THE GREAT 3D PRINTING DELUSION: ARCHITECTURE'S MOST OVERBLOWN PROMISE OR ACTUALLY SOMETHING THAT MAKES OUR LIVES BETTER?

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> They said 3D printing would allow for bold, curving designs. So why does every printed building look like a lumpy sandcastle? *Zaha Hadid, 2016*

If there's a more perfect encapsulation of architecture's 3D printing fantasy versus its grim reality than Hadid's observation, I haven't found it in my two decades of research. What began as a genuinely revolutionary manufacturing technology has devolved into architecture's equivalent of crypto-currency: a solution desperately searching for a problem, championed by zealots who mistake technical capability for architectural merit.

Twenty years ago, when I first encountered 3D printing through an article in a technical journal, it represented something truly revolutionary. For the first time in manufacturing history, we could create objects based purely on their intended function rather than being constrained by traditional manufacturing limitations. No longer did we need to worry about how a drill bit could reach a particular spot or how to assemble complex geometries. We could print a perfect sphere inside a sealed cube, create cooling channels that follow close to the surface of metal injection molds or design components that would be impossible to manufacture any other way.

This was, and remains, revolutionary — in its proper context. But architecture, with its perpetual addiction to the

next big thing, couldn't resist the siren call of scaling up this technology to building-sized proportions, consequences (and physics) be damned.

The early days were intoxicating. I remember when the first architectural-scale 3D printer appeared in the Netherlands with a build volume of around 2x2x3 meters, so big enough to create parts you could stand in. I watched as our profession lost its collective mind. Back then, I was working with an 80,000 Euro machine that could easily print architectural models and Christmas decorations that have to be distanced to the Christmas tree candles because the plastic material was not fire proof, yet suddenly everyone was talking about printing entire houses, as if scaling up a technology designed for precise, small-scale manufacturing to building-sized proportions was as simple as adjusting a few settings.

This technological infatuation reached its apex in my university teaching. Just last semester, I had a student propose a world where everything — from toothbrushes to entire buildings - would be printed on demand and immediately recycled after use. Of course, a bed is just a waste of material if its unused over day and could already become the toilet after breakfast ...When I asked about the catastrophic energy implications, she looked at me as if I was the one who didn't understand the future. In architecture schools today, "It'll be 3D printed" has become the equivalent of "a wizard did it" — a magical solution that absolves students from having to think through real construction challenges.

But let's talk about what happened when we tried to scale up 3D printing to architectural proportions. Instead of Zaha Hadid's bold, curving designs, we got what I call the Concrete Spaghetti Monster aesthetic — building after building featuring the same dreary, layered appearance, like someone left a giant Play-Doh extruder running overnight. These structures don't evoke the future; they evoke poorly executed ceramics projects writ large and of course the creators evolved quickly — the printing mishabs became the handwriting of the machine and shows creativity as an artist by itself would have.

The problem isn't just aesthetic, though that's bad enough. In my years of teaching architectural engineering, I've always emphasized how traditional architecture benefits from what builders call "happy accidents" — those small imperfections and on-site adjustments that often lead to creative solutions and unexpected beauty. Not to forget following our so beloved design by experiment method, where you look for gold and invent porcelain...

With 3D printing, there are no happy accidents. There are just accidents, period. And they usually manifest as walls that look like melted candle wax or, worse, structural uncertainties that keep my engineering colleagues awake at night. Back then we talked to Khoshnevis with his Contour Crafting technologies who was quickly joined by the concrete supplier and Caterpillar eager to build the biggest machines to print entire neighborhoods 24/7... horizontal floors still a challenge, and the Chinese shocked the world a year later with concrete printed elements lying flat and flipping upright after the grey paste cured, a true revolution for this who fought gravity. While others were dreaming about printing houses they were doing it, quickly and bold and clever enough to cover their ugly surfaces with a layer of plaster — manually applied — to hide the crime and cover the electric conduits and pipes. Why ? Because the Chinese people do not want to live in these ugly houses, they print houses because its faster, was the answer back then.

Let me give you a concrete example (pun intended). In my office, we have an IKEA bookshelf that costs €49, produced through highly efficient, automated processes refined over decades. When students suggest 3D printing such items, I have to explain — usually multiple times — that this fundamentally misunderstands both the technology's strengths and the basic principles of efficient manufacturing. Yet this is exactly the kind of thinking that pervades architectural discussions about 3D printing.

The famous bookshelf also serves another story I can't help telling here as a little sidenote. While the bookshelf itself could only be offered for such a low price because of its fully automated production where almost no human hand has touched a single piece of wood ever, it's sold because of its low price and not because it's made by robots. When architects use robots to make the worlds first whatever it is for sure announced as the world's first robotically or 3d printed thing. It's not to solve the world but to end up on the cover of the magazine, ok I have to stop here, but did I mention how happy my grandma is with her hearing aids? Made possible with 3d printing, my grandma doesn't know that its made with 3D scanned silicone putty that was formed in her ears and then 3D printed to secure a perfect fit. High-tech in production technology at the disposal of the acoustician lab. She likes it because it is fast and they don't fall out anymore!

What is particularly maddening to me, is how this obsession with printing entire buildings has distracted us from the technology's genuine potential in architecture. In my research environment, we've had remarkable success creating complex nodes for free-form structures and specialized components — areas where 3D printing actually makes sense. Instead, we're busy trying to print entire houses that look like they were squeezed out of a giant pastry bag.

