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Project Manager Competencies in the context of the Industry 4.0

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Abstract

Nowadays, Project Management is facing a more complex and dynamic environment, mostly because of the recent fourth industrial revolution, called Industry 4.0. The digitisation and the characterisation of all of the assumptions, methodologies, and processes of the Industry 4.0 can cause disruptive effects for the traditional project management and the role of the project manager. This new paradigm requires a more active role from the project manager, accompanied by new technical, contextual and behavioural competencies. In line with this, this work aims to identify the skills or competencies that the project manager must present to follow the fourth technological revolution. To accomplish this task, the most relevant concepts that are associated with industry 4.0 and with the project manager competencies are presented. From the literature review, it is possible to conclude the existence of more behavioural or soft skills associated with the 4.0 project manager profile, compared to the traditional project manager profile.

Keywords: Industry 4.0; Project Management; Project Manager; Competencies

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1. Introduction

Over the past centuries, society has suffered significant changes and technological advances through industrial revolutions. The concept of industrial revolution suggests a set of transformations into the organisational and productive processes that, evolutionarily, have been causing profound changes in the economic dynamics of countries, since the end of the 18th century [1].

The first industrial revolution - Industry 1.0, took place in England, between 1760 and 1840 and was due to the development of science and its application to the industrial sector, namely by the introduction of new technologies based on the use of coal, as the primary source of energy. The emergence of the steam engine and later of the locomotive, was decisive for a profound change of the industrial paradigm, providing a new way of transporting people and goods. This era was characterised by the introduction of machines in industrial processes that reduced the dependence of artisanal mechanisms and, simultaneously, guaranteed considerable increases in productivity [2]. The constant search for new technologies, far more developed and efficient, dictated a new milestone in industrial evolution, with epicentre in the United States and Germany - we entered the era of the second industrial revolution, or Industry 2.0. [3]. The main characteristics of this industry were cost reduction, lead production times, the concept of large-scale production, the introduction of technical and organisational innovations, namely through the creation of automated lines production [4]. The third industrial revolution - Industry 3.0, originated in the United States of America in the post-war period (1970) was based on the development of technological information systems [3]. The computerisation of processes and the use of innovative and more sophisticated technologies, like robotisation, saw an exponential growth at the end of the century XX, especially after the emergence of the internet. Indeed, the possible transmission of data over the internet leveraged the growth of commercial relations worldwide and citizen mobility [5]. This period was also characterised by the emergence of new sources of energy, such as nuclear power, being associated with important discoveries in the field of biotechnology and genetics, which led to some transformations in the industry [5].

At the beginning of the 21th century, the evolution of innovation and technology, characterized by the development of automated systems and cyber-physical systems and through the creation of large networks of "things" enabled a real and disruptive transformation in industry. Currently, the creation of value in the industry, in the most developed countries, is being driven by the fourth stage of industrialisation, called Industry 4.0. This term comprises a variety of new technologies for the digitisation and automation of the production environment, as well as the creation of new digital value chains. The new industrial revolution consists of the development of intelligent systems that allow the monitoring of systems and decision making in real-time [6]. Wherefore, the manufacturing systems are vertically connected with the business processes within the company and horizontally connected with other points in the chain value, to increase the efficiency and response times of any request, with the main focus being the client [7] [8] [9].

Thus, a new paradigm is imposed on the modern management of companies with new technologies to enable the integrated optimisation of processes. Despite the numerous advantages associated with industry 4.0, this paradigm shift has also associated with a set of challenges and difficulties in topics such as the rehabilitation of human resources, investments, collaboration, standardisation, modernisation of new information technologies and greater complexity of projects. Projects will continually grow in scale, complexity, and uncertainty, but the main elements of project management will continue to require a unique human combination [10].

Therefore, the general objective of this literature review work is to identify the skills or competencies that the project manager must have to follow the fourth technological revolution. The main innovative characteristics of it are related to the identification and development of a guideline containing the main competencies that the project manager must present in the industry 4.0 context. In addition to addressing new scientific concepts, this guideline can assist companies in hiring the most capable project managers for their projects related to industry 4.0. The mentioned guideline will also be able to identify more effectively the most desired/required manager profiles by the industry and, at the same time, it can provide a road map between project management educational offerings in universities and the requirements of the markets.

