Automating Fab Cities: 3D Printing and Urban Renewal

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Abstract  Building upon past work on 3D printing, intellectual property and regulation, this chapter considers the opportunities and challenges of 3D printing in urban design, planning, and renewal. The development of Fab Cities and Maker Cities intersects with the construction of smart cities. The local circular economy focus of Fab Cities and Maker Cities also has a resonance with the planning of climate-resilient cities. Fab Cities and Maker Cities are also means of addressing the focus on sustainable cities and communities in the United Nations Sustainable Development Goals 2015, and the push to implement the right to adequate housing in terms of human rights. Fab Cities and Maker Cities have also been helpful in providing a networked response to the coronavirus COVID-19 crisis. Section 1 looks at the Fab City Global Initiative—which has emerged out of the Barcelona Fab Lab. It considers the concept of a global network of Fab Cities. Section 2 focuses upon the growth of Maker Cities in the United States. It considers some of the opportunities and challenges in respect of this model. Section 3 examines the ambitious project of the United Arab Emirates to integrate additive manufacturing into its construction industry. Section 4 explores future applications of 3D printing in the context of military logistics; disaster relief; and space missions to the moon and Mars.

Keywords 3D printing · Additive manufacturing · Intellectual property · Innovation · Makerspaces · Fab cities · Smart cities · Maker cities · Urban Design · Urban Planning · Urban renewal

This chapter examines 3D printing within the context of urban renewal and design through the adoption and deployment of the technology in mainstream product and construction applications. Globally, there has been a developing narrative of ‘Fab Cities’, ‘Maker Cities’ and Smart cities that are orientated on the socio-economic benefits of 3D printing in product design and manufacturing as part of the cityscape (Khoshnevis 2012; Davison 2015).
Beyond technical applications of 3D printing technology in the construction process explored in Chapter 5, the technology has clear implications for automating the restoration and reconstruction of cultural heritage. For example, Creative Commons has used large-scale 3D printers to reconstruct architectural works captured in the Free Palmyra Project (Saunders 2017). In the Republic of Trinidad and Tobago, Cintec—an engineering firm based in Wales—used additive manufacturing in the restoration works of the historical governmental building, the Red House (Vialva 2018). The Dutch company Concr3de proposed rebuilding parts of Notre-Dame Cathedral by using 3D scanning and 3D printing (India Block 2019). The company had 3D printed a replacement gargoyle for the building. There has also been debate about the use of 3D printing of Egyptian artefacts in Berlin (Weinberg 2019). However, it remains to be seen whether 3D printing will be used more commonly for cultural heritage projects (Emerging Objects 2020).

Building upon past work on 3D printing, intellectual property and regulation, this chapter considers the opportunities and challenges of 3D printing in urban design, planning, and renewal (Mendis et al. 2019). The development of Fab Cities and Maker Cities intersects with the construction of smart cities (Goldsmith and Crawford 2014; Crawford 2018). The local circular economy focus of Fab Cities and Maker Cities also has a resonance with the planning of climate-resilient cities (Bloomberg and Pope 2018). Fab Cities and Maker Cities are also a means of addressing the focus on sustainable cities and communities in the United Nations Sustainable Development Goals 2015. The development of Fab Cities and Maker Cities may also be a means to implement the right to adequate housing in terms of human rights—especially if 3D printing can be used to develop low-cost, affordable housing (Office of the United Nations High Commissioner for Human Rights 2009).

This chapter explores innovation policies in respect of 3D printing and cities in several contexts. Section 1 deals with the Fab City Global Initiative—which has emerged from the Barcelona Fab Lab and the European Union. It considers the concept of a global network of Fab Cities. Section 2 focuses upon the growth of Maker Cities in the United States. It considers some of the opportunities and challenges with respect to this model. Section 3 examines the ambitious project of the United Arab Emirates to integrate additive manufacturing into its construction industry. Section 4 explores future applications of 3D printing in the context of military logistics; disaster relief; and space missions to the moon and Mars.

1 The Fab City Global Initiative

The director of M.I.T.’s Center for Bits and Atoms Neil Gershenfeld (2005) developed the model of the Fab Lab at M.I.T. in the United States. The Fab Lab—a fabrication laboratory—is designed to be a workshop, which provides access to digital technologies, such as laser cutters, CNC milling machines and 3D printers. The Fab Lab movement has been informed by a philosophy of open source licensing and sharing (Menichinelli 2017). The Fab Lab Movement has grown into a larger global network
of Fab Labs. The Fab Lab model has been particularly popular in the European Union.