And let's talk about this supposed "building material revolution." In labs all over the world, they have tested countless "innovative materials" for 3D printing, but let's call this what it really is: concrete with a marketing degree. We're still fundamentally dealing with cement-based materials - one of the largest contributors to global CO_2 emissions. I've spent twenty years watching us go from genuine innovation in small-scale manufacturing to essentially creating oversized cement sculptures with questionable longevity.

Figure 1: Scan-milling bookshelf base.

Speaking of longevity, there's a darkly comic aspect to how we're approaching these experimental structures. In project meetings, when I ask about the durability of 3D-printed buildings, I hear phrases like "we think" and "probably" – the kind of confidence-inspiring language that makes mortgage lenders reach for their anxiety medication. In my teaching, I emphasize that traditional building materials have centuries of proven performance. 3D-printed structures? We're basically running a giant architectural experiment with people's homes as the test subjects, but that was always a common practice in architecture.

Want to modify your 3D-printed home after it's built? Good luck with that. I've spent years in my research demonstrating how traditional construction methods, despite their supposed limitations, actually offer far more flexibility for future modifications. Your 3D-printed home is essentially a monolithic structure – it's about as adaptable as a concrete submarine.

The facade issue deserves special mention. In my workshops with students, I often compare traditional facades, crafted with intentional texture, depth, and character – the result of centuries of architectural evolution and craftsmanship. I've watched craftsmen, from woodworkers to masons, develop techniques over generations to create buildings that are both functional and beautiful. 3D-printed facades, by contrast, look like abandoned art projects from a giant's pottery class. Each layer is visible, creating a horizontal striping effect that makes buildings look like

topographic maps of particularly uninspiring hills. Honestly I have also seen facades made out of small scaled clay tiles, following a curvature, covered in artisanal glazing that look wonderful, understanding the limitations and used to create an entrance while the rest of the building is covered in regular bricks, so do we learn how to apply it already in a more decent manner ?

And then there's the circular economy myth. In my lectures, I emphasize how automation in construction should serve efficiency, not become a feature in itself. Yet with 3D-printed buildings, we've created structures that are nearly impossible to recycle effectively. Their custom-mixed materials and monolithic construction make them the architectural equivalent of nuclear waste — future generations will have to figure out what to do with our experiments.

The limitations of the technology itself are particularly ironic. In my early research, I was excited about how 3D printing promised freedom from traditional manufacturing constraints. Yet in architectural applications, we've simply traded one set of constraints for another, more limiting set. Architects may dream of fluid forms and gravity-defying structures, but 3D printers have other ideas. I've spent countless hours explaining to enthusiastic students that the reality is far more constrained: basic shapes, limited overhangs, and a constant battle against gravity. As I often tell my classes, "Just because you can 3D print something doesn't mean you should."

So where does this leave us? After two decades of research and experimentation, I've come to a crucial conclusion: technology should be applied where it offers genuine advantages, not simply because it's available. The future of 3D printing in architecture isn't in printing entire cities or in magical on-demand buildings. It's in the careful, considered application of the technology where it makes genuine sense - in those complex nodes for glass facades and roofs, specialized components, and specific applications where traditional manufacturing falls short.

We need to stop treating 3D printing like it's architectural penicillin — a miracle cure for all our construction challenges. Instead, we need to understand it for what it is: a powerful tool with specific applications and significant limitations. After twenty years of working with this technology, my conclusion is clear: the real innovation isn't in printing entire structures but in finding the right applications for the right technologies. Whenever it is easier to drill a hole in a plank of wood, do it — printing an entire plank around the hole with printable wood is not the right answer in saving material.

As I reflect on Zaha Hadid's acidic observation about lumpy sandcastles in the beginning which was put in her mouth by using artificial intelligence, I can't help but think that the real failure isn't in the technology itself, but in our profession's persistent tendency to mistake novelty for innovation. It's time to bring some much-needed sobriety to our discussion of 3D printing in architecture, before we create a legacy of experimental structures that future generations will regard as monuments to our technological hybris.

The choice is ours: We can continue to indulge in technological fantasies, or we can start engaging with 3D printing's real potential in architecture. The former might make for better headlines, but the latter will actually advance our field. And perhaps then we can finally move beyond building lumpy sandcastles and start creating architecture worthy of the technology's genuine promise.

So where do we go from here? First, we need to reset our expectations. 3D printing isn't going to solve all of architecture's challenges, and it's certainly not going to replace traditional construction methods wholesale. Instead, it will find its place as part of our broader toolset, excelling in specific applications while being inappropriate for others.

Second, we need to focus our research and development efforts on applications where the technology's unique capabilities offer genuine advantages. This means moving away from headline-grabbing demonstrations of printing entire buildings and towards more nuanced applications that actually advance the field.

Finally, we need to develop a more sophisticated understanding of when and why to use 3D printing in architecture. This means teaching students not just how to use the technology, but when it's appropriate and — just as importantly — when it isn't.

The future of 3D printing in architecture isn't in printing entire cities or in magical on-demand buildings. It's in the careful, considered application of the technology where it makes genuine sense. Until we accept this reality, we'll continue to chase architectural fantasies while missing opportunities for real innovation.

This essay was created by using AI tools that summarized a lively discussion between Caro Hoogland and Marcel Bilow about the application of 3D printing in architecture, while the 3D printer was humming in the background of the kitchen and creating a cardboard folding tool.