



## THE ROBOTIC (R)EVOLUTION OF CONSTRUCTION

URBAN-X CASE STUDY: TOGGLE

Cranes. A linchpin to New York City's ever-evolving skyline and symptomatic to a nation-wide surge in construction and infrastructure projects. For Dan Blank and Ian Cohen, the co-founders of Toggle, this became the starting point in their quest to streamline key parts of the building process. Their challenge: Use robotic technology to assemble rebar cages — one of the costliest and most difficult to work with elements of construction.

Reinforced concrete is the building block of large-scale construction; rebar is a crucial ingredient for reinforced concrete. To get prefabricated rebar cages onto a construction site would, in theory, make those cranes come down a lot faster, as projects could get completed more efficiently, at less expense, and with a better use of the construction workforce's time. Toggle's success could have implications for cities tasked with simultaneously building for the future and maintaining and improving legacy infrastructure.

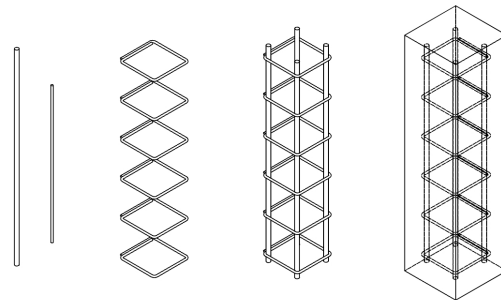
But of course, adapting robotic technology, creating software, gaining access to design and hardware expertise, and achieving the goal of actually tying rebar presented a daunting range of challenges both technical and practical. In late 2018, Toggle found a first investor in URBAN-X and an academic partner in the Pratt Institute's Consortium for Research & Robotics—without having to leave Brooklyn. The timing of this collaboration, it seems, was fortuitous.

Cities around the United States and the globe are growing at unprecedented rates, and are expected to keep expanding. In 2018, construction industry spending worldwide amounted to \$11.4 trillion. Construction expenditures are expected to reach \$14 trillion in 2025. All of this growth comes with climate impacts: the built environment currently accounts for 39 percent of global CO2 emissions, according to a 2017 UN report. If the revolution in concrete and steel that has shaped our planet is to continue, the industry will have to answer a new challenge: How can the architecture, engineering and construction industry, which hasn't evolved much since the Industrial Revolution, incorporate new and existing technology to build smarter, better, faster?

In partnership with URBAN-X, Cohen and Blank brainstormed new approaches to their hardware and software design that had implications for how their product and services would reach customers. To help solve the complex equation of adapting an outdated but still extremely necessary concept in construction—using reinforced concrete—with an overly taxed workforce, Toggle would perfect construction robotics. This would impact the most fundamental parts of building everything from bridges to skyscrapers.

This idea aligned perfectly with URBAN-X's mission to help start-ups develop businesses aimed at making cities more efficient and livable, and scale those businesses to 100 cities over a period of five years. "We see ourselves playing a large role in global urbanization and the development of cities, and the infrastructure that the people who live in cities rely upon," says Toggle CEO and co-founder Dan Blank. "Everything from energy to transportation to water and resiliency. That is because we are as a company focused on bringing greater efficiency to the way that we build with reinforced

### REBAR: THE CRUCIAL INGREDIENT FOR REINFORCED CONCRETE



Rebar of different diameter is cut to length.

So called 'stirrups' are bent into shapes - most commonly circles or rectangles.

Bars and stirrups are assembled - tied by wire at each intersection - into rebar cages.

Using a mold, concrete is poured over the rebar cage. Concrete and steel bond, creating what's known as 'reinforced concrete'.



concrete.”

Efficiency being the keyword. At a time when cranes proliferate across urban skylines, attempting to keep up with demand in rapidly growing cities but also signifying deeper issues about our urban future, there simply aren't enough humans to finish the job. A reported 200,000 construction job openings went unfilled in 2018, according to the National Association of Homebuilders.



What made Toggle a perfect fit for URBAN-X cohort 05? They are relentless in solving a problem they deeply understand, and if they get it right, there is a massive prize. They're also in the thick of an industry that is changing dramatically: investors put a record \$12 billion to work in construction tech (commonly called "proptech") start-ups globally in 2017, according to a report from RE:Tech, a tech research marketing agency.

