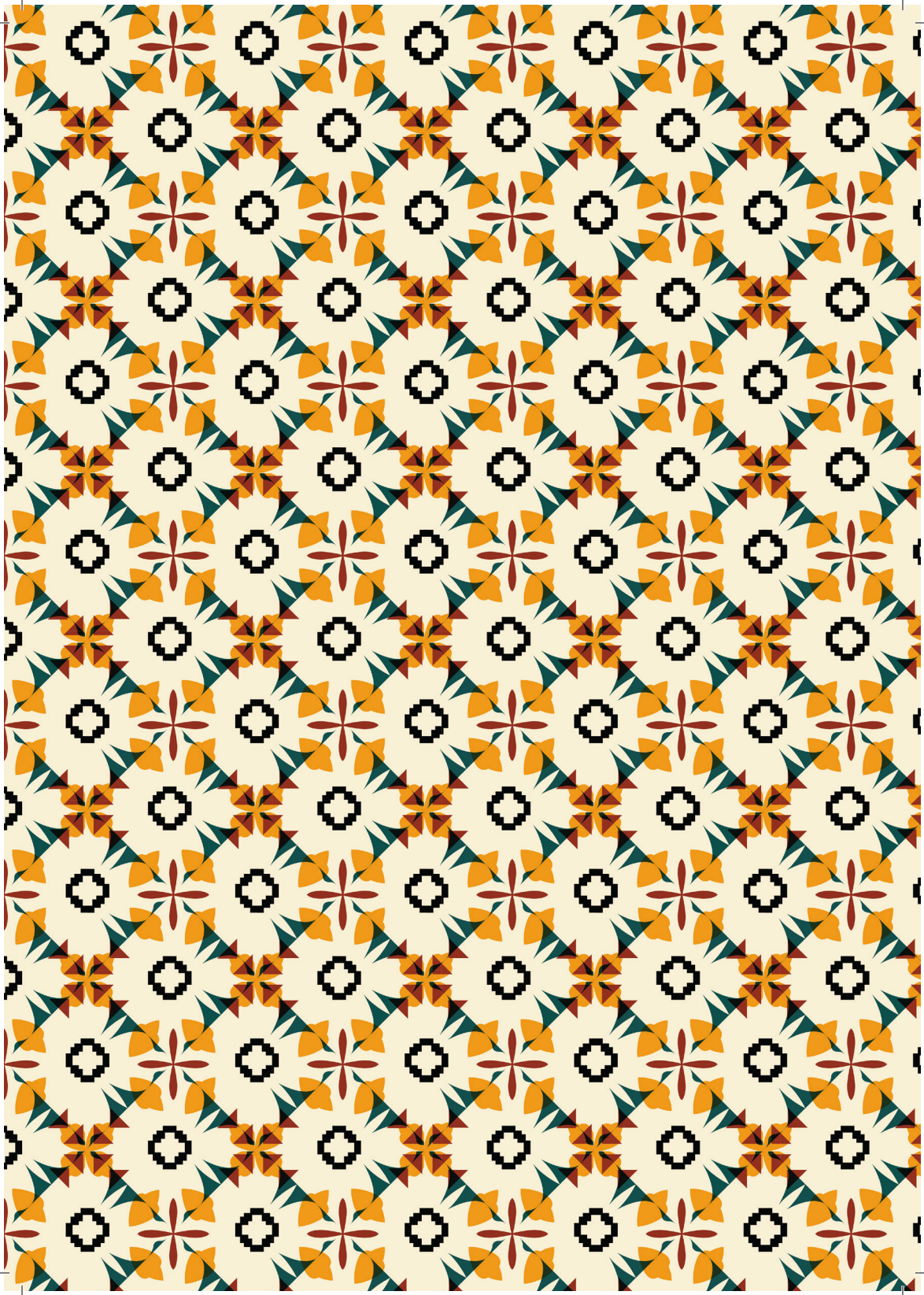

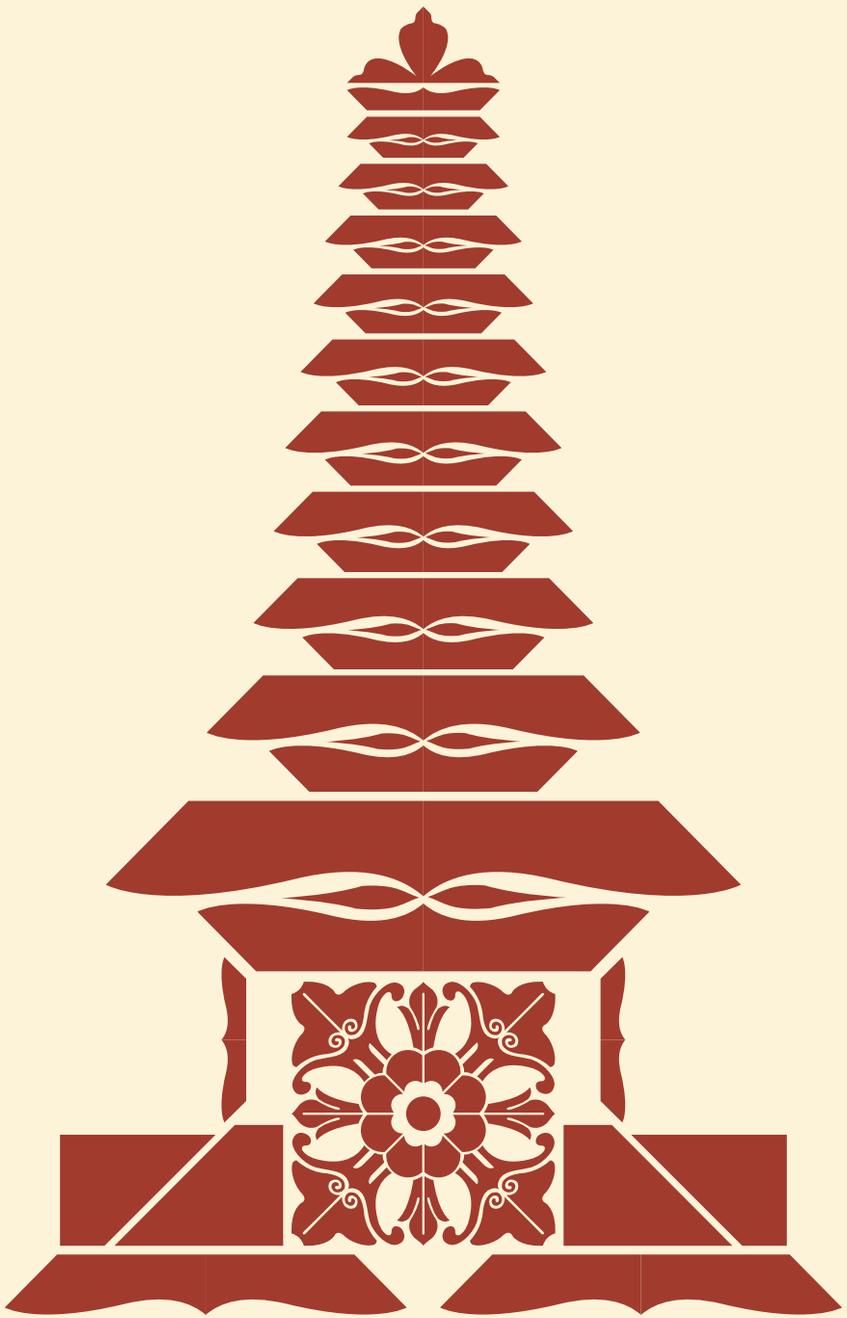

Fab City

Designing Emergent Realities

Foreword 2022

Tomás Díez
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In 2018, we first published Fab City: The Mass Distribution of (almost) everything. It was a book about the power of human-centered technology to transform urban environments and our socioeconomic systems. It collected contributions from key representatives and enablers of the Fab City Network, coming from many disciplines such as science, design, architecture, urbanism, technology and sociology, who expressed their insights on enabling new processes to produce systems change both at local and global scales.