In 2014, the Mayor of Barcelona, Xavier Trias, challenged other leaders to develop a new urban model where ‘cities… produce everything they consume locally, while sharing knowledge globally’ (Atlas of the Future, ‘Fab City’). This led to the development of Fab Lab Barcelona, based in the Institute for Advanced Architecture of Catalonia, which has been a key leader in the movement for Fab Lab Cities. Fab Lab Barcelona declares: ‘Our mission as a Fab Lab is to provide access to the tools, the knowledge and the financial means to educate, innovate and invent using technology and digital fabrication to allow anyone to make (almost) anything, and thereby creating opportunities to improve lives and livelihoods around the world.’ Fab Lab Barcelona has produced projects such as the Fab Lab House, and has also been engaged in a Smart City innovation project; the development of the new generation of Fab Labs (including a Food Lab, an Energy Lab, and a Green Fab Lab), and the development of new production models for cities, with the Fab City project being implemented in Barcelona (Atlas of the Future 2020c; Valldaura Lab 2020). This Fab City initiative has led to the development of a global networked system of Fab Cities, regions, and countries—with Barcelona at the hub.

That same year, the City of Barcelona planned a 40-year road map in its progression as a Fab City. The Chief Architect of Barcelona City Council, Vicente Guallart, envisaged the development of a self-sufficient city. In particular, he focused upon the rise of personal manufacturing. Guallart (2014: 89) predicted: ‘In a world where the production of many objects that are used in daily life can happen in our homes or where the production of objects in our buildings, or our city blocks, can take place in a copy shop, the rules of industrial production have completely changed’. The architect suggested: ‘The technology can signify a paradigm shift similar to when the printing press was invented or the steam engine, in that it individualizes the production of objects, and gives the dwelling back the productive character it had in medieval cities, or in the California garages where the computer culture was first born’ (Guallart 2014: 89).

Another leading Fab City is Amsterdam in the Netherlands. Waag—the Amsterdam Fab Lab—has developed a Smart Citizens Lab (Waag 2020). The Smart Citizens Lab ‘explores tools and applications that help make sense of the world around us’. Waag (2020) observes:

In recent years, improved access to open hardware tools and makerspaces, as well as the creation of online data sharing platforms, has made possible the design of low-cost, open-source sensors that citizens can use to measure the environmental health of their neighbourhoods. By collectively measuring and making sense of their environment, citizens become aware of how their lifestyle affects the ecosystem and, hopefully, adopt more sustainable behaviour as a result.

The Fab Lab takes a collaborative approach: ‘We work with citizens, scientists and designers to tackle environmental issues ranging from air and water quality to noise pollution.’

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1Fab Lab House https://www.youtube.com/watch?v=bO-Dvm5OTuU.
The Fab Lab City project has become a global initiative—‘Core to the initiative is a network of cities, regions and countries that have pledged to work towards producing everything they consume by 2054.’ Participating cities include: Barcelona; Zagreb; Thimphu; Shenzhen; Georgia; Curitiba; the Occitanie Region around Toulouse in France; Puebla; Mexico City; Auvergne-Rhône-Alpes; Amsterdam; Cambridge; Kerala; Sacramento; Belo-Horizonte; Ekurhuleni; Brest; Boston; Toulouse; Paris; Santiago; Velsen—a municipality in the Netherlands; Seoul; Oakland; Somerville; Detroit; Kamakura; and Sorocaba. As of July 2019, the Fab City network comprised 34 members (Fab City Global Initiative 2019).

The Fab City Manifesto consists of ten principles ‘to enable the urban transition towards locally productive and globally connected cities’. The adherents to the Fab City Manifesto vow: ‘We embrace strategies in circular economy and digital social innovation, and foster collaboration between a global network of European and worldwide cities and territories to meet the planetary challenges presented by climate change and social inequalities.’

The first principle focuses on ecology—‘We take an integrated approach to environmental stewardship, working towards a zero-emission future while also preserving biodiversity, rebalancing the nutrient cycle, and sustaining natural resources.’ This is very much in keeping with the United Nations SDGs—and its focus on sustainable cities and communities. The second principle looks at inclusion: ‘We promote equitable and inclusive policy co-design, through the development of a Commons Approach, regardless of age, gender, income-levels and capabilities.’ The Commons Approach suggests that there will be a sharing of resources in common—rather than a proprietary approach.

The third principle looks at glocalism: ‘We encourage global knowledge sharing between cities and territories in order to provide access to tools and solutions that could be adapted to local cultures and needs.’ The fourth principle relates to participation: ‘We engage with all stakeholders in decision-making processes and empower citizens to take ownership of innovation and change-making.’ The fifth principle looks at economic growth and employment through ‘investing in building the skills, infrastructure and policy frameworks needed for the twenty-first century.’

