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Future critical competencies for smart factories production processes

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Abstract

The main purpose of our research was to determine the critical competencies for smart factories production processes. For the purpose of study, we used the qualitative research paradigm as it represents a research approach. We used a semi-structured interview as a method of data collection. With the help of interviews, we have acquired the critical competencies that workers in smart factories production processes will need. Participants of the research identified the following competencies as critical for smart factories production processes: flexibility, openness, adapt to change, curiosity, communication skills, critical thinking, analytical thinking, team or group work, emotional intelligence, positive conflict resolution, technological skills.

Keywords: Critical Competencies, Smart factory, Production processes, Industry 4.0, Automotive industry.

Riassunto. *Competenze necessarie per i processi di produzione nelle Smart Factories*

Lo scopo principale della nostra ricerca è determinare le competenze critiche per i processi di produzione delle smart factories. Ai fini dello studio abbiamo usato un'intervista semi-strutturata per la raccolta dei dati. Con l'ausilio delle interviste, abbiamo acquisito le competenze critiche di cui avranno bisogno i lavoratori nei processi di produzione delle smart factories. L'intervista includeva domande riguardanti la flessibilità, il pensiero critico,il pensiero analitico, il lavoro di gruppo, l'intelligenza emotiva, la risoluzione dei conflitti.

Parole chiave: competenze critiche, fabbrica intelligente, emotional intelligence, processi di produzione, industria 4.0, industria automobilistica

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1. Introduction

Industry 4.0 has brought and will continue to bring significant changes to the structure of work, as robots and other high-tech work tools/devices impact the division of labour and planning within an organization. Human Resources (HR) is looking to build a competency profile, in regards to critical competencies needed to adapt existing jobs, which would help HR professionals to understand the added value of smart manufacturing operations and principles. Organisations should therefore carefully evaluate skills and competencies present in the organization, and recognise the digital skills among their staff and to continue to recognise where competencies are lacking in the workplace (Hecklau *et al.*, 2016). For our study, we conducted a case study on the competencies of the future in smart factories production processes. The following research question were set: RQ1: What are the future critical competencies for smart factories production processes?

2. Literature review

2.1. Industrial revolutions

The mid-1980s brought forth the transformation from a "traditional heavy industry" to a technology-driven economy (Alavi and Leidner, 2001). The creation of a knowledge society that significant impacts organizational change, in terms of transformation strategies, structures and governance modes have been encouraged by technological transformation processes (Aue, Biesdorf and Henke, 2016). Changes appear in steps that could also be described as four steps of the industrial revolution.

The first industrial revolution began to develop from 1760 onwards, when water and steam energy were invented (steam engine - James Watt, 1769), which allowed the transition to machine-made products. This was marked by the first rebellion of a simple peasant population who did not understand the changes that were occurring, while on the other hand the revolution also resulted in many moving to these new industrial centres to find a job. Prominent characteristics of the revolution were that the labour force was unskilled and poorly paid, along with the growth of capitalist values, such as private property and commodity production, capital accumulation and individualism (Hobsbawm, 1968).

The second industrial revolution took place from 1848 to 1905, during which there was a transition from the use of a steam engine to the use of a internal combustion engine. During this time, many new discoveries arose in various fields (chemistry, biology, physics, medicine, automotive, aviation, communication). The main source of energy at the time were oil, gas and electricity. The second revolution contributed to greater immigration, the revival of transport, industrialization, the abolition of customs ties, the emergence of joint-stock companies, banks, the integration of capital (capital moves into foreign countries) and the emergence of modern capitalism (Hobsbawm, 1968).

A third industrial revolution emerged in the second decade of the 21st century, bringing new technological developments that involve high robotics. This not only affected the migration of jobs caused by globalization, but also the loss of jobs (Lasi *et al.*, 2014).

In the year of 2011, a new concept of German economic policy was developed, based on a high-tech strategy called Industry 4.0 (Mosconi, 2014). The concept has set up a fourth industrial revolution (Möller, 2016), in addition to continuous communications over the Internet, which enables continuous interaction and information exchange also among machines (Roblek, Meško and Krapež, 2016). The digital industry transformation is still going on, with artificial intelligence, large data and connectivity pointing towards the certainty of a new digital revolution (Lasi *et al.*, 2014).