At the time of it's compilation, just before the Fab City Summit Paris 2018, Fab City was establishing itself as a global initiative: a Collective of stewards, a cities Network of 28 cities and it was in the early stages of establishing a Foundation. Four years on, a global pandemic, catastrophic weather events, new and on-going wars and a looming global energy crisis are reshaping the urgency for Fab City thinking. The potential that the 'mass distribution of almost everything' has to reshape our planet for a more livable future is more profound than before and only becomes more so. Over the past four years we have worked on concretising a Fab City global agenda. During this period we have recognised that beyond the need to distribute 'everything' there is also a need to provide the conditions to steward the futures that are emerging outside Europe and the USA. This year, for our first in-person annual event since 2019, we have chosen the theme Designing Emergent Realities. It aims to highlight a local and global approach that can boost the transformation economy in countries disadvantaged in the world system.

On the occasion of this historic event we're revisiting Fab City: The Mass Distribution of (almost) everything in this second book, Fab City: Designing emergent realities. Some articles reappear from the 2018 publication, but with a renewed focused on the advancements that the Fab City Global Initiative has made since 2018. Along with key articles from expert contributors, it presents an updated version of the Fab City Full Stack and recent case studies from the Fab City Network members.

Four years on

Since we first published the book, the Fab City Foundation has been established in e-Estonia. This has provided the global initiative with the administrative framework and decentralized governance capacities to support and coordinate global efforts. It is one of the three key pillars of the global initiative.

The Fab City Network, the Network of cities that have pledged to work towards producing (almost) everything they consume, has grown to almost 50 cities, regions and countries. This year Bali will pledge to be the first 'Fab Island' in the Network. A key part of revisiting the book for republication as part of Bali Fab Fest was seeking new case studies from the Network members. In this edition, we curate a state-of-the-network that sheds light on the diversity of approaches being taken by the network members to implement the Fab City agenda in each location. The Fab City Global Initiative now spans all continents thanks to the growth of the Fab City Collective, a group of experts and enthusiasts that steward the development of the Fab City Roadmap in their respective areas of interest. Over the past four years, the growth of the Network and Collective has been focused on diversifying the international reach of the Foundation, beyond the borders of Europe and the Americas, a key reason for our presence in Bali, Indonesia and the ASEAN region this year for our annual event.

This edition of the book is a major contribution to the Bali Fab Fest 2022; the first ever Fab Fest which brings together the Fab City Global Initiative and Fab Lab Network on the island of Bali to accelerate the transition to a regenerative economy. The convergence of the annual Fab17 event, global Fab Academy graduation and the 8th Fab City Summit including the Fab City Pledge for new cities, is a historic moment to review the state of this powerful international network.

The Fab Foundation, the coordinating entity of the global Fab Lab Network has extracted the following numbers from the fablabs.io platform (the social network of the Fab Lab Network) which speak to the economic and social importance of this event and global community.

Total fab labs registered: 2,582
Verified labs: 2,081
Organizations: 208
Users: 59,534
Active users: 31,765

Across small community labs, regular labs in schools and larger labs in a research or university context, Fab Foundation estimates a workforce of around 5,000 employees (an average of two per lab); a global investment in infrastructure of ~ $243 million dollars and a conservatively estimated ~ 385,000 users accessing these labs worldwide. Beyond infrastructure, the learning programs run by the Fab Foundation (Fab Academy, Bio Academy, Fabricademy) reach over 500 new students each year at 80-100 sites and And the informal educational outreach for K-12 aged students in Fab Labs connected to the network has easily reached 500,000 in the last 5 years.

