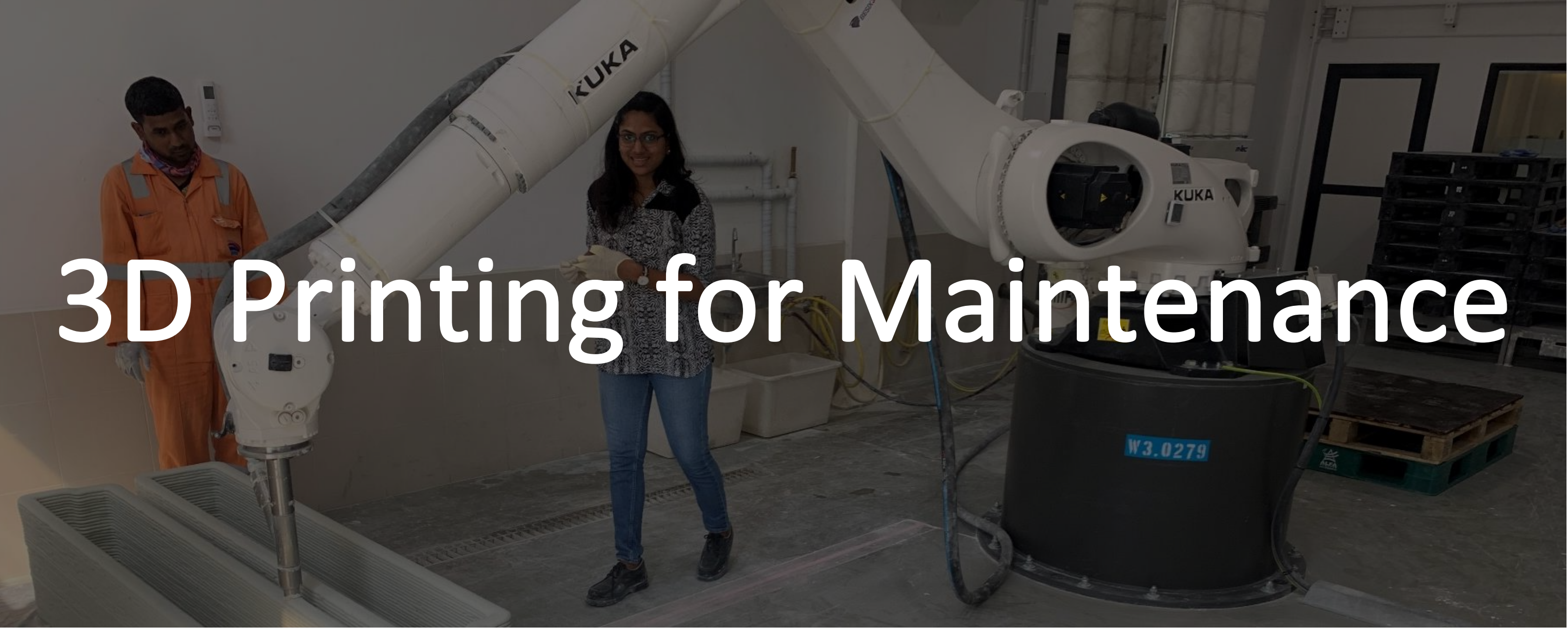

3D Printing for Maintenance

DETAILS

SECTOR | Transport, Energy, Water and Waste

STAGE | Project Design and Construction; Operations and Maintenance

TECHNOLOGIES | 3D Printer, 3D Scanner, Material Technology

SUMMARY

A 3D printer is a machine that can create a physical three-dimension object based on a computer-aided design (CAD) model. The process is usually done by extruding material (in molten form) through a nozzle that moves around precisely under computer control. The material is added layer by layer until completion. 3D printing was first developed in the 1980s as a cost-effective method of creating prototypes for product development. From the mid-2000s, 3D printers began to diversify, with new uses geared towards part production for high value, highly engineered, and complex parts.

3D printing can be used in many sectors. It can enable the creation of entire pieces of infrastructure, such as the MX3D Bridge in Amsterdam, or printers in factories can enable pieces of infrastructure to be prefabricated off site and transported to the construction site for modular construction (*see also the Prefabrication and Modular Construction use case*). However, the relative immaturity of the technology today means that 3D printing in the short term is more frequently used to assist in manufacturing specialist components than completely replace traditional construction techniques.

Where limitations in the complexity of traditional infrastructure design and construction exist, 3D printing has the potential to enable more design freedom and rapid and cost-effective formulation of parts. 3D printed components can also improve construction safety by minimising worker participation in the manufacturing of components.