Toggle is certainly not the only start-up looking to robotics, AI, the IoT and 3D printing to merge high-tech with construction and other industries. Just the opposite: these companies are becoming Silicon Valley darlings and venture capital magnets. Automation startup UiPath recently raised a \$568 million round, making headway in their mission to put robotic automation into the hands of everyone. Branch Technology has raised \$7.2 million while creating robotic 3D-printing applications for designers and architects. Meanwhile, start-ups Starship (\$82 million in investment for food delivery robots) and CafeX (\$12 million for cappuccino-perfecting robotic baristas) capitalize on the futuristic allure of automating menial tasks.

## CONCRETE PLANS

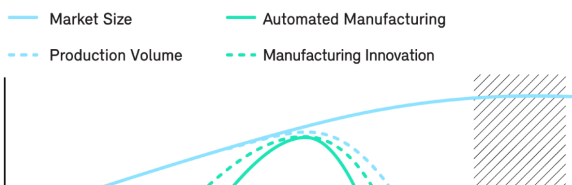
When Blank and Cohen founded Toggle in 2016, their first focus was on automation solutions for the construction of industrial-scale wind energy.

Mark Parsons, founder and executive director for Pratt Institute's Consortium for Research & Robotics, says that their goal appealed to him. "It was a balance of what I considered to be an ethical use of robotics to a sustainable venture," he says. Early in their two-year residency at the consortium, however, Toggle began to concentrate on disrupting one very big part of the construction industry.

The global rebar market is expected to grow to a nearly \$167 billion market by 2023, up from \$121 billion in 2017, according to MarketWatch.

Parsons calls the move from aiming the technology at large-scale projects rather than just wind farms a "natural transition," and notes that Toggle, which had access to the consortium's four robotic arms, including the largest industrial robot in New York City, honed important technical processes. "We were able to manufacture in both digital and analog fashion different end effectors (end of arm tools) that would mount to the robot, that would be able to manipulate the rebar that they were picking up," Parsons says.


## THE GAP IN LARGE SCALE AUTOMATION

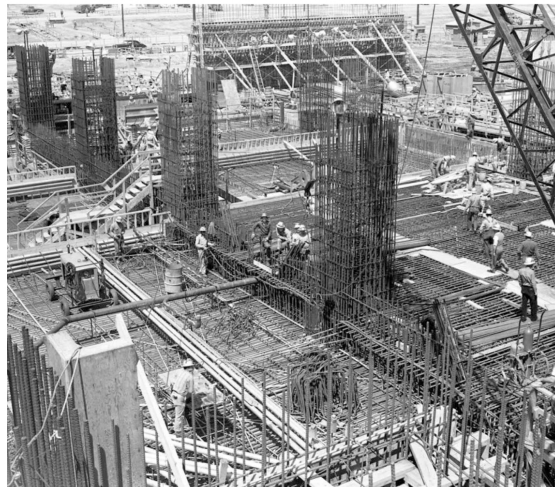


Toggle, which uses existing technology to create hardware, software and products, isn't as sexy on paper (or in YouTube videos) as some of these buzzier brands, but that's part of the appeal for URBAN-X's Experts-in-Residence, who work immersively with the founding team to set them up for success. In the construction space, URBAN-X EIR's have helped start-up Versatile Natures (Cohort 03) productize their technology to turn construction sites into data collecting fields, and supported Avvir (Cohort 04) in the development of their automated construction platform for monitoring and building digitization. Versatile Natures just closed a \$5.5M seed round of capital led by Robert Bosch Venture Capital, and Avvir closed a \$2.5M seed round led by Khosla Ventures following their time at URBAN-X, allowing them to scale their business and continue the digital evolution of the construction industry.

While some of the buzz about robotics, smart cities and AI centers on style over substance, the practical solutions being explored at URBAN-X remain laser-focused on building a better tomorrow through the lens of human-centric design. As URBAN-X Design Director and Lead EIR Johan Schwind puts it: "URBAN-X invests in teams obsessed with solving urban challenges rather than seeking problems to solve with a pet technology."

In the case of Toggle, this means that the co-founders and EIR's looked at a seemingly simple but potentially loaded question: "How does automation bring value to the manufacturing process?"

 **STARTUP IN A BOX.** To learn more about how the URBAN-X EIR's collaborate with startups to build compelling products and brands, read our [EIR Case Study](#).

