IMPACT OF COVID-19 ON MANUFACTURING – CASE STUDY OF CROATIA

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Abstract

The covid-19 pandemic has caused a major effect on the manufacturing industry all over the world. At the same time, the concept of digital manufacturing called Industry 4.0 (I40) marks its tenth year of presence and availability on the market. The purpose of this paper is to provide an overview of current findings on the impact of the pandemic on the digitization of the manufacturing industry and compare the world results with the research conducted in Croatian manufacturing companies. For the worldwide state-of-art contributions, the review of papers published in Web of Science database is conducted, while for the impact on Croatian companies, authors have conducted a research in 53 local companies, as online questionnaire. The results have statistically been analysed and most significant results have shown that, unlike the rest of the world, most of the Croatian manufacturing companies yet aren't familiar with digital manufacturing concept, while the pandemic had a mild influence on their businesses. In the world, the pandemic has caused the change in perception of the need for I40 and enhanced digitization. Half of the Croatian participants haven't yet heard of the new digital manufacturing concept strategy and don't consider implementing it soon. The pandemic hasn't changed their perception, while most of the digital technologies implemented were only the ones that enable remote working while only a few implemented advanced I40 elements such as digital twin. The pandemic has caused mild disruptions in the supply chain, but most of the manufacturing companies managed to fulfil the business goals set at the beginning of 2020. Practical and social implication was to built framework for the future strategic development of Croatian manufacturing companies, while also this is the beginning point for the future research expansion to other countries of Balkan region, but also to service-oriented industry.

Key words: digitization, supply chain management, COVID-19, Industry 4.0, manufacturing

1. INTRODUCTION

The concept of digital manufacturing, in Europe often called Industry 4.0, has been presented ten years ago and ever since has remained somewhat a goal of every manufacturing company. Flexibility and real-time data analysis within the complex cyber-physical systems enables market competitiveness but also the fast and accurate reaction on dynamic markets and unexpected changes. The year 2020 has brought the most unexpected change - COVID-19 pandemic and restrictive lockdowns all over the world. The impacts of it could vary, depending on the industrial sector. The need for remote working and travel disruptions demand the implementation of new digital technologies and require changes in the usual working environment. Before the pandemic, the research conducted in Croatian metal machining companies revealed that only 54% of the participants were familiar with I40 (Trstenjak et al. 2020) while the research from 2015 revealed the readiness level of 2.15 for Croatian manufacturing companies which represents the fact that in average, many companies haven't reached and implemented technology of 3rd industrial revolution (Veza et al., 2015).

High financial demands, specific knowledge requirements and overall change of the working environment were one of the reasons and main barriers in I40 implementation (Vuksanović Herceg et al., 2020). After a year in a pandemic that required innovative skills in work planning and organization, there might be an unexpected change in perception of I40, but also in the level of digital development. This has motivated the research with the following as the main research questions and objectives:

RQ1: *Has the COVID-19 pandemic accelerated digitalization in manufacturing companies?*

RQ2: *Were the companies that are more familiar with Industry 4.0 and at a higher development level more successful in overcoming the pandemic obstacles?*

RQ3: *How has the COVID-19 pandemic impacted the supply chain?*

2. LITERATURE REVIEW

Literature review was provided by Web of Science database research, to provide the most relevant and accurate results in the field. The research by keywords "industry 4.0" OR "manufacturing" AND "covid-19" OR "coronavirus" OR "pandemic".

The studies on the impact of the pandemic on manufacturing can be grouped by several mutual characteristics. Those published in 2020 mostly deal with the predictions and study the usage of modern technology in manufacturing and the impact of pandemics on the organizational level. Global researches of leading consulting companies deal with the perception of I40 by the manufacturing industry

and the level of implementation of digital technologies caused by the COVID-19 pandemic.

Ibrahim et al. (2021) have mentioned the importance of 3D printing (additive technologies) during the pandemic, with the rapid development and increased usage. The biggest usage was found in medical equipment, from oxygenation equipment to non-invasive and invasive ventilatory felt, as well as innovative solutions for infection control. They claim that this has caused the rapid reconfiguration of the traditional supply chain while the efforts might limit the impact of this and future pandemics. By the study of Longhitano et al. (2021), this kind of technology might be used very often in the future for emergency cases. Mathew et al. (2021) see 3D printed objects as a good solution in supply shortages or delays resulting from governmental policies. They also discuss the use of antimicrobial materials in additive manufacturing which is one of the innovative approaches in protection against pandemics.