For the Fab City Foundation, educational programs that help develop the creative skills in learning environments in which experimentation, prototyping and hands-on experience are as important as books and theoretical knowledge. In just about two decades, the global network of Fab Labs has turned the planet into a distributed campus for 21st century education, their collaborative educational offering is called the Academy of Almost Anything. Following this path, Fab City is developing the Master in Design for Distributed Innovation (MDDI) which is an invitation to reimagine education and innovation in an online and place-based learning experience. In the same way that the Academy of almost Anything has been instrumental to the growth and development of the Fab Lab Network, we hope that MDDI sets the grounds to help Fab Cities to achieve their goals through iterative ever-improved distributed program nodes that help embed students into their local ecosystems. MDDI will serve as the incubator of ideas to transform the productive model of cities and regions, providing the platform to bring projects to realisation in community-based interventions within specific territories such as neighborhoods, rural towns, and other forms of human settlements operating within bioregional dynamics, while connected as a global network of knowledge.

As you will read more about in this edition of the book, this path from distributed infrastructure to educational programs, projects, communities, neighborhoods, bioregions and the planet, shows how the Fab City Full Stack could articulate the implementation of the ambitious Fab City Global Initiative plan to revert the current global systemic crisis. For Bali Fab Fest, alongside the traditional activities of the Fab events (workshops, talks, working groups and symposium), we have developed a curated program around the Full Stack. In addition to this, the Foundation has deployed the first edition of a MicroGrants program which has been instrumental to incorporate a new program into the Fab event, the Fab Island Challenge. The Fab Island Challenge brings together local and global innovation communities from over 32 countries to propose meaningful interventions that enrich, empower and scale Bali's emerging regenerative economy. Teams from around the world are invited to focus and learn about ten local initiatives then propose and prototype design outputs to win seed funding for implementation. Through the MicroGrants program we expect to funnel support to local initiatives not only in Bali, but in the rest of the Fab City Network, and to facilitate the creation of opportunities for innovators and creators to bring solutions to ongoing challenges related to climate change and geopolitical instability.

As a relatively newly established foundation, we are grateful for the support given by our Supervisory Board, Network members, members of the Collective, founding members and collaborators like the Fab Foundation, Institute of Advanced Architecture of Catalonia (IAAC) and P2P Foundation. Our efforts are collective and we believe that, together, we can produce historic moments like the Bali Fab Fest as key milestones on our roadmap towards 2054.

Bali Fab Fest

In October 2022, the island of Bali is set to pledge to become the first Fab Island in the world. The island will join regions, countries, townships and cities that aim to produce (almost) everything they consume by 2054. The opportunity to welcome Bali to the Fab City Network is historic. In the same year Bali will be the first Fab Island and the first south-east asian network member, it will also host the first Bali Fab Fest - a unique event that converges the 17th Fab Lab Conference and the 8th Fab City Summit and responds to our post-pandemic reality and need for meaningful connection. Like Amsterdam 2016, Paris 2018 and Montreal 2021, the opportunity to host the global meeting of the Fab City Global Initiative will accelerate Bali's Fab City journey towards a regenerative economy.

As a local and global collaboration between the Fab Foundation, the Center for Bits and Atoms at MIT, the Fab City Foundation, and the Meaningful Design Group, Bali Fab Fest is designed to embrace agonism, balance creative tension between global and local perspectives, advanced technologies and crafts, cultural diversity and multidisciplinary. It will be hosted at the Jimbaran Hub – an innovative community cultural space in southern Bali - under the theme 'Designing Emergent Realities'.

Design: We believe in the power of design to transform systems and solve problems, an approach to design that is open, holistic and inclusive.

Emergent: We are witnessing yet another transition period in which uncertainty and complexity increases as we speak, hence we believe adopting a flexible approach to education, research and innovation is necessary.

Realities: aiming to boost the transformation of the island's economy through harnessing local and global knowledge.

The event is curated using the Fab City Full Stack, the multiscalar framework for developing new strategies for distributed production in cities and regions. At the Bali Fab Fest, it will be used to help conceptualize how each activity in the program can contribute to the local collective Fab City roadmap, guiding how we leverage a distributed global network of experts and cities to organise the event. It also provides evidence for how the framework can influence productive relationships between communities, cities, territories and the environment and kick-start the collective efforts of the Balinese ecosystem.