The main focus of this use case is on using 3D printers to produce individual components on-site to allow for a fast response to maintenance requirements. For example, on-site printers in railway maintenance facilities can enable the rapid production of parts (e.g. chair armrests for trains) to replace faulty parts and allow a train to re-enter service. This on-demand 3D printing style is increasingly being adopted in public transport maintenance facilities, such as those operated by Bombardier, Siemens Mobility and Deutsche Bahn.

It has been estimated that on-site 3D printing can reduce the manufacturing time of spare parts by up to 95%[1] compared to traditional external part sourcing and manufacturing methods[2]. It provides a level of flexibility to operators, who can create and replace parts on-demand without relying on delivery from external suppliers and minimizes the need for operators to keep spare parts in a stockpile. Instead a digital inventory can be created that will reduce costs associated with holding physical parts (e.g. storage space and the high prices of spare

[1] "Application Spotlight: 3D Printing in the Rail Industry", AFMG, Accessed 20 May 2020.

[2] "3D Printers", Chris Woodford, Accessed 8 May 2020.

parts) and delays associated with long lead times. Thus, a more agile supply chain is created. 3D printing could also enable obsolete or discontinued parts to continue to be produced, potentially extending asset life spans.

With improved precision and quality, 3D printing can minimise the cost associated with human errors. Errors can be identified and corrected within the CAD model prior to printing. It is estimated that 3D printing can reduce the price of objects by 20% to 25%, the cost of materials by 25% to 30%, and the labour required by 45% to 55%[3].

The use of 3D printing in the infrastructure sector is expected to mature further through ongoing research and development. For example, in Dubai the market for 3D printing is expected to be USD $300 billion by 2025 with 25% of Dubai's buildings to be 3D printed by 2030[4]. Furthermore, by combining 3D printing technology with artificial intelligence and autonomous robots, printing can occur with minimal human interaction.

VALUE CREATED

Improving efficiency and reducing costs:

- Reduce the time required to obtain spare parts by up to 95%[5] and enable vehicles/machines to return to service faster thereby reducing the cost associated with their downtime.
- Reduce cost to produce spare parts by decreasing the costs associated with materials and labour.
- Eliminate the need for a physical stockpile of spare parts by building a virtual inventory thereby enabling the repurposing of stockroom space and reducing the cost associated with purchasing spare parts in advance due to long lead times.

Enhancing economic, social and environmental value:

- Improve the precision and quality of components, ensuring parts are produced identically each time and improve the standardization of component production, including time to produce, therefore enabling better maintenance planning and scheduling.
- Improve safety by enabling the remote control of printers thereby eliminating worker handling of components during formulation and decrease material waste by minimizing errors.
- Enable flexibility in design especially in the use of spheroid or hyperbolic shapes.

POLICY TOOLS AND LEVERS

Legislation and regulation: Governments should develop regulations for 3D printing that outline the minimum standards for operation and quality, testing and maintenance of equipment and product testing to ensure safe use.

Transition of workforce capabilities: For transport operators 3D printer terminals are best placed on-site at maintenance facilities. This will enable rapid on-demand production of components in response to the malfunction or failure of parts. Therefore, on-site staff will need to be trained on the use and upkeep of the equipment.

Funding and financing: Most implementations of 3D printing are taking place in the private sector, however there are clear uses for it in the public sector, such as for public transport operators. Funding can therefore be public or private.

Procurement and contract management: Any contract with the transport operator should identify the requirements around 3D printer equipment testing, to ensure ongoing performance. It should also include testing of parts produced to ensure they meet a quality standard and are safe for use.

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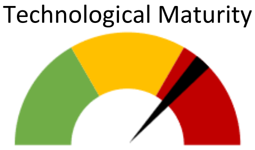
[3] "Contour Crafting: Automated Construction", TEDxOjai, Behrokh Khoshnevis, Accessed 10 May 2020.
[4] "Dubai 3D Printing Strategy", Dubai Future Foundation, Accessed 8 May 2020.
[5] "Application Spotlight: 3D Printing in the Rail Industry", AFMG, Accessed 20 May 2020.