The sixth principle looks at local production: ‘We support the efficient and shared use of all local available resources in a circular economy approach, to build a productive and vibrant city.’ The seventh principle is humanistic: ‘We give priority to people and culture over technology, so that the city can become a living and resilient ecosystem’. In this vision, ‘Autonomous vehicles, digital tools, artificial intelligence and robotic machines must be placed at the service of the people’s well-being and expectations.’ The eighth principle calls for a holistic approach to urbanism: ‘We address urban issues in all their dimension and interdependencies to build sustainable, resilient and inclusive cities for everyone.’ The ninth principle consists of an open source philosophy: ‘We foster a Digital Commons Approach that adheres to open source principles and values open data, in order to stimulate innovation and develop shared solutions between cities and territories.’ The tenth principle emphasizes the importance of research, development, and experimentation in respect of ‘low impact supply chains; distributed production; renewable energy and smart grids; sustainable
food and urban agriculture; recycling and reuse of materials, sustainable resource management for energy, food and materials.’

The Fab City Approach involves a full stack approach. The organisation says: ‘From the local to the global, we work across multiple layers of practice and deployment, scaling the FabLab approach to a city and systems level.’ The Global Initiative engages in ‘action research directly in the city by prototyping and deploying strategies across localities in our network.’ The Global Initiative also seeks to build common knowledge: ‘As a global network, we are connected through the knowledge we share across common tools and platforms.’ The Global Initiative also seeks to document and share its findings from prototyping and action-research. This has seen the creation of material such as the Fab City Handbook. The Fab City Network is building a roadmap through action research and experimentation, with a growing network of supporters.

In 2017, Diez (2017) discussed their ambitions to further develop the Fab City Global Initiative. He observed: ‘There is a pressing need to reimagine cities and how they operate in order to respond to the ecological and social challenges of our time’ (Diez 2017). In his mind, ‘Cities hold the potential for the reinvention of the current linear economy paradigm to a Circular Economy, and the Fab City Prototypes project aims to accelerate this paradigm change, allowing consumers to become actors of the design, prototyping and production processes at the local scale, while sharing knowledge globally’ (Diez 2017). Diez hoped: ‘Linking micro-enterprise and citizen-led spaces with corporate and government sectors will create an ideal test ground to develop and implement approaches for an inclusive and impactful Circular Economy’ (Diez 2017). Areas of experimentation would include fashion and textiles; furniture and household products; food; and mobility. Diez suggested: ‘The ambition is to pave the way for locally productive and globally connected cities that foster social cohesion and well-being’ (Diez 2017).

Diez enumerated a number of impacts of the Fab Lab Global Initiative. The project will ‘support the use of existing platforms and experience coming from the consortium partners in open source and commons-based products, supply chain transparency, re-pair and re-use for life extension’ (Diez 2017). The project would also enable the development of new approaches to product and service design. Diez argued that the Global Initiative would reduce the supply chain length through ‘[r]elocalisation of production using novel technologies like 3D printing (TRL9), [creating] a new demand for local materials and supplies, which increases the potential of reusing and repairing products’ (Diez 2017). The project would facilitate the inclusion of resource and materials criteria in designing products and services. The Fab Lab Global Initiative would demonstrate economic, social, cultural, and environmental sustainability. Diez suggested that the project would help implement the SDGs—particularly the development of sustainable cities and communities under SDG 11.

Diez and Posada (2013) contend: ‘The provision of tools for citizens to reinvent their cities could change the dependency of technology, and furthermore develop a closer relationship between humans and machines, working together for a common purpose.’ Tomas Diez says that the Fab City Global Initiative involve: ‘thousands of
people... making the transition from an ‘extractive’ economy to a ‘generative’ one, by giving communities access to the means of production’ (Atlas of the Future, ‘Fab CIY Cities of Tomorrow’). Diez stresses: ‘This is not based on individual heroism, but a global collaboration’ (Atlas of the Future, ‘Fab CIY Cities of Tomorrow’). He is interested in ‘dismounting the current economic and political model.’ (Atlas of the Future, ‘Fab CIY Cities of Tomorrow’).

Diez suggests that the Fab City Global Initiative will help support sustainable development: ‘Our approach is closely linked to the notion of circular economy, in the sense that we aim to shorten and localize production loops’ (Shareable 2017). He suggests: ‘With the right infrastructure and knowledge we could reduce the amount of material that a city imports and rescale globalization’ (Shareable 2017). In such a vision of the Fab City, companies would be able to ‘create social value and not only profit’ (Shareable 2017).