Zhu & Liu (2021) have discussed the impact of pandemics in the sharing economy, which is one of the most affected sectors, because of the psychological component of fear within their customers. The prices of this kind of service are now lower due to smaller demand, except for the delivery sector, which has increased their demands and revenues. The pandemic has also presented a new form of sharing economy: shared employees. This means that the employees from companies that are very affected by the pandemic go to companies that have higher demand during the pandemic.

Ibn-Mohammed et al. (2021) saw an opportunity for a more resilient, low-carbon economy. The rethinking of the global economic model is needed, to create a more sustainable one towards the characteristics of a circular economy.

As for the supply chains, most of the companies, due to airway and waterway disruptions have now relied on roadway transport where the disruptions were caused by local regulations and health problems of the drivers. Tolosa & Celis (2020) mentioned the importance of the health and safety of workers and the importance of investments in this segment. Also, they noticed the different dynamics of the goods distribution and demand within the single type of industry. A similar trend, but in the consumer electronics market was noticed by Coughlin (2021).

That is why lean manufacturing principles, which were shown as very useful before the pandemic, may seem as vulnerabilities today. Due to supply chain disruptions, they also suggest the implementation of circular economy principles. On the other hand, Lin-Gibson & Srinivasan (2020) claim that standardisation might improve productivity in the biotechnology industry and result in rapid developments of new projects. Greener manufacturing and modification of national strategies were also inspired by the decrease of PM, as the most dominant pollutant in the world due to the lockdown (Huang et al., 2020).

To make a good response to unexpected events in the dynamic market, an innovative approach towards manufacturing is needed. Saleeby et al. (2020) explored the rapid retooling and benefits of hybrid manufacturing processes which increase the flexibility of the manufacturing system to make a response in the shorter time possible.

Brooks & Roy (2020) mention the importance of self-engineering systems which automatically respond to "return lost functionality and improve product resilience

without human intervention". The focus is set to self-healing materials, self-reconfiguring electronics, and self-adapting robotics.

Diaz-Elsayed et al. (2020a) suggest that the companies in the post-COVID-19 era have to operate at high technology level in the times of stability, but also be flexible enough to make quick and correct responses in the time of crisis. One of the solutions for supply chain shortages is supporting local suppliers but also providing accurate asset mapping, which was proven to be efficient at the US/Mexico Border region. Online product marketplaces, which also rely on complex digital technologies, have proven to be an innovative solution for supply chain disruptions (Haapala et al., 2020).

Wuest et al. (2020) discussed the rapid introduction of digital technologies to the workplace and the adoption of the workforce to it. They mention the rise of "Operator 4.0" as one of the key elements in an unexpected digital transformation strategy, which also has to be beneficial in the long-term. Digital technologies not only enable remote working, but also they keep the workers safe. The perception of I40 of the workforce has therefore changed, but yet the fear about the future, post-pandemic, job possibilities remained. They also mention the gap between the "white" and "blue" collar jobs, which is now wider, which can also be understood as one of the challenges for the future in terms of workers' motivation and feeling of personal safety.

Terry et al. (2020) emphasise the fragility of the supply chains, with the suggestion of flexible smart automated technologies use as a good assistance in the recovery, while Diaz-Elsayed et al. (2020b) are relating pandemic to possible future disasters due to climate changes so digital and sustainable manufacturing principles might be solution for quick and efficient adaptation to new disasters, or its avoidance. Huang (2020) suggests that in achieving a sustainable system, complex decision-making analysis and methodologies should be used. Li et al. (2020) enhance the importance of creating a safe environment by automated manufacturing assets "which are monitored by the networked sensors and controlled by the intelligent decision-making algorithm". Adaptive planning is one of the key elements of new digital system, which, combined with AI technologies and sustainable principles, can be useful is unexpected situations like the pandemic.

McKinsey and Co. in their annual reports (Agrawal et al., 2021 & 2020) consider pandemics as an inflection point for I40. The manufacturing companies were forced to implement certain digital technologies and were facing rapid changes that require financial investments. Those who have adopted those technologies before the pandemics were more flexible which resulted with higher adaptivity level to sudden changes on the dynamic market and the disruptions in the supply chains. Those who were avoiding implementing a new digital concept in their manufacturing process were left unprepared and had a very hard time in adapting to the pandemic conditions. At the same time, digitization was aggravated because of travel restrictions and cash constraints. In 2019 the biggest challenge was the lack of people, skills and knowledge, in 2020 it was the lack of funding because of COVID-19 pandemic. Agility and flexibility have now become higher strategic priority than cost, while biggest focus was set on digital technologies that enable remote work implementation.