IMPLEMENTATION

Ease of Implementation 	To implement this method of manufacturing, operators would need to select a 3D printer supplier and set up a new supply chain for materials. A digital inventory of parts would need to be developed based on existing designs. In-house staff would require training to operate the machine and new operations processes would need to be defined. Maintenance of the machine would be performed by the supplier, enabling updates of the technology as its advances. Testing of the new parts should ensure their quality and safety for the specific purpose.
Cost 	3D printers can be purchased outright or leased from suppliers. The initial investment to purchase printers is relatively high, with printers ranging from USD 6,000 to USD 200,000 depending on size and functionality. 3D printers are decreasing in cost as they continue to be developed. To roll them out across multiple sites would require significant investment. However, 3D printers can reduce the operational cost of maintaining assets, through reducing the cost of materials and labour, and reducing the time to produce and therefore replace a part, enabling an asset to return to service faster.
Country Readiness 	Today, 3D printing is used by many transport operators in developed countries including Bombardier Siemens Mobility and Deutsche Bahn. It is increasing in popularity due to its demonstrated time and cost savings, and as assets get older it becomes increasing difficult and expensive to source replacement parts from suppliers. For developing countries, the cost to procure 3D printers may be disproportionate to the cost of having assets out of service, or too costly. Collaborations with researchers and technology suppliers could be investigated to determine a suitable leasing style model.
Technological Maturity 	While there are some 3D infrastructure printing projects that have been done around the world (Amsterdam, Dubai), the technology is not mature enough yet for them to be widely used to produce entire assets. Further research and development are needed. However, to produce components, the technology has been readily tested.

RISKS AND MITIGATIONS

Implementation risk

Risk: 3D printers require high amounts of energy, which will increase demand on the energy grid and potentially increase energy costs for the operator. Additionally, the types of materials that can be used in 3D printing are limited, thereby limiting the choices of materials that can be used. In some circumstances, 3D printing would not be suitable.

Mitigation: 3D printing technology is continuously advancing, and new materials can be used such as metals. Similarly, energy consumption is being reduced. To cope with the increased energy demand, operators should develop a sustainability plan that outlines their solutions to minimise energy consumption and managing demand. For example, a dedicated energy source (e.g. solar) could be implemented to power the 3D printer and reduce its effect on the energy grid.

Social risk

Risk: By introducing 3D printing, the technology will minimize the need for workers to produce components. This could lead to a need to transition workers to complete different tasks.

Mitigation: Employees should be retrained to work with the 3D printer and perform services/maintenance on the equipment or redeployed to other activities. Improved production capacity from 3D printing can be used to increase output.

Safety and (Cyber)security risk

Risk: 3D printing is based on a computer-based system. There is, therefore, a risk that data could be hacked as a result of cybercrime or sabotage. Designs could be altered which would present a risk if undiscovered, as the parts could be installed into an asset and potentially cause accident or injury.

Mitigation: Organizations must ensure their systems are robust to eliminate the threat of cybersecurity. Furthermore, governments should set legislative frameworks to outline the requirements of these systems to repel cybersecurity attacks and protect data.

Environmental risk

Risk: 3D printers consume large amount of energy when melting plastic or other materials with heat or lasers. They can potentially generate toxic emissions and carcinogenic particles according to research at the Illinois Institute of Technology[6]. This could pose a risk to workers and the surrounding community and environment.

Mitigation: Appropriate measures should be taken to protect workers from these fumes, and ensure they are not allowed to be released into the environment. 3D printing should be performed in a dedicated on-site location, with ventilation and air purifying systems installed. Workers should be required to wear appropriate personal protective equipment to reduce their risk.

[6] "Emissions of Ultrafine Particles and Volatile Organic Compounds from Commercially Available Desktop Three-Dimensional Printers with Multiple Filaments", Illinois Institute of Technology, Accessed 8 May 2020

EXAMPLES

Example	Implementation	Cost	Timeframe
Stratasys' Rail Industry Solution	3D printers used to produce spare parts for trains. The company has established partnerships with Angel Trains, Bombardier Transportation, Chiltern Railways, Siemens Mobility and DB ESG, who have found additive manufacturing to be an ideal solution for producing spare parts for trains on demand.	According to Stratasys an operator can spend €18,000 every day a train is out of service. Often, it is a part worth less than €100 that is the cause of disruptions. 3D on-demand printing can minimize the time that train is out of service.	3D printing can reduce the time to obtain a spare part by up to 95%.
Deutsche Bahn	Deutsche Bahn (DB) is primarily using 3D printing for maintenance purposes and has printed more than 6,000 parts covering 110 different use functions for its range of high-speed trains.	In one example, DB printed replacement tube fixtures for display lights used in the train's electronic onboard information system. The project took one month with total manufacturing costs 80% lower than traditional injection moulding.	In September 2016 the company founded the Mobility goes Additive network to facilitate collaboration between companies, institutions, and researchers involved in the 3D printing and mobility space.
Chiltern Railways	The cross-industry collaboration between Angel Trains, DB ESG and Stratasys who have partnered to 3D print replacement parts for trains.	The lead time for armrests using conventional manufacturing methods is four months. Using 3D printing, the armrest can be manufactured within a week, decreasing the lead time by 94%, with possible savings of up to 50% per part.	First announced in December 2018. Trials began in September 2019.