2. Industry 4.0

At the beginning of the 21st century, with the development of the internet, small and powerful sensors at affordable prices, sophisticated software and hardware and the ability of machines to learn and collaborate by creating a vast network, a transformation in the industry have started. This transformation was dubbed by professors Erilk Braynjolfsson and Andrew McAfee of the Massachusetts Institute of Technology as the second age of the machine. In 2011 at the Hannover Industrial Fair in Germany, there was the first discussion about Industry 4.0 [6]. The term "Industry 4.0", "Smart factory", "Intelligent factory", "Factory of the future" are terms that describe a vision of what a factory will look like in the future [10]. In this view, the factories will be much more intelligent, flexible, dynamic and agile. Another definition for "industry 4.0" is a factory that makes smart products, on smart equipment, in smart supply chains [7]. Industry 4.0 will also promote horizontal integration between flexible units, interconnected with value chain partners [11]. This "collaborative" innovation is believed to drive synergies at key points that allow introduce significant gains and achieve new competitiveness factors, not only in terms of increasing efficiency but also in increasing added value in products and services, flexibility, response time, customisation products, involvement and the increase of customers' loyalty. Therefore, Industry 4.0 reflects a paradigm shift in operations and not just a simple technological improvement of productive capabilities. The main principles of industry 4.0 can be summarised as:

- Interoperability - Existence of cyber-physical systems (CPS) that allow people, factories, and systems to be interconnected towards being able to communicate with each other.
- Virtualisation - Possibility of creating a virtual copy of the smart factories, allowing the simulation of models and remote monitoring of processes, through the use of data sensors.
- Decentralisation - Ability of the CPS to make decisions according to needs production in real-time.
- Capacity in real-time - Ability to collect and analyse data and make decisions instantly.
- Guidance for the services - Use of service-oriented software, combined with the IoS concept (Internet of Services).
- Modularity - Flexibility of smart factories allowing adaptations by changing the requirements, replacing or adding production modules [11] [12].

The impact of Industry 4.0 goes beyond simple digitisation, through a much more complex form of innovation based on the combination of multiple technologies, which will force companies to rethink the way they manage their businesses and processes, how they position themselves in the supply chain value, and how as they think about the development of new products and its underlying strategy to introduce them into the market, adjusting the marketing and distribution actions [11]. According to Klaus Schwab in his book "the fourth Industrial Revolution", there are four main changes expected in the industry in general: Changes in customer expectations; Smarter and more productive products; New forms of collaboration and partnerships; The transformation of the operational model and conversion to a digital model [7]. To fulfill these changes, there are several enabling technologies and trends available that are considered to be the main pillars of the industry 4.0: The Cyber-Physical Systems (CPS); Internet of Things (IoT); Cloud computing; Big Data and data analysis; Additive industry (3D printing); Robotics; Virtualisation and simulation; Cybersecurity and Augmented Reality [11].

3. Project Manager Competencies

The definition of competencies is not new, but it is instrumental when researching how different project managers' skills fit the challenges of industry 4.0 projects. Müller et al (2018) stated that, while managerial competencies are sometimes significant, sensitive competencies always make a significant contribution to project success [5].

A competency or skill is an individual's primary characteristic that is causally related to effective performance in a job or situation. Competency can predict performance in a wide range of situations and job tasks. A person needs competencies, which are abilities to use the knowledge and to make things happen [12]. According to Hopkins & Bilimoria (2008), competencies always include intent; in other words, motives, traits, self-concept, social roles, and knowledge. Therefore, behaviour without intent does not define competency [13]. According to Varziani (2010),

competency is defined as a capability or ability that consists of a set of alternate behaviours organised around an underlying construct, so competencies require both action and intent. The same author refers that are three clusters of competencies: cognitive competencies, such as system thinking and pattern recognition; emotional intelligence competencies, including self-awareness and emotional self-control; and social intelligence competencies, including social awareness and relationship management competencies [14]. Thus, competencies are a behavioural approach to emotional, social and cognitive intelligence [15].

Over the years, several guidelines such as PMI competence development framework, PMCD and IPMA standards – Individual Competence Baseline, have been developed. The global scope achieved by these standards demonstrates the evident growth in awareness and acceptance of the need for formal project management methods [16].