In 2018, Diez published an edited collection on the topic of the Fab City (Diez 2018). As part of the collection, Neil Gershenfeld—the developer of the Fab Lab model at M.I.T.—observed that he considered ‘the Fab City project to be one of the most important (and unexpected) realizations of the promise of Fab Labs’ (Gershenfeld 2018: 7). He reflects upon the growth of the Fab City Model:

Smart cities are instrumented to provide services more efficiently; a Fab City looks beyond even further, aiming to cross the boundary from digital to physical. This could start with making furniture, say, then progress to building wireless data networks, and then aquaponics systems to grow food. All of these things exist as Fab Lab projects in prototype form today; what remains is to propagate them at scale (Gershenfeld 2018: 7).

Gershenfeld reflects upon the expansion of the Fab City project: ‘Pressing the button is the easy part for each of the participating cities; as the countdown continues the bar (and opportunity) is raised for them’ (Gershenfeld 2018: 7).

In March 2019, Sylvie Albert (a Professor from the University of Winnipeg) and Tomas Diez considered the future implications of 3D printing for urban design: ‘The Fabrication City concept puts manufacturing back in the hands of communities—using 3D printers’ (Albert and Diez 2019). The pair argued that fab cities ‘could have far-reaching implications for economic development, environmental sustainability, inclusion and other benefits.’ The researchers contended: ‘Just as the digital economy is making platforms available for anyone to sell globally, new technologies such as additive manufacturing are allowing us to rethink where and how we make things.’ The writers foresee that fab cities will part of a local manufacturing revolution: ‘This manufacturing revolution will have substantial implications, providing cities and local entrepreneurs with the opportunity to mass customize and produce for just-in-time delivery.’ Albert and Diez (2019) suggested that this will be an opportunity to rethink local production:

Imagine cities equipped with flexible factories using local supply chains and locally sourced materials. These fabrication sites use waste materials, disassembled components and other sources to manufacture products digitally and customised for citizens. From prosthetic limbs to plastic waste used to create seating in city parks, to yes, a fridge, there are an increasing number of products being manufactured by local entrepreneurs.
Albert and Diez (2019) contend that Fab Cities ‘create a unique ecosystem that attracts innovative people and organisations, which allows cities to diversify and offer an unparalleled quality of life’. They concluded: ‘Fabrication cities are a powerful game changer in the way that we make and dispose of everything we consume’ (Albert and Diez 2019). Albert (2019) has edited a further book on sustainable cities.

In 2020, a number of the Fab Cities were involved in seeking to develop innovative solutions to fight the outbreak of the coronavirus COVID-19. Armstrong (2020) explains that Fab Labs and Fab Cities have participated in the European Commission hackathon, #EUvsVirus. Mariya Gabriel—the European Commissioner for Innovation, Research, Culture, Education, and Youth—was the patron of the hackathon. She emphasized: ‘When times get tough, we come together, work together and we will beat this virus together for everyone’ (Armstrong 2020). The Fab City Foundation members acted as mentors for the event, providing feedback for participants in the fields of Design, Social Cohesion and Business Continuity: Value Chains & Logistics. The public health epidemic has certainly reinforced the need for local making and manufacturing.

2 Maker Cities

In the United States, the Obama Administration was a champion of 3D printing and additive manufacturing as a means of supporting education, training, innovation and manufacturing. At the White House Maker Faire, President Obama (2014) discussed his plans to transform American cities into sites of advanced manufacturing:

We announced new steps that we’re taking to help entrepreneurs turn their ideas into products. More than 90 mayors made commitments to help entrepreneurs manufacture new things in their communities, and we’re proud to have some of those mayors here today. So we’re going to do whatever we can to bring good manufacturing jobs back to our shores, because our parents and our grandparents created the world’s largest economy and strongest middle class not by buying stuff, but by building stuff – by making stuff, by tinkering and inventing and building; by making and selling things first in a growing national market and then in an international market – stuff “Made in America.”

Obama recalled a Golden Age of American manufacturing: ‘This is a country that imagined a railroad connecting a continent, imagined electricity powering our cities and towns, imagined skyscrapers reaching into the heavens, and an Internet that brings us closer together.’ He hoped that there would be a new era of innovation in the United States: ‘And I hope every company, every college, every community, every citizen joins us as we lift up makers and builders and doers across the country.’

One of the key initiatives of the Obama Administration was to establish America Makes in 2012—a private–public partnership, which was designed to assist and accelerate the research, development, and dissemination of 3D printing and additive
manufacturing.\textsuperscript{2} America Makes is based in Youngstown, Ohio—an old manufacturing hub in the United States. America Makes is the flagship institute of Manufacturing USA, and is run by the National Center for Defense Manufacturing and Machining. America Makes has since established three satellite centres—with the Texas A&M Engineering Experiment Station, the National Institute for Aviation Research at Wichita State University, and the University of Texas at El Paso.