The four key components of Industry 4.0 are cybernetic physical systems (CPS) (links between real and virtual worlds), Internet of things (IoT), Internet services (IoS) and smart factories. Machine to Machine (M2M) and smart products are not considered as stand-alone parts. An important factor is the development of the Internet of Things, which enables communication and knowledge exchange at the level of hardware communication, which can be viewed from the perspective of knowledge management (Dominici *et al.*, 2016). Smart factories are one of the key components of Industry 4.0. The concept of smart factory is a vision of factories in the future (Radziwon *et al.*, 2014), an industrial network in the future. They represent the next step in the evolution of factories (Lucke, Constantinescu and Westkämper, 2008), for digital and virtual factories (Westkämper, 2006). We can see the smart factory as a technology (Madu *et al.*, 1994), an approach (Zuehlke, 2010), or a paradigm (Yoon, Shin and Suh, 2012). Smart factories surveil their manufacturing environment with sensors and send collected data to autonomous systems for analysis, in order to form a command that governs equipment and machines used in manufacturing. The "smart" aspect of this kind of manufacturing lies in the ability of advanced learning algorithms to use the data, which travels in feed-forward and feed-back loops between sensors and machines/equipment, to improve/optimize its own decision making (Roblek, Meško and Krapež, 2016).

2.2 Predicted jobs and competencies needed for smart factory production processes

Life, as we know it, is changing in its foundations. Jeremy Rifkin (2007), in his work The End of Work, points out that the introduction of advanced technologies, together with the accompanying increase in productivity, consequently increases the production of goods and services. This means that the development of technology increases the production and profit of an organization, while the number of workers in production and value of wages decrease. The resulting question that remains is where will all these workers go, what jobs and competencies will exist in the future?

The literature on predicted job creation or loss within the upcoming years is mixed. MIT technological review looked at all the predictions they could find from leading experts in economics and technology, however they found that their methodology differed, as well as their predictions. Within the 18 studies found, the predicted number of jobs worldwide lost was estimated to be from several million up to several billion, the same was also true for the predicted amount of jobs that will be created, however the amount of jobs that are predicted to be lost tended to be several times higher than the prediction of new jobs that will be created (Winick, 2018). According to Segal (2018), three workers per robot will be lost in the United States and predictions have been made that unemployment would rise by 1%, which equals half as many jobs worldwide as were lost to trade with China. In addition, in the US, car manufacturing, due to it being the biggest adopter of these new digital technologies, has seen the greatest drop in jobs. However, on the positive side, it seems that in countries, where automation is more developed, jobs are becoming complex, harder to automate and thus job security is increased (Nedelkoska and Quintini, 2018; Segal, 2018).

Bernevik (in Cirkvenčič, 2012), is pessimistic about the loss of jobs, particularly in manufacturing, giving forecasts that the share of employees in production will fall from 35% to 25% in ten years, while in 20 years it will drop to 15%. In doing so, he is interested in where all these workers will go and to which jobs. Due to the tendency for capitalism to seek increasing greater profits, it could be asked: «What kind of salary will these individuals have?» The International Metalworkers' Federation from Geneva is even more pessimistic about jobs in production. An extremely pessimistic study suggests that in 30 years «in order to produce all the goods needed to meet the total demand», only two percent of the world's workforce will be needed (Rifkin, 2007).

While several jobs will be automated due their repetitive nature, there are several applications of large data and machine learning/AI algorithms that will not take away jobs, because those jobs would not replace old jobs, but will instead complement previous jobs by analysing large amounts of data in ways that were not possible previously. For example, big data analysis has already had several successes in detecting several kinds of fraud, increasing digital security through encryption, weather forcasting and natural disaster management, as well as increasing the effeciency of energy consumption (Granville, 2014; Kosoleva and Ropaite, 2017). Big data is also becoming increasing present in the sciences, for example by collecting several petabytes of data, scientists were recently able to detect gravitational waves and to take the first pictures of a black hole, both findings giving strong support for the general theory of relativity that Einstein proposed aproximately a century ago (Castelvecchi, 2017; Event Horizon Telescope, 2019). In medicine there is also potential for big data, which could help better understanding and predicting disease and help advance precision medicine, in ways that are complementary to, but cannot be achieved through traditional methods (Schadt and Chilukuri, 2019; Hulsen *et al.*, 2019).

