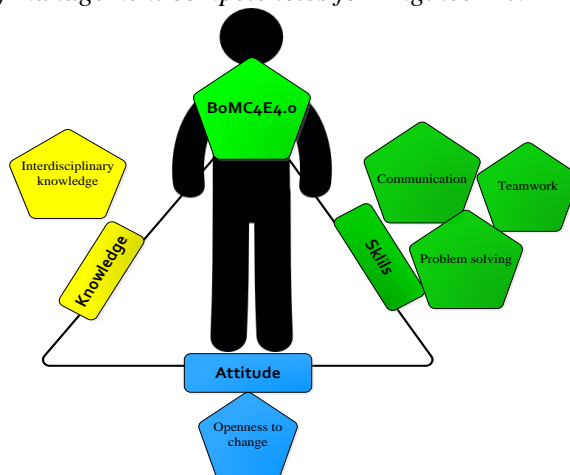
On this basis, we conclude that the set BoMC4E4.0, includes a 5-element set of:

$\text{BMC4E4.0} = \{\text{Interdisciplinary knowledge, communication, problem solving, teamwork, openness to change}\}.$

The collection answers the research question RQ4.

In further research, we developed a proposal for a model Body of management competencies for Engineer 4.0, graphically presented in Figure 2. The results of the research, indicate that the managerial competencies of Engineer 4.0, includes elements relating to knowledge (interdisciplinary knowledge), skills (communication, problem solving, teamwork) and attitudes (openness to change).

Figure 2. Body of management competencies for Engineer 4.0



Source: Own creation.

4. Conclusions

In the context presented, it is important to mention the planned investment in digital technologies in Poland. The planned investment is part of the Polish Digital Valley initiative, which involves state institutions, universities, and private companies (National Cloud, OChK).

As part of this activity and planned is also a comprehensive and long-term program to raise competence in the labor market. It will include numerous training courses, workshops, hackathons and e-learning programs on cloud computing, artificial intelligence, machine learning, the Internet of Things, big data processing, etc. The program envisages developing competencies 4.0 and increasing the competitiveness of Polish enterprises, increasing the employability of local professionals, and facilitating Polish employees to effectively innovate and implement competency transformation strategies 4.

Summarizing it can be concluded that the fourth industrial revolution, known as Industry 4.0, has forced changes in the formation of competencies of both engineers and managers. It would seem, perhaps, that the focus on digitization, automation and robotization of industrial processes requires a manager to have engineering and IT knowledge. However, as our research has shown, in terms of

requirements for Engineers 4.0 and Managers 4.0, the common denominator in this area is interdisciplinary knowledge.

The results we obtained, prompt us to continue and deepen our research on the managerial competencies of Engineer 4.0, both in terms of literature and field research.

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