As well as establishing the innovation hub of America Makes, the Obama Administration promoted the idea of Maker Cities. In 2014, the White House encouraged Mayors from around the country to join the Mayors Maker Challenge. Kalil et al. (2014) commented that Mayors could play a key role in bolstering the Maker Movement:

The Maker Movement has already changed the landscape of American manufacturing in small towns and big cities, offering a uniquely American path to revitalizing our manufacturing sector. This transformation has the potential to unleash new opportunities for entrepreneurs looking to make the next world-changing product, students interested in hands-on engagement with Science, Technology, Engineering, and Math (‘STEM’), and companies hoping to manufacture their products with American workers passionate about the latest manufacturing technologies.

The White House envisaged that cities could get involved by ‘Hosting Maker Faires and Mini-Maker Faires’; ‘Fostering local maker ecosystems’; ‘Supporting maker spaces’; ‘Encouraging accelerators’; Supporting women and under-served communities in Making’, and ‘Helping schools integrate Making into their STEM curriculum’ (Kalil et al. 2014). The event-based, franchised Maker Faire model has been a key part of the Maker Movement in the United States.

The Mayors Maker Challenge asked cities to build on this work by committing to action, including spurring ‘local partnerships and catalyze public and private commitments to strengthen the local Maker Movement’. By 2016, there had been over 100 Mayors who had taken the Mayors Maker Challenge because of its potential to foster economic development, job creation, and entrepreneurship in advanced manufacturing and hardware (Kalil 2016). Many of the cities participated in the Urban Manufacturing Alliance.

In his book \textit{Makers}, Anderson (2012) envisaged that 3D printing and additive manufacturing could spark a reinvention of factories, and a process of urban renewal, particularly in depressed old manufacturing regions of the United States. Similarly, Peter Hirshberg, Dale Dougherty and Marcia Kadanoff have written about the role of 3D printing and the Maker Movement in reinventing American cities (Hirshberg et al. 2016). This book contends that an open innovation ethos can be helpful in promoting urban renewal and open innovation: ‘Maker Cities embrace not just the Maker movement but also the Open Innovation, the idea that the best solutions… must be created through collaboration and engagement that looks outside for answers and examples of what to do to affect change’ (Hirshberg et al. 2016: 13).

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\textsuperscript{2}America Makes, https://www.americamakes.us/.
Hirshberg et al. (2016: 41) considered the relationship of the maker movement to cities, envisaging the Maker City as a ‘dynamic, open ecosystem of resources that spur economic and cultural growth through collaboration and innovation’.

There is an exploration of the role of Maker Cities in fostering education and learning. President Obama (2014) was especially interested in the role of schools in maker education, saying: ‘We’re helping schools take shop class into the twenty-first century, because one of the things I’m really interested in is how do we redesign high schools so that young people are able to do stuff as they are learning.’ He was interested in not only reviving old manufacturing cities, but education across the country: ‘And that’s not just true for schools in inner-city Philadelphia, that’s true for schools generally, in part because it also then gives new opportunities for young people who may have different learning styles to thrive in ways that they might not if they’re just sitting there listening to a lecture.’ There is also a keen interest in the role of Maker Cities in workforce development—providing for training, jobs, and lifelong learning.

Hirshberg et al. (2016: 129) also considered advanced manufacturing and the supply chain, arguing that 3D printing and related technologies enable ‘small firms to produce high quality, high value products and take advantage of emerging local and increasingly distributed supply chains’. They suggested that ‘along the way, industries such as fashion, furniture manufacturing, textile production, and even electronics are being reclaimed and reimagined in the Maker City’. They insisted: ‘Local economies in particular stand to gain from new forms of goods that are not mass-produced but instead made locally, in relatively small batches, often with advanced materials and customized to better fit what people truly want and need’ (Hirshberg et al. 2016: 128).

There is a focus upon the development of the Urban Manufacturing Alliance, with Executive Director Lee Wellington explaining the impetus for the initiative:

There was a realization that we would be stronger in numbers if we wanted to see any global initiatives or any policies local manufacturing. There are so many cities doing disparate research projects and the methodology is so different in each one. What we want to become is a clearinghouse of all of these ideas in the Maker Movement (Hirshberg et al. 2016: 163).

The Urban Manufacturing Alliance has promoted local branding and marketing to assist local manufacturing. The organisation has supported accelerators for early-stage maker start-ups. The organisation has also considered land use in real estate markets. The organisation has encouraged new strategies for youth. The Urban Manufacturing Alliance has also been focused upon supporting equity, inclusion, and diversity in new maker communities.