In order to successfully manage all the changes occurring in the external and internal environment of organizations, relevant re-shaped or new competencies will play an important role for organizations. So far, the technical view of Industry 4.0 as well as smart factories has been discussed, while research in the field of human resource management is very limited. The competency model consists of the desired competencies for a specific task and may also include a description of individual competencies (Mirabile, 1997; Lucia and Lepsinger, 1999; Markus, Cooper-Thomas and Allpress, 2005) and indicators for measuring performance and results. These lists may contain different levels of detail and also describe the relationship between competencies. Many competency models have been developed over the years. For example, Nippa and Egeling (2009) developed a classification by separating competencies into the meta, domain, method, and social competencies. Erpenbeck and von Rosenstiel (2007) offer a model with the separation of competencies into four categories: personal, social/interpersonal, with fact-related and domain competencies.

- Personality competencies

Personality competencies can be understood as an individual's ability to act responsibly and autonomously. Personal competence also includes the ability to learn and to develop their own relationships and the ethical value of the system (Erpenbeck and von Rosenstiel, 2007).

- Social/interpersonal competencies

Skillful cooperation and communication within various social contexts, for the purpose of establishing social networks with particular individuals or groups, also known as social competence, is importantant within an organization context or any context that requires stable and healthy social structures for optimal functioning (Erpenbeck and von Rosenstiel, 2007).

- Action-related competencies

- Action-related competence are the ability of an individual to use personal and social/interpersonal competencies together at times when it is desirable and to take ideas into actions. The individual can incorporate concepts into his agenda to successfully transfer plans into reality, not only on the individual but also at the organizational level (Erpenbeck and von Rosenstiel, 2007).

- Domain competencies

Another kind of competency is called a domain competency, which requires the individual to have skills, abilities, knowledge, that is not related to the context and environment that these competencies can be applied to. Domain competencies are considered to be more general, such as non-trivial knowledge and experience in using methodologies, languages and tools that can apply to various different tasks found in various different business or other kinds of contexts/environments (Erpenbeck and von Rosenstiel, 2007).

Competency profiles are quickly outdated because of constant changes in the market and in the environment, resulting in a need for a partial or full revision of a competency profile model. This includes the following:

- obsolete competencies (those that are no longer relevant);
- emerging competencies (those that are becoming important),
- transitional competencies (those which facilitate the implementation of a change in the competency model) and
- critical competencies (those that are always important, etc.).

Our study is focused on understanding and exploring the critical competencies in Industry 4.0.

3. Methodology

For the case study we looked at smart factories in the automotive sector. The automotive industry is one of the most rapidly changing industries, and for this the dynamics of competence implementation will be greater than in some other industries. Given that the automotive industry is intensely focused on the production and development of electric and hybrid vehicles, and even autonomous vehicles, this will bring about a series of changes.

We used the qualitative research paradigm in the study, since we wanted greater detail of the events, behaviour, organization functioning, relationships and the environment of the organization (Easterby, Thorpe and Lowe, 2007, p. 85). A qualitative paradigm gives us a deeper understanding of the phenomenon of smart factories. The advantage of this approach that it enables us to be more involved in the research process itself and enables us to see the whole picture of the phenomenon under consideration. We decided for the qualitative aproach also because it is difficult to collect enough credible quantative data for a statistical analysis.

For the aim of our study, we used a semi-structured interview as a method of data collection. Interviewees explained the purpose and course of the research. The transcripts of interviews were made. The credibility of the qualitative research was enhanced by the use of data sources triangulation, allowing a more comprehensive (broader) view of the problem under study. For the purposes of the research, the most knowledgeable informants were included in the study. These are:

1. six industry experts - members of the Slovenian Automotive Cluster (ACS),
2. three experts in the field of education,
3. three experts from the ministries.