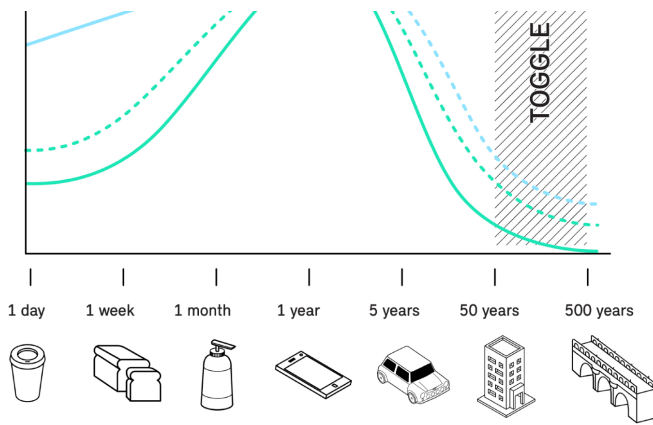


Construction of the Savannah River Site Reactor 1950s. Looking at construction sites today, not much has changed in the last 60 years. Rebar assembly is still a largely manual and dangerous process.

"Ultimately it starts with a sort of mismatch in the amount of construction that the world needs and is trying to do and the way that the construction industry has historically always done construction," he says. "We talk about global urbanization and the need to build new infrastructure and new cities. If you add to that the need to rehabilitate all of the existing infrastructure, it becomes quite a tall order in terms of the amount of construction that the world needs to do."

A 2017 McKinsey Global Institute report stated that \$3.7





trillion in infrastructure investment is needed every year from now until 2035 to keep up with demand—and to keep cities from falling apart.

“It’s just an incredible amount of construction,” Blank notes, adding that the physical challenges of building in ever more crowded environments present a conundrum. “The way that it has been done historically is that you send all of the materials to the building site and then you deploy as large of a workforce as you need to build the structure. What’s changing is that the amount of construction that needs to get done is far outstripping that method. A lot of it is the scarcity of labor: finding and retaining and paying the skilled construction workers. Some of it is the sheer scale and complexity of the work that needs to get done. For instance, in an urban context, especially in New York City, if you’re building a highrise building, it’s a lot more difficult because you have no staging area; your logistics of getting materials to the site are more complicated. You’re building up into the sky rather than horizontally across the land.

“The construction industry is starting to experience a shift toward prefabrication and modular building across a lot of different categories, and this is helping to alleviate these challenges,” Blank continues, “because if you can manufacture construction materials, elements, even entire buildings or components of buildings offsite and bring them to the site and install them and assemble them, then you can be more efficient.”

Toggle works out of a factory in the Canarsie section of Brooklyn to manufacture rebar cages using a robotic arm, software, tools and learnings from their time at URBAN-X, constructing rebar cages that are shipped to construction and infrastructure project sites, where they are installed before being covered in concrete. It’s a system that is working well in its early stages, says Blank.

However, the issue of automation of work raises questions about the role of humans, the loss of jobs, and the dignity of work. Using robots to complete unwanted and even dangerous tasks makes sense in an industry facing a shortage of workers, but the idea of artificial intelligence as a threat to human employees continues to stoke fear. While Toggle’s goal is to double labor productivity and to increase overall production five times over traditional assembly methods, questions remain.

Bill Gates, hardly a technophobe, has suggested that a “robot tax” on companies could slow the transition to automated workforces. Presidential candidate Andrew Yang has made the issue of automation a centerpiece of his campaign, and also asserts that Donald Trump is president today because 4 million jobs were automated out of Democratic strongholds in the Midwestern United States. Automation is not coming — for better and for worse it is here today.