In the collection, there is a consideration of real estate matters. The book observes that there is a need to consider urban planning for makerspaces:

Co-working spaces. Innovation centres. Makerspaces. These forms of real estate are not only relatively new, they are startlingly different than past expressions of commercial real estate. Each is designed to break down barriers between people, build a sense of community, embrace technology, and encourage experimentation and the creation of new forms of economic value inside our cities. What kind of space will best service the Maker and innovation economy is suddenly an important topic in urban planning (Hirshberg et al. 2016: 175).
Further consideration is articulated through case studies such as the Brooklyn Navy Yard, Manufacture NY, the Chicago 1871 Project, and a larger analysis of a maker metropolis. There is also an exploration of civic engagement Wasielewski (2018) has raised concerns about the gentrification of Brooklyn—and how the technology industry has infiltrated urban spaces and artistic practices. As Applin (2019) has noted, the cost of real estate can be a significant barrier to sustaining makerspaces in urban sites.

Finally, Hirshberg, Dougherty and Kadanoff consider that the future of the Maker City will support a vision of Open Cities:

Each urban challenge we face can’t be solved by any one stakeholder. But the promise of Open Cities is that we can enlist each other. Together we can untangle the knotty problems that ensnare communities and cities. The future is within reach… The map… highlights the technology catalysts Makers are using to accelerate their strategies (Hirshberg et al. 2016: 242).

They conclude: ‘Our hope is that we can help you reimagine your city or any city as an Open City and think about ways to bring the future forward’.

Mark Hatch—former CEO and a co-founder of TechShop (now defunct)—has also been a champion of Maker Cities. In his book, The Maker Revolution, Hatch emphasizes that cities should be a part of the maker movement:

We need to think about a maker ecosystem, not just a single space. The ecosystem will include the city, library, museums, corporations, schools, and independent makerspaces. There will be after-school programs, fast retraining, job access, art festivals, trade programs, and funding to kick-start makerspaces across the city. These should then be integrated into the junior colleges and universities in the city (Hatch 2018: 139–140).

Hatch warns against universities building a makerspace and walling it from the rest of the city. He recommends that cities ‘work with developers, give them the density they want in exchange for creating permanent light maker zones and light industrial buildings or art zones’ (Hatch 2018: 140).

TechShop—which Mark Hatch led for a while—ran commercial makerspaces in a number of cities in the United States—including Allen Park, MI; Arlington, VA; Chandler, AZ; Pittsburgh, PA; Redwood City, CA; Round Rock, TX; San Jose, CA; San Francisco, CA; St Louis, MO, and Brooklyn, NYC. The United States network of TechShop closed down as a result of bankruptcy (Woods 2017). This collapse has raised issues about the viability of commercial makerspaces. A number of International TechShops in Japan, France, and UAE still remain open.

There is a further question of community acceptance of such models of urban planning and design. Rundle (2014) queries if there would be widespread public acceptance of Maker cities. He commented: ‘Though there may well be a substantial role for 3D printing of basic structures at the scenes of natural disasters, few people are likely to want to live in an entirely 3D-printed Building (though doubtless they will eventually become hipster chic) (Rundle 2014: 65). He suggests: ‘Most likely, the majority of people would combine a degree of 3D printing with hands-on fashioning of individual living spaces’ (Rundle 2014: 65).
Despite early experimentation with civic hacking of urban administration under the maker movement (Currie 2019), there has nonetheless been political criticism of the movement. Morozov (2014) has argued that the Maker Movement’s revolutionary potential has been compromised and co-opted by its proximity to political and commercial power.

There is an overpowering emphasis upon the role of Maker Cities in respect of economic innovation in much of the United States discourse. However, the United States discussion of the Maker City model does not necessarily give much prominence to the SDGs. There is little discussion of the right to adequate housing as a human right in the debate over the Maker City in the United States—despite affordability of housing, skyrocketing of rents, and homelessness being key issues.

Moreover, in spite of the enthusiasm of its advocates and proponents, the Maker City model has faced economic challenges. As Applin (2019) has observed, the growth of cities, and the rise in real estate rents, has made it more expensive to operate makerspaces. As discussed, TechShop in the United States has closed down, because of bankruptcy. Maker Media—which ran Make Magazine—and the US-based Maker Faires in New York and San Francisco have both collapsed. Despite these developments, there has been an effort by Dale Dougherty to revive the venture on a not-profit model (Constine 2019). However, such failures do raise questions about the economic foundation of the Maker City model.