3. METHODOLOGY

The latest findings in the literature were the motivation to conduct research on the impact of COVID-19 pandemic in the Croatian manufacturing industry. The research was based on the following research questions:

RQ1: *Has the perception of Industry 4.0 and digital technologies in the Croatian manufacturing changed due to the pandemic?*

RQ2: *Did the pandemic force the Croatian manufacturers to implement additional digital technologies due the pandemic?*

RQ3: *What kind of impact had the pandemic had on the supply chains of Croatian manufacturers?*

The research was conducted through an online questionnaire and the participants were selected through an online database of the Croatian chamber of economy. The questionnaire was sent to a total of 324 participants and 53 answers were received, which makes 16% of the response rate. The questionnaire was formed in the Google Forms app and consists of 38 questions. At the first part of the questionnaire, participants were asked to give basic answers about their position within the company, years of work experience in the field and company size. Second part of the questionnaire is formed with questions about their familiarity and perception of I40 concept and impact of pandemics on their work and supply chain. The questions were simple to answer, most of them based on the Likert scale from 1 to 5 while others were simple YES or NO questions. 53.7% participants were from medium companies, 25.9% from large, 16.7% from small and 1.9% from micro and craft companies.

4. RESULTS AND DISCUSSION

At the very beginning, one of the most interesting results was the fact that only 50% of the participants are familiar with the I40 concept. McKinsey and Co. research results claim that those already familiar with I40 and those who have implemented it fully or partially were the ones that weren't affected with the pandemics as much as those who haven't (Furtado et al., 2020). However, representers of Croatian manufacturing companies claim that they have fulfilled most of the goals set at the beginning of 2020. The average grade was 3.62 it can be concluded that the pandemics hasn't affected radically but mildly. On the contrary, those companies that are familiar with I40 were more affected than those who aren't, with an average grade of 3.48/3.77. The mild effect on their position on the market was also noticed. The participants have rated this segment with 3.21. With the thought of quick digital transformation needed because of new rules of the working environment and the need for remote working, this also hasn't encouraged the digital transition. The average grade of new digital technologies implementation rate was low 2.49 with extremely little difference between those who are familiar and those who aren't with I40 concept. At the same time, they haven't changed their production organisation, with an average grade of 2.40, where 1 means no changes at all and 5 the need for complete change and reorganisation. Their perception of average digitization rate (Figure 1) before the pandemics was 3.09 - 3.41 of those familiar with I40 and 2.77 of those who aren't. At

the same time, both groups consider that their company is more digitised today, with an average grade of 3.38. The implementation of new digital technologies had caused a resistance within the workers, rated with 3.34. Again, those companies familiar with I40 had lower rate of resistance (3.15) and those unfamiliar higher 3.54.

Figure 1. Perception of estimated level of digitization before the pandemic and today

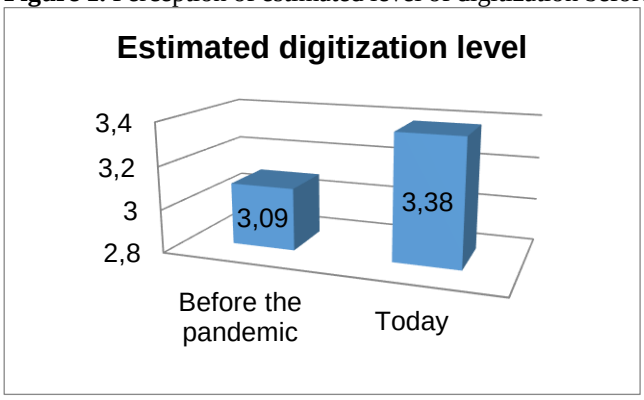
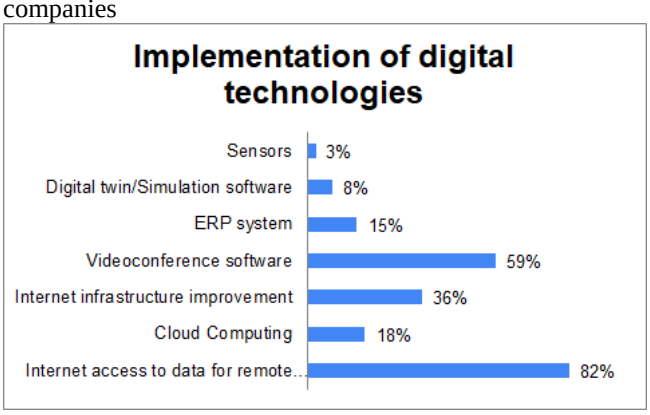
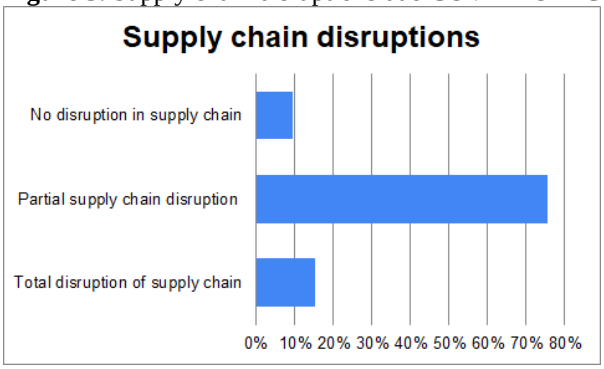