The PMI competence development framework, the PMCD (Project Management Competence Development), presents Lynn Crawford's (1997) definition of competence, which considers "Competence as a term with different meanings for different people. But it is generally accepted as something that encompasses knowledge, skills, attitudes, and behaviours that are causally related to superior job performance" [17]. PMI (2007) adds that, when applied to Project Management, competencies can be divided into three different dimensions: knowledge, performance, and personal characteristics [17].

The four version of the ICB - IPMA shows the meaning of the word "competence" which comes from the Latin word "*competentia*" which means "is authorised to judge" or "has the right to speak". Also mentioning that project managers must be "competent to orchestrate project activities". For project management, the ICB presents like the PMCD from PMI, a division into three distinct groups: technical skills, contextual skills, and behavioural skills. These 46 skills are divided into three groups: 20 are technical skills, 11 are contextual skills, and 15 are behavioural skills. The eye of competence represents the integration of all the elements of project management, as seen through the eyes of the project manager when evaluating a specific situation. The eye also represents clarity and vision [15].

However, other authors propose different classifications for the critical competencies of project managers. Vale et al. (2018) investigated the individual competences of project managers through a methodological approach that combines a systematic literature review and an analysis of employment opportunities. The authors concluded that it is possible to classify and codify competencies in four categories (contextual, managerial, technical, and behavioral). These authors will also include the concepts of soft skills and hard skills to classify the competencies of project managers [18]. Cakmakci (2019) also proposes a classification of project manager competencies in soft skills and hard skills. These authors studied project management competencies through a systematic review of the literature. These authors stated that the competency profile should be divided across 11 dimensions: influencing, communication, emotional, contextual, management, cognitive skills, professionalism, knowledge and experience, project management knowledge, and personal skills and attributes [19] [20]. Table 1 presents a summary of the characteristics and key competencies analysed in the most relevant reports, guidelines and research articles that the project manager must-have. It is important to notice that the project manager competencies are related to traditional project management, which is directly linked to industry 3.0. Due to the new context of industry 4.0 and society's digitalised transformation, it will be important to identify what kind of competencies will be needed towards being able to perform in an adequate and efficient project manager's profession. In other words, it is crucial to identify the gaps between the traditional project manager competencies and new competencies imposed by industry 4.0.

4. Project Manager in Industry 4.0

Until the end of the 20th century, the classical project management approach has been in the construction and production industries. The contribution of the human factor to the actions of the project associated with industry 3.0 is seen and observed in all processes of the project management. Project actions could be checked from project announcement meetings to project feasibility analysis. These actions and tasks are defined, timed, and used as an instrument in project management and control, depending on the planning of the project in coordination with the project planning and finally includes all activities up to the termination of the project. The initiation, planning, implementation, monitoring and control of the project, as well as project closure processes, constitute the sub-processes of the classical project management approach. In other words, much of the daily work of a project manager has not dramatically changed over the last 30 years in industry 3.0 projects [21].

Table 1. Summary of Project manager competencies.

Classification	Dimension	Competencies
Soft Skills	Influencing Skills	1 Leadership; 2 Influence/persuasion; 3 Motivating others; 4 Conflict management; 5 Negotiation; 6 Charisma
Soft Skills	Communication Skills	7 Verbal communication; 8 Written communication; 9 Listening; 10 Reading; 11 Multi-level communication; 12 Open communication; 13 Clear, direct and concise communication; 14 Engaging communication; 15 Multi-cultural and contextual communication; 16 Presentation skills;
Soft Skills	Team Working Skills	17 Collaboration; 18 Support; 19 Developing others; 20 Team building; 21 Delegation; 22 Escalation; 23 Trustworthiness
Soft Skills	Emotional Skills	24 Interpersonal sensitivity; 25 Interpersonal skills; 26 Empathy; 27 Self-awareness; 28 Stress management; 29 Self-motivation
Soft Skills	Contextual Skills	30 Contextual awareness; 31 Political awareness; 32 Adaptability; 33 Strategic alignments 34; Networking;
Hard Skills	Management Skills	35 Planning; 36 Prioritising; 37 Directiveness; 38 Organization and coordination; 39 Monitor and control
Soft Skills	Cognitive Skills	40 Vision and imagination; 41 Strategic perspectives; 42 Critical analysis; 43 Intuitiveness; 44 Problem solving; 45 Decision-making; 46 Learning; 47 Creativity; 48 Professionalism Ethics; 49 Accountability
Hard Skills	Knowledge and experience	50 Technical expertise; 51 Business expertise; 52 Administrative expertise; 53 Experience
Hard Skills	Project management knowledge	54 Human resources management; 55 Resource management; 56 Requirement management; 57 Scope management; 58 Cost and finance management; 59 Procurement and contract management; 60 Time management; 61 Stakeholder management; 62 Risk management; 63 Quality management; 64 Communication management; 65 Integration management; 66 Project management methods; 67 Client/customer management; 68 Knowledge and information management; 69 Health and safety management; 70 Change management; 71 Supply chain management
Soft Skills	Personal skills and attributes	72 Achievement orientation; 73 Commitment; 74 Initiative; 75 Confidence; 76 Courage; 77 Openness; 78 Detailist; 79 Sense of humor; 80 Multitasking; 81 Discipline; 82 Curiosity

