3D printers as part of Construction 4.0 with a focus on transport constructions

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Abstract. Digital and technological innovations that have grown rapidly in recent years have been referred to as the 4th Industrial Revolution or Industry 4.0. The paper comprehensively deals with the description of the 3D printers as part of Construction 4.0 with a focus on transport construction. The aim of the article is description of this issue comprehensively and with the help of SWOT analysis identify weaknesses, strengths, opportunities and threats with focus on the transport constructions. The content is complemented by an assessment of the current situation, indicating the possibility of use in practice.

1. Introduction

Autonomous self-guiding and self-learning systems are embarking on a number of activities. This process seems to be taking on the rapid acceleration. Dynamics these changes and their importance in shaping the whole company was named 4th industrial revolution or Industry 4.0.

In the 21st century, there are four major changes in construction:

- Technology is the driving force. Virtual and augmented reality, 3D printers, advanced building materials, prefabricated and modular designs, Big data and predictive analytics, 3D scanning and photogrammetry, autonomous vehicles and drones, cloud collaboration (real-time collaboration) or wireless monitoring and interconnection devices, thanks to mass expansion they become cheaper and affordable.
- The needs, requirements and attitudes of end users have changed drastically
- Construction focus is also shifting towards mass adaptation, particularly in the urban area, on the one hand; and mass production at a very high speed in the countryside (for housing and other infrastructure).
- Due to climate change, particular emphasis is placed on sustainability and green construction, which has not been a priority in the past [3].

These changes increase the demand for construction, cost pressure and cost-effectiveness not only of the construction itself, but of the whole life cycle of buildings with regard to sustainability. The construction industry is beginning to run into the limits of the technologies used so far and the methods of planning and managing buildings. Figure 1 shows the need for construction 4.0, where construction productivity in EU is stagnating compared to most other sectors.

The construction industry thus requires a fundamental change, which seems to be the transition to the fourth industrial revolution, which began after 2010, building on the use of so-called cyber-physical systems and the digitization of the entire product life cycle. A necessary condition for the transition of the construction industry to such a system seems to be digitization of the entire life cycle of buildings, i.e. design, implementation and operation [5].
2. 3D printers as a digitized production method

3D printers or 3D printing as manufacturing technology was raised in the late 1980s. Connection with construction industry was established in 1997 [1]. 3D printing, also known as additive manufacturing, is process based on a three-dimensional digital model, using automatic technology to create a physical objects layer-by-layer without human intervention [2].

The materials currently used in 3D printing are mostly either Portland cement-based [6] or geopolymer-based [7]. The possibilities are wide. Most materials are in the research phase. Thus, very diverse materials such as resin mortar or clay are used [8]. Another example of material is stainless steel [10].

2.1. Examples of using 3D printers with a focus on transport construction

Below are examples of how to use 3D printers. The possibilities are very wide, so it is only a cross-section of the most important ones.

2.1.1. Stainless steel bridge. The Dutch company MX3D developed the technology for 3D printing from metal and in 2018 printed stainless steel in Amsterdam with this patented technology a fully functional footbridge [10].

![Figure 1. Evolution of labour productivity for the EU-28 (2000=100) [4].](image1)

![Figure 2. 3D printing a fully functional stainless steel bridge [10].](image2)
2.1.2. Concrete bridge. The Marines used an ACES (Automated Construction of Expeditionary Structures) printer to print a 3D footbridge that can carry the intended load. The printer uses concrete instead of paste or mortar. With this printer it is also possible to create other types of structures such as obstacles, protective structures, arches, culverts and spokes [11].

![Figure 3. 3D printed concrete bridge [11].](image)

3. SWOT analysis
Possibilities and possible problems of 3D printers or 3D printing in relation to swot analysis have been discussed with fourteen other researchers and experts. The following information was established on the basis of the questioning. In addition, an extensive research of previously published articles was also carried out.

3.1. Weaknesses/Threats
- Possible errors in digital model creation.
- Inappropriate material.
- Inconsistency of possible use in technical standards and legal regulations / regulations.
- Lower production speed.
- Poor surface quality - need for additional treatment.
- Different mechanical properties due to material layering.
- For tall buildings up to tens of meters or even hundreds of meters, first of all there must be a printer that matches the height of the building, which means the higher the building, the higher the cost [8].
- High price of new technology (price of 3D printers and printing material) compared to established procedures including convective construction equipment and standard organization of human labour [9].

3.2. Strengths/Opportunities
- New possibilities of design both practical and aesthetic. It is possible, for example, to design noise barriers which, due to the materials and profiles used, have a better ability to absorb or withstand sound. The advantages of 3D printing technology are also detailed construction accuracy. But that depends a lot on the 3D printing technology used.
- 3D printing technology facilitates the production of curved concrete components, allowing construction companies to create better structural sound structures. Unlike conventionally manufactured components, 3D components can be made from hollow centres, which is very practical, for example, when installing electrical wiring.
- This technology also produces less waste than conventional technologies. For example, lost, pruned and increased consumption due to the way the material is used.
• Printing building components requires less human work, saving not only time but, above all, the cost of the work itself. This is associated with another indisputable advantage, which is the fact that this technology reduces the risk of injury to construction site workers.

• 3D printing also has great potential for the use of environmentally friendly materials, such as bio-plastics. It is also possible to combine different types of materials.

• It is possible to print mechanically connected parts. It is not necessary to connect them directly on site.

4. Conclusion
Currently, 3D printing technology is in the exploratory research and development phase. It will take some time to overcome the current shortcomings and obstacles and become a commonly used means for use in construction. As such, however, it should play an important role in Construction 4.0.

The ideal picture for the future is shown in the following figure. However, this is still a long way off, even though research in this area is moving forward by leaps and bounds.

![Figure 4. Future of 3D print [12].](image)

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**Acknowledgments**

This work was supported by the Grant Agency of the Czech Technical University in Prague, grants No. SGS19/010/OHK1/1T/11 and No. SGS20/100/OHK1/2T/11.