Figure 2. Implementation of digital technologies due COVID-19 in Croatian companies



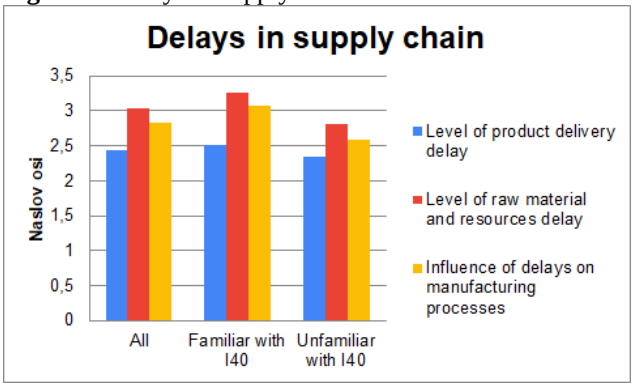
As shown in Figure 2, most companies have invested in internet access to data for remote working, followed by videoconference software. Pandemic was an encouragement to implement ERP systems for 15% of the participants, while only 8% have invested in digital twin or simulation software. Only 3% invested in implementation of sensors. It can be concluded that the companies, in most cases, have implemented only elements of I40 that were needed in order to keep the work running during the lockdowns and travel restrictions, but the more advanced elements of I40 were rarely invested in, which means that the pandemic wasn't a motivation for complete digital transformation in most cases.

Figure 3. Supply chain disruptions due COVID-19 in Croatian companies



As shown in Figure 3, supply chains were affected only partially in most cases. Only 9% haven't had any disruptions of the supply chain, while 13% had total disruption of the value chain. Delivery process of their products, according to their perception, hasn't had as many delays as the delivery of the raw material and resources (Figure 4)

Figure 4. Delays in supply chain due COVID-19 in Croatian companies



Product delivery delays were rated on average with 2.43 while the raw material and resources with 3.04, but it hasn't had as big an effect on their manufacturing process (rated with 2.83). Those familiar with I40 had a bigger effect of delays on manufacturing (3.07) than the unfamiliar ones 2.58. Those delays haven't made them implement any new digital technology, nor made them to start the collaboration with the local suppliers more (1.79). Regarding the perception of moderate influence on the supply chain, the pandemic has caused unexpected costs, rated with 3.15. Many of them got financial support from the local government (62%), but only few of them used it to upgrade the digital technologies of the company (4%).

5. FRAMEWORK OF FUTURE STRATEGIC DEVELOPMENT

The results have shown a slight difference between the global research and the current situation in the Croatian manufacturing companies. One of the biggest challenges in the digitization is the fact that half of them aren't familiar with I40, therefore they can't have any strategic vision for the digital transition in the near future. Their perception of the future development wasn't examined, so that the correlation between the ambition of the market competitiveness level and the path of their future development can't be predicted, but from the impact and reaction to COVID-19 pandemic several conclusions can be given. The conclusion is that most of the Croatian companies weren't as affected with the consequences of the pandemic as those in the world, but also their awareness of the importance of existence and use of digital technologies in their working environment hasn't changed radically because of the current situation. Most of their goals that were set at the beginning of 2020 they managed to achieve, while the delays in the delivery of their products has also been minimized. On the other hand, the delays in the delivery of the raw material and other resources were more present, but this judgement can be very subjective, because of the possible reputation of the company in the public. The disruptions of supply chain were partially present, but this hasn't inspired the company leaders to implement the digital technologies. The local government has given the financial support to most of the participants, but not many of them used it for the digital transformation, which is the proof that there yet isn't any digital strategy within the most of the companies, nor the digital manufacturing concept is being recognized as the solution for the dynamic and unpredictable situation due the pandemic.