In contrast, industry 4.0 represents a new organisation and control path for full value-added systems. The principal objective is to meet individual customer needs with mass production costs. For this reason, order management affects all areas such as research and development, production, commissioning, delivery and recycling of manufactured products. The new opportunities are the digitisation of production with the help of the base, cyber-physical production systems. For this reason, resources such as all employees, products, resources and systems must be integrated as intelligent, self-organising, inter-company, real-time and autonomously optimised examples [19]. For example, nowadays in the manufacturing sector, which is the pioneering sector in which the Industry 4.0 approach is applied, the human factor is gradually being replaced by robots and full automation in the sub-processes of applying, monitoring and controlling the processes, especially in the automotive and electronics sectors. The functions of these processes are transferred to robots and machines. In this case, the initiation and planning processes gain more importance than the features of the classical project management approach. That is, the identification of the human factor involved in the initiation and planning processes of the project needs to be restructured to include its functions during the implementation, monitoring and control of the project [22].

In fact, complexity and uncertainty which are the two main theoretical traditions in project management play also a big part in Industry 4.0 projects, shaping and defining necessary features to handle the workload and they are related with the increasing complexity of the projects. According to Simion et al (2018), project management in industry 4.0 is characterised by digitisation, virtualisation, trans-nationalisation, professionalisation, switching from Waterfall to

Agile, focusing on the project-organisation relationship and the maturity of organisations in project management. These authors also pointed out the critical changes of project management in each knowledge area (Table 2) [22].

Table 2. Principal changes of project management in each knowledge area for industry 4.0 projects.

Project management knowledge area	Project Management new features for industry 4.0 projects
Time management	Real-time monitoring of project execution; Eliminating gaps in progress reports.
Cost management	Update real-time cost progress indicators; Foresight on the cost of projects.
Quality management	Automatic quality control of deliverables; Digitalisation of project quality control.
Project team management	Generalise the use of virtual teams; Using gamification as a method of preparing and developing human resources; Collective intelligence.
Communication management	Accelerating communication processes within projects; Removing physical communication support and increasing connectivity; Use of human-machine and machine-machine communication in the execution of projects; Less time spent on progress reports; Auto-generation of progress reports.
Project risk management	Project execution simulation; Using techniques to identify and analyse risks as involving the use of large volumes of data.
Procurement and resource management	Sharing knowledge about purchases; Using virtual platforms in procurement processes; Strengthening the share of acquisition and use of knowledge resources in project implementation.

As can be seen from Table 2, the project management in industry 4.0, through the manifestation of their characteristic elements, will have an essential influence on the planning and execution of projects in different fields of activity, which was already stated previously.

Regarding the project manager competencies, the future of project management will be heavily influenced by technological breakthroughs, and there is no doubt that industry 4.0 and technological improvements will change the course of how project management tasks are delivered and controlled in the future [19]. Information in Industry 4.0 is expected to flow more quickly and dynamically. Work teams will be diverse and will comprise very different areas of study. CPS and IoT will allow the development and use of faster and more predictive management tools. The robotisation of the industry will increase its efficiency, but it can also remove the human factor in certain circumstances. The use of Big Data tools will allow the flow of a massive amount of information, quickly, and with a wide spectrum (5G) [21]. All of these factors will trigger significant changes in the form of management and, consequently, in the project manager (PM). These changes could be highlighted in PMs soft and hard skills:

1) Soft skills for Industry 4.0 project manager - In Industry 4.0, the soft skills of project managers will undertake a significant transformation mainly related to the new ways of interacting with project stakeholders [23]:

   ▪ Communication skills - To react in real-time and consequently speed up the processes of problem-solving and decision making, the management and sharing of knowledge will play in the main role. While time is passing, information is going to decrease value. Information should be shared with all stakeholders in order to enhance the management of critical issues and encourage the creation of integrated collaboration.
   ▪ Authority - In Industry 4.0, project managers are among the main actors of this industrialisation change process. Their leadership will be expressed as more authoritative and less as a simple position in the organisational chart. In this sense, the project manager should have the right to create project agreements, define resource management and the team position in the processes, be available to get involved and demonstrate skills in valuing resources.

- Team management - The PM's fundamental task should be to encourage the team's spirit of initiative without losing sight of the strategic objectives of the project. From a technical or cognitive view and relational point of view, the project manager should be able to choose the right people for the composition of the team with the delocalisation of the different project teams.
- Management of unforeseen events - Speed will be a keyword in Industry 4.0. Therefore, an integrated flow of data and communications that allows stakeholders to have a picture of the situation in the real-time will be crucial to the high speed of decision making and for the diligence in reacting to unexpected events. Project managers should have a consistent problem-solving capacity and act quickly, maintaining the right balance at the same time.
- Negotiation skills - Traditional hierarchical relationships will gradually change into a flat structure in Industry 4.0. Project team members will become independent professional figures, able to develop their creativity with greater freedom than in the past. Therefore, the project manager should build her authority on the 360-degree knowledge of the project and of its related domain. To manage effectively, the project manager should communicate the team members with transparency and with responsibility [23]

2) Hard skills for Industry 4.0 project manager - In industry 4.0 projects, the project manager plays a crucial part of a project: However, these projects require a full comprehension of Cyber-physical systems from the project manager along with deep domain knowledge while the implementation is mainly delegated to project team experts or virtual assistants. The most important hard skill for project managers is experience with innovative technologies and projects, big data analysis and predictive algorithms that will help them to manage projects correctly and focused on the objectives to be achieved. The authoritativeness of project managers will be based on their ability to see the flow of processes that will regulate the projects of the future not only in its entirety but in all its components [23].

Pessl (2017) in his study, clustered the identified competencies into four main categories. These categories are:
- Technical competence such as state-of-the-art knowledge, process understanding, technical skills, etc.
- Methodological competencies including creativity, entrepreneurial thinking, problem-solving, conflict solving, decision making, analytical skills, research skills, and efficiency orientation.
- Social competencies such as intercultural skills, language skills, communication skills, networking skills, ability to work in a team, ability to be compromising and cooperative, ability to transfer knowledge and leadership skills.
- Personal competencies include flexibility, ambiguity tolerance, motivation to learn, ability to work under pressure, sustainable mindset and compliance [24].

5. Conclusion and future research

With the analysis of the most relevant concepts in industry 4.0, project management and competencies of project managers in industry 4.0, it is possible to conclude that the industry will unequivocally transform the business sector worldwide. These developments will change the way products or services are produced, but also how organisations will manage their processes and projects, which is also related with the industry 5.0 definition which proposes utilise a workforce of machines and people efficiently, in a synergic environment. In this context, the key role that the project manager will have in this process of digitalisation of the industry is also highlighted. Therefore, the changes and challenges that the industry will experience for this digitalisation will also be accompanied by changes and challenges to the project manager. The most significant changes will focus on the way of communicating, interacting, the speed and capacity of work and the basic knowledge that the project manager must present. After analysing the necessary skills and responsibilities of traditional project managers and industry 4.0 project managers in this literature review work, we found that there are many challenges in industry 4.0 project manager, especially ways of management and technical skills. Although there could be a specialised project manager related to each element of Industry 4.0, it is sure that project manager must have enhanced soft skills and hard skills to accomplish the complex and autonomous

Industry 4.0 projects. Recent studies proved that the competencies associated with industry 4.0 go further than the competencies defined by the PMI or IPMA for the project manager role.

To dissipate uncertainties and confirm the concepts analysed, the next stage of this research project is to develop focus groups with Portuguese project managers. This step will be crucial for identifying the competencies, establishing and defining a guide containing the main competencies that a project manager must present in projects of industry 4.0.

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