The public health epidemic of the coronavirus COVID-19 has led to a reconsideration of the role of Maker Cities. Dougherty and Hwang (2020) have observed: ‘In the face of COVID-19, shortages of medical equipment, such as ventilators for patients, and protective gear for personnel in hospitals are becoming a critical problem.’ They noted that Plan A involved Federal Government production of equipment, and Part B included America’s private industry. Dougherty and Hwang (2020) argued: ‘The Maker Movement might provide a “Plan C” for America and the world.’ They observed that ‘groups of independent makers, entrepreneurs and innovators’ are ‘excited by the prospect of creating open designs and rapidly producing ventilators in makerspaces.’

3 The 3D Printed City

The United Arab Emirates has developed a 3D Printing Strategy (Dubai 3D Printing Strategy) that focuses upon the construction sector; consumer products; and medical products:

In 2025, based on Dubai Municipality’s regulations, every new building in Dubai will be 25% 3D printed; this move will start from 2019, starting at 2% with a gradual increase to the strategic goal. Dubai Health Authority has committed to regulating and setting the standards to the use of the technology in the health sector, and will explore the use of 3D printed prosthetic limbs, 3D printed teeth, and 3D printed hearing aids in public clinics and hospitals (Dubai 3D Printing Strategy).
In the field of construction, the Dubai 3D Printing Strategy plans to focus on lighting products, bases and foundations, construction joints, facilities and parks, buildings for humanitarian causes and mobile homes and hopes that 3D printing technology will cut construction costs by 50–70%, and labour costs by 50–80% (Dubai Future Foundation 2016). The Dubai 3D Printing Strategy was also hopeful that the technology would reduce waste produced in construction operations by up to 60%, which will reflect positively on the economic returns of the sector and contribute to sustainable development (Dubai Future Foundation 2016).

In 2018, the Dubai-based Immensa Technology Labs filed the UAE’s first patent relating to the use of 3D printing in construction (Wadlow 2018). The application relates to a reusable mould that permits the casting of concrete, cement and gypsum materials in numerous forms. Engineer Edem Dugenboo explained the invention:

> We came upon the process for this mould while working on various projects related to concrete casting. After facing many challenges, we utilised a unique process that comprised a number of different elements and individual processes to come up with a full and effective solution using 3D printers (Wadlow 2018).

Elias El Dik of Immensa observed: ‘We will continue to invest resources in developing further applications for 3D printing in the construction sector’ (Wadlow 2018). He commented: ‘Immensa works closely with its partners on construction-related R&D projects, and we believe there are many applicable uses for 3D printing in the sector’ (Wadlow 2018).

In 2019, Immensa reflected upon the impact of 3D printing upon the construction industry (AlShawwa 2019). The company considered the activity in the United Arab Emirates:

> In Dubai, there are five concrete 3D Printers as of today, of which at least two of those systems use gantry based process while the others are using robotic extrusion process… Other projects implemented in Dubai such as the 3D Printed office and the 3D Printed DEWA Lab, as well as the 3D Printed house project in Riyadh, should be viewed as R&D projects in which the learning achieved was very important (AlShawwa 2019).

Nonetheless, the company was of the view that the technology was still at an early stage, saying that ‘the construction industry is still at least 2 years away from being able to build commercially viable 3D Printed buildings’ (AlShawwa 2019). The company was conscious of regulatory challenges: ‘Although Dubai is a global leader in pushing 3D Printing in Construction, and there is an extremely active push by various Dubai authorities on incorporating 3D Printing in the UAE’s building regulation, the process takes time’ (AlShawwa 2019). The company also stressed that there were technology limitations—particularly with the composition of concrete.

In October 2019, Dubai unveiled a 3D printed two storey building, which was compliant with local building codes and regulations (Webster 2019). Dawoud Al Hajri—Dubai Municipality director general—said that the project was a major turning point for the construction sector: ‘3D printing technologies in construction will increase the speed of execution and [lead to the] completion of buildings in record time.’ He hoped that 3D printing would be an efficient technology in the housing and construction industry: ‘This will reduce construction costs and contribute to
the development of solutions to demographic challenges by reducing the number of
construction workers.’

There is a strong focus upon the economic aspects of 3D printing cities in the
United Arab Emirates. However, there is a lack of engagement about the connection
between 3D printing and the SDGs and the right to adequate housing as a human
right thus far.

The United Arab Emirates (2020) has established a portal on the SDGs. There
is a Masdar City Green Initiative, which is designed to boost sustainable cities and
communities. This is focused on innovation with clean technologies and renewable
energy. There is also a project focused on developing an international humanitarian
city.

It remains to be seen whether these utopian plans for 3D printing construction are
realised on a large scale in the United Arab Emirates.