With this in mind, this is why the strategy for the near future development of the manufacturing companies can be formed so that the companies could remain competitive in the post-pandemic era. The following segments are the basis of the I40 and simple key points (basis) to implement for the healthy and successful future development of Croatian manufacturing companies:

- *Education of workers*. Primarily, the awareness about the benefits of I40 should be raised. The education should begin with upper and middle management so that they could define the future predictions for the companies' position on the market and how the digital technologies enhance their competitiveness level. The optimal transformational plan is to be defined next, personalized and detailed, it avoids the possibility of possible failures in the future state of the company which can easily cause very high financial loss.
- *Cloud Computing.* Without the presence of the advanced internet infrastructure digital transformation of any kind wouldn't be possible. Strong and stable high-speed internet connection is essential for implementation of every other I40 internet. Appropriate internet infrastructure doesn't only depend on the manufacturer, but also on the local government who can and has to provide part of infrastructure. Procedures and online processes enable

the easier remote working and quicker reaction of the process supervisors and data availability.

- *Cyber Security.* After the implementation of cloud computing, one of the biggest challenges for every company which has accepted the digital manufacturing concept is the safety of data on the cloud. Entire know-how of the company is now available online and subject to possible theft, but also once the control of the current running processes is also available online, someone can interact with the manufacturing in the real time and cause much damage.
- *Horizontal and vertical integration.* Horizontal integration enables the control of the manufacturing processes in the real time while the vertical integration enables the simple and accurate data flow within the entire company, standardisation and better correlation between the organisation and planning and physical manufacturing.
- *Continuous improvement and innovation environment.* The principles of lean manufacturing and the culture of continuous improvement can be very helpful in the transitional period, but also as a beneficial addition to smart digital factories. The continuous improvement combined with the innovation environment can improve the flexibility and is one of the essential elements for the market competitiveness.

6. CONCLUSION

The COVID-19 has not only changed everyday life but also the manufacturing process and industrial organization. The digitalization in terms of Industry 4.0 has been known and available on the market for ten years now, but yet not many companies have accepted the new manufacturing concept and implemented the digital technologies in their system. The remote working due to the pandemic has changed the perception of I40 in the global companies but in Croatia the radical changes aren't noticed. On the global level, those who have partially implemented digital technologies remained more flexible and therefore more adaptive to the new and unexpected consequences of dynamic and unpredictable markets. Those who haven't were left behind and gained more loss than their digital competitors. The research results conducted in 53 Croatian manufacturing companies showed that half of them today aren't even familiar with the I40 concept, which means that digital transformation, at this point, can't be, their top strategic priority, as it should be, by global trends. The pandemic hasn't made them in general to accelerate the digital transformation or to partially implement certain digital technologies which would enable them the remote work, apart from the standard videoconferences software, which provides an answer to RQ1. Only few of the participants were triggered by the pandemics and realized the importance of Cloud Computing, ERP system and Internet

of Things, but in general, the familiarity with I40 haven't influenced the resourcefulness during the pandemics, which answers RQ2. The impact of the lockdown can be seen in disruptions of their supply chains, but yet they claim that the distribution of final products wasn't as affected as the raw material and resources distribution, which answers RQ3.

The resistance towards digitization is most of the time result of underestimation and unawareness of its benefits. Therefore it is very important to put enhance on the education of workers on every level in organization. Another very important solution is the support from the local government, on financial, infrastructural and administration level. The local policies are one of the many barriers which impacts the Industry 4.0 concept, and after the "forced" and partial implementation of certain digital technologies due the pandemic, this can be one of the solutions for the healthy future development not only of the single manufacturers, but also the entire geographical region.

For future work, it is recommended to study the impact of the company size and regional affiliation on their perception of I40 after the pandemics. Another path of future research can be the definition of the framework of the strategic transformation, provided by global results and adapted to regional needs and infrastructure.

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