In order to gain new knowledge on the basis of primary data, we used the method of content analysis, because with its help we structure qualitative data in a well-established, empirically-based way, in our case this refers to the text from the transcribed interviews. The method of content analysis is a research method, more precisely an empirically based method, which is mostly used in social sciences (Neuendorf, 2016).

The limits of the research are divided into content and methodological. Among the content restrictions, it is worth pointing out the consideration of only some aspects of Industry 4.0. The aspect that we deal with is the aspect of the competencies of new jobs. Methodological limitations include a constraint that is related to the type of research, that is, to a qualitative research paradigm. This limitation is that we cannot generalize the results of the research.

4. Results and discussion

For the purpose of our study, we used categorization of competencies according to Erpenbeck and von Rosenstiel (2007) model due to the reason it encludes multi-dimensional construct of competencies.

The research question of our study was:

What are the future critical competencies for smart factories production processes?

From the interviews, we coded critical competencies into the four categories presented in the Table 1.

Category of competence	*Critical competencies*
Personality competencies	Flexibility, openness, openness to changes, adapt to change, curiosity, communication skills, critical thinking and analytical thinking
Social/interpersonal competencies	cooperation with others, to be able to work in team or group, emotional intelligence, and to find conflict resolution in a positive way
Action-related competencies	Technological literacy, knowledge of ICT technologies, and electronics
Domain competencies	Cooperation with robots, knowledge of computer science (such as programming)

Table 1 – Future critical competencies for smart factories production processes.

For the first time, Boyatzis (1982) defined personality competencies in the book entitled The competent manager as «the characteristics of a person who are necessary but not sufficient effective and/or superior performance in a job or situation».

The critical competencies, mentioned by participants of the study, are flexibility, openness, openness to changes, adapt to change, curiosity, communication skills, critical and analytical thinking. Hecklau *et al.*, 2016 also stated that skill sets requiring flexibility and openness, such as openness to receiving a higher level of education, flexible responses, openness and flexibility in problem solving and to complexity will increasingly be needed. Segal (2018) states that employees will need to adapt to changes, i.e. new technology. For those that believe that the pace of big data analysis and associated technologies is growing too quickly, policy can also help slow things down, in order to ease the stress with which the workforce will need to go through to adapt to these new digital technologies.

The participant believe that cooperation with others, team or group work, emotional intelligence, and positive conflict resolution will be needed in the upcoming fourth industrial revolution. Also stated that emotional intelligence is the one of the cruical skill needed for Industry 4.0 (Cotet, Balgiu and Zaleschi, 2017).

Participants also believe that technological literacy, knowledge of ICT technologies, and electronics, will be a critical action-related competencies. Erol *et al.* (2016) found out that action-related competencies needed for assembly process are problem analysis and structuring, solution development, data analysis and interpretation, and method, tool selection and use.

Knowledge of computer science (such as programming) and cooperation with robots are domain competencies mentioned by participants of our study. This makes sense, as smart manufacturing will include the continuous information flow and exchange between humans and machines, while at other times machines by communicating with each other (Cooper and James, 2009; Greengard, 2015; Roblek, Meško and Krapež, 2016).

Finally, it is interesting to note some of the competencies that are not technical. For example, participants believe that everything will be important, as smart technology alone does not guarantee competitiveness. Some of these skills that were also stated by the interviewees were leadership, motivation and social responsibility.

5. Conclusion

Our research is focused on understanding and exploring the critical competencies that employee will need to perform work in new and restructured workplaces at smart factories in automotive industry. After reviewing domestic and foreign literature, this area was perceived as a rather unexplored and worthy of in-depth scientific treatment. There is a small amount of research done abroad on future competencies. These surveys are mostly literature reviews on Industry 4.0 and not empirical research or competence reviews for specific jobs. With the help of interviews, we have acquired the critical competencies that workers in smart factories will need. In the future, we could develop a model of competencies in production processes, which aims to implement the concepts of Industry 4.0, so as to improve traditional processes in the field of human resources.

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