4 Beyond Fab Cities: Military Logistics, Emergency
Deployment, and the Final Frontier of Space

In addition to civilian uses of 3D printing, there has been military interest in the use
of 3D printing to build temporary structures and housing.

Potential military applications of 3D printing arise from its unique construction
methodology. Indeed, the United States Army has obtained a patent in respect of
a ‘printable concrete composition’ (Al-Chaar et al. 2016). The United States Army
explains: ‘This invention relates to the field of concrete building material and more
specifically to a concrete building material adapted for use in 3D printing’ (Al-Chaar
et al. 2016). The abstract gives a sense of the nature of the patent application: ‘A
printable concrete composition is made from the combination of a solid mix, water,
and various liquid admixtures’ (Al-Chaar et al. 2016).

The patent claims relate to variations of a ‘printable concrete composition.’ The
patent application contains the stipulation: ‘The invention described herein was made
by an employee of the United States Government and may be manufactured and
used by the Government of the United States of America for governmental purposes
without the payment of any royalties thereon or therefore’ (Al-Chaar et al. 2016).
In September 2018, the United States Army tested the technology, and 3D printed
an army barracks in two days (Aouf 2018). Captain Matthew Friedell, a project
officer from the Marine Corps System Command additive manufacturing team, said:
‘This is the first-in-the-world on-site continuous concrete print’ (Aouf 2018). He
commented:

In 2016, the commandant said robots should be doing everything that is dull, dangerous
and dirty, and a construction site on the battlefield is all of those things. In active or
simulated combat environments, we don’t want marines out there swinging hammers and
holding plywood up. Having a concrete printer that can make buildings on demand is a huge
advantage for Marines operating down range (Aouf 2018).
Friedell said the technology could also advantage communities when the military was engaged in humanitarian missions in respect of aid—especially for disaster relief. In 3DPrint.com, Saunders (2017) reflected: ‘This technology could also be very useful in 3D printing office buildings and homes, along with emergency housing shelters.’ As part of its technology transfer program, the United States Government has been willing to license the patent—and a couple of related patents—to business (Federal Labs 2018).

In the wake of Hurricane Katrina in New Orleans, and the Haiti earthquake, there has been an interest in the development of digital fabrication to create emergency shelters in the event of a disaster (Gershenfeld et al. 2017: 35). MSF have set up a 3D printing workshop in a refugee camp in Jordan in order to provide health services (MSF 2018). There has been a variety of efforts to use 3D Printing in the face of the public health emergency in respect of the coronavirus COVID-19 (Petch 2020). A number of Fab Labs, makerspaces, and 3D printing hubs have sought to engage in local manufacturing in the public health emergency (FDA 2020). There has been a particular focus on developing personal protective equipment, and parts for medical equipment, such as ventilators during the public health crisis. There has also been the development of temporary structures and buildings to cope with the overflow of cases. In the wake of the disruption of supply chains, the pandemic has led a number of nation states and governments to reconsider the importance of local manufacturing, and their over-reliance on distant manufacturing (Sas 2020).

In the future, there will also be an interest in 3D printing structures, buildings, and architecture in space. Indeed, NASA has been holding a competition to build a 3D printed habitat for deep space exploration, including the agency’s journey to Mars (NASA, STMDL Centennial Challenges). NASA has used a Prize model to encourage competition (NASA and Bradley University 2019). The challenge has had three phases. Phase 1 was a Design Competition; phase 2 was a Structural Member Competition; and Phase 3 was an On-Site Habitat Competition. In July 2018, NASA and its partner Bradley University selected five teams to share a $100,000 prize in a stage of the agency’s 3D-Printed Habitat Centennial Challenge. Monsi Roman, program manager for NASA’s Centennial Challenges, commented: ‘They are not just designing structures, they are designing habitats that will allow our space explorers to live and work on other planets’ (NASA 2018). Lex Akers, Dean of the Caterpillar College of Engineering and Technology at Bradley University, said: ‘We are encouraging a wide range of people to come up with innovative designs for how they envision a habitat on Mars’ (NASA 2018). He commented: ‘The virtual levels allow teams from high schools, universities and businesses that might not have access to large 3D printers to still be a part of the competition because they can team up with those who do have access to such machinery for the final level of the competition’ (NASA 2018). It will be interesting to see whether there was any spin-off intellectual property from NASA’s 3D printing prize competitions (Margolis and Intagliata 2019). Much like the United States, China has also revealed plans to 3D print houses on the Moon’s surface (Vialva 2019).

There will also no doubt be commercial activity in respect of the use of 3D printing in space (Fernholz 2018; Davenport 2018).
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