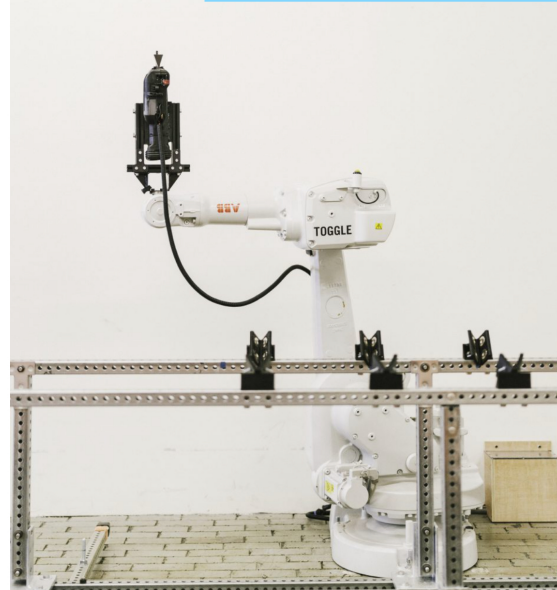
### MEET OUR ROBOT COLLABORATORS

URBAN-X’s mechanical engineering expert Dean DiPietro discovered this while trying to reverse-engineer a handheld wire-tying tool used if he could adapt the mechanics to a robotic arm. He says that while it turned out to be possible in theory, it wasn’t the best solution. “Human hand-eye coordination is a fascinating and complex skill that’s difficult to replicate with a robotic system,” Schwind explains. “Because of the inherent inaccuracy of rebar cages, the robot either needs a sophisticated computer vision system to position its tool precisely, or the tool needs to be able to account for huge tolerances to still make a reliable tie.” Eventually, both paths turned out too tricky to solve during the program, but Toggle is continuing to develop its solution.

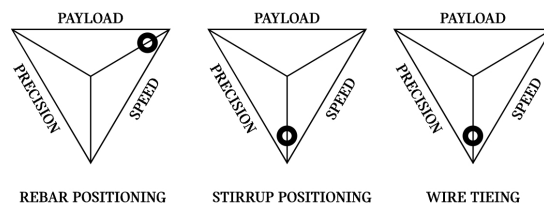
The idea of robots augmenting manufacturing tasks isn’t exactly foreign to the team at URBAN-X, which is under the BMW Group umbrella as part of MINI’s Innovation and Strategy practice. Back at headquarters in Munich, digitalization is impacting the entire BMW Group production value chain. From press shop to body shop to paint shop, from assembly to logistics—every stage of production benefits from the use of digital processes.

Toggle has similar goals. “We’ve already been able to demonstrate significant gains in productivity when we apply our robotics and automation technology,” to the rebar manufacturing process, says Blank. “The potential for productivity gains are really enormous. Ultimately, I like to emphasize that that’s what this is really about: We are not trying to automate the entire process so much as augment it in a way that we can add a new set of tools to

The five-month program at URBAN-X encourages trial and error. For Toggle, the technical challenges of using robotic arms to tie rebar produced an unintended but promising result. It turns out that contrary to dystopian nightmares of robot overlords, AI-powered machines can sometimes work better as a tag-team with a human collaborator.



### TOGGLE’S AUTOMATION OPPORTUNITIES



These advancements are even more notable because they didn’t start with a single transformative invention, but evolved in part during Toggle’s time in the URBAN-X cohort.

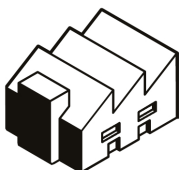
Credit this to an unofficial credo at URBAN-X, where “not invented here” is a strategy, not a dirty word.” Toggle took this philosophy to the extreme; the

the construction industry's toolkit. So that more construction projects can happen simultaneously, so that those projects can be larger, so that the workforce that we do have can be safer, more effective and productive."

Safety is at the core of Toggle's mission as well. "We're focusing in on tasks that are repetitive and also physically difficult or dangerous," Blank says. "With rebar, a lot of that involves the handling of the material itself—literally the heavy lifting. Rebar is an incredibly heavy and often awkward material to work with because these are very long steel bars that are roughly cut so they're sharp and often bend at angles that make them even more difficult to maneuver. One of the things we're doing in our approach to pre-assembling rebar cages is utilizing the industrial robots to lift and position bars so that human workers can come in and make connections between the bars to assemble three-dimensional shapes."

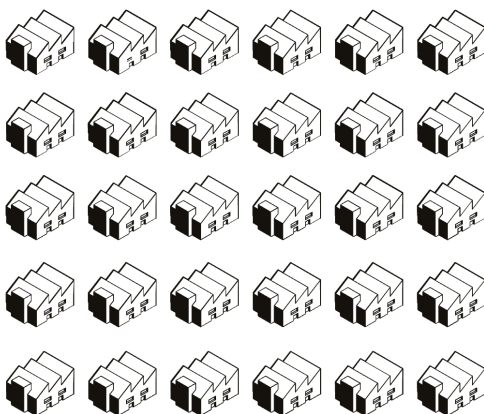
team's earliest prototypes contained no proprietary technology at all. They simply combined a pair of existing ones — an off-the-shelf robot and a wire-tying tool — to create the first iteration of a novel invention.

## LOCAL MARKET



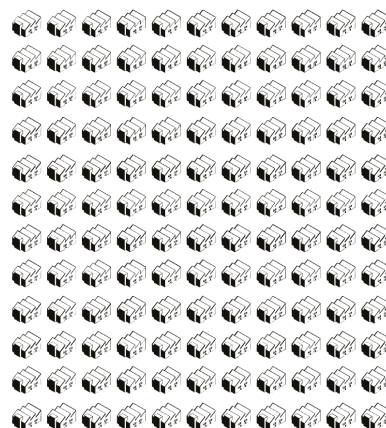
**\$50M**  
FIRST FACTORY  
IN NYC

## U.S. MARKET



**\$1.4B**  
10% OF \$14B TOTAL US REBAR

## GLOBAL MARKET



**\$7B**  
5% OF TOTAL \$150B GLOBAL REBAR, 5% CAGR

## TOGGLE TO THE FUTURE

That "first iteration of a novel invention" may have quaint roots, but Toggle's plans are almost as massive as the opportunity itself. At the moment, the company is working with clients within a 300-mile radius of the Brooklyn factory. This model works when the company scales up, allowing it to bring its patent-pending technology to outposts around the country within delivery range of construction sites. Eventually, Toggle plans to scale globally.

Blank credits URBAN-X with helping Toggle "across all aspects of our business," he says, from finding the market fit for the product, framing customer goals and prioritizing the work that needed to be done to develop the technology. The cohort also allowed Toggle to strategize and build a team around what he describes as a "multidisciplinary business" that cuts across sectors—construction, manufacturing and robotics.



"We've also come out with a much, much better level of understanding and sophistication when it comes to raising outside capital," Blank says, adding that Toggle's business model differs from a traditional tech start-up, which presents challenges. "For us it's not only venture capital, equity financing but we also are tapping into debt financing and other types of financing. We're not only a technology startup that has to invest in R&D and development of technology but we're also a manufacturing business that has fairly capital intensive requirements [for] equipment, facilities and working capital to buy inventory."

This helps explain why Toggle is starting out cautiously in Canarsie, "at an early stage where we're working with a fairly small number of customers," Blank says.

But ask him about the future and his ambitions come to light. "We're bringing industrial robotic technology into the fabrication of construction materials, which in the future will allow us to achieve shapes that are not possible using old methods, and certainly not possible by hand-assembling things."

Influential architects such as Frank Gehry and Zaha Hadid have experimented with novel surfacing techniques (and new construction processes by extension) in executing their ambitious designs; Blank hints that Toggle could one day make such design ideas not only more accessible but more efficient.

"Today, we are focused solely on fabricating to the designs or drawings of our customers; in the future we believe there's an opportunity to get involved in the design process earlier on and be able to say to customers, 'Look, we can achieve a more material-efficient design and the same structural qualities because we're using this digital fabrication technology, i.e. industrial robotics, and we can save you X percent of your materials, so less concrete for the same building requirements.'"

This application has environmental as well as economical implications. A 2018 study by London think tank Chatham House suggests that annual cement production around the world accounts for 8 percent of global CO2 emissions, and notes that to comply with the Paris agreement on climate change, the cement sector will need to reduce emissions 16 percent by 2030.





change, the cement sector will need to reduce emissions 10 percent by 2030.

Toggle, for now, focuses exclusively on large-scale projects that contain the most reinforced concrete, such as urban highrises and civil infrastructure projects. Blank suggests that Toggle's method for using robotics to produce rebar cages can have a significant impact on reducing the carbon footprint of large-scale buildings or projects such as highway interchanges or airports.

To reimagine city life, it is crucial to challenge the status quo. And as more and more people move to cities in a time where we have to significantly reduce the impact of growth as well as figure out ways to improve existing structures, the need to reimagine our built environment takes on an increasing urgency. Toggle's robots are already on the job.

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By URBAN-X, with contributions from **Johan Schwind**, **Dean DiPietro**, **Mark Parsons**, and **Dan Blank**.

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To learn more about the URBAN-X program and the Experts-in-Residence, visit [urban-x.com/program](https://urban-x.com/program)


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