The Fab City Foundation has reflected deeply on the impact of bringing over 200 guests physically to Bali amidst global pandemic, war and climate crisis, and we stand by the decision to serve the ASEAN region with this event. We are taking steps to reduce the ecological impact of the event, developing long-term strategies to boost the local agenda including the establishment of new production spaces to increase the manufacturing capacity, energy generation, and food production capabilities at the local scale. Bali Fab Fest will also host the kick-off of the Master in Distributed Design and Innovation which is the Fab City Foundation's ultimate long-term action to educate and reskill leaders in systems-oriented Fab City thinking.

We hope that Bali Fab Fest serves as an experience for local and global participants to enable long-term transformation through small scale design interventions. Ultimately, this approach to planetary living is based on the principle of 'Think Global, and Fabricate Local', with all implications it entails to radically transform the current industrial society and create positive impact during uncertain and complex times.

Fab Island Challenge

10 international teams.
10 challenges by local innovation initiatives.
10 days during the Bali Fab Fest.
1 goal: Accelerate the Transition to a Regenerative Economy in Bali.

In the wake of the pandemic, the world is opening up into a very different place. As a global innovation community that meets on an annual basis, we have the responsibility to make our physical travel more purposeful. Convening the Fab Lab and Fab City communities in Indonesia at Bali Fab Fest has given us an opportunity to connect international designers, scientists, makers and artists with the local ecosystem within the framework of the Fab Island Challenge. This is a unique program that aims to boost the island and region's transition to a regenerative economy.

Fab Challenge has been developed by the Fab City Foundation as a framework to prototype this distributed design and innovative approach. It provides a context-aware approach to explore needs based, project driven, and hands on innovation that involves a variety of design and non-design profiles. Bali Fab Fest will host the third challenge that has been developed in the Fab City global initiative, the Fab Island Challenge, which aims to give a narrative boundary to support collaborative efforts to approach some of Bali's most pressing issues around sustainability and life systems. Teams from over 32 countries will travel to Bali, supported by the Fab City Foundation, to focus and learn about specific local initiatives, propose and prototype design outputs to win seed funding for the implementation of their ideas.

The Challenges

Empowering Sustainability with Plastic Exchange

Plastic Exchange is a sustainability movement that empowers communities to change their waste behavior through dignity-based exchange systems that result in cleaner, healthier environments. They have multiple challenges from efficient data collection and digitalization, effective data communication to convey impact, designing a cover for the compost holes, and scaling eco-enzyme fermentation products.

Supporting Smallholder Farmers with Kopernik

Kopernik works with agriculture communities in Bali. They have identified two processes that require automation in order to boost efficiency, regenerative efficacy and resilience. One challenge looks at sorting raw harvested coffee and the other, keeping weeds from cocoa plantations.

Align and Identify

Teams are formed by application prior to the event. They attend onboarding calls to meet their hosts and team members and understand the local challenge.

Arrive and Connect

Teams visit local hosts locations in a series of tours across Bali, Gili Islands and Lombok.

Explore and Learn

Through hands-on exchange at the Fab City Campus, local and global teams collaborate, iterate and learn from each other.

Ideate and Design

In parallel with the Bali Fab Fest program, teams develop their responses to the challenges. Accessing inspiring talks, workshops and the guidance of the international community who are gathered from Bali Fab Fest.

Prototype and Test

Teams develop a quick-and-dirty prototype using the Fab Lab facilities at the Fab City Campus. They prototype and test it, iterating the design based on feedback from the community and expert practitioners.

Share and Showcase

Teams will display their results at the Makerverse day - an open community day at Bali Fab Fest. Winners will be awarded seed funding based on a series of evaluations by the general public and an expert jury.

Making Connections with BambooU

Bamboo U promotes bamboo design, architecture and construction. Over the years, we have found that though bamboo building is beautiful and full of potential, the joinery in round pole construction remains an issue due to the irregularity and diversity of bamboo poles. We already know how to harvest, how to treat, how to design and build. Now how do we design better joints that are faster, cheaper, and stronger and have a positive impact on our craftspeople and community?

Water for Life with IDEP Foundation

Currently, measuring and monitoring a well's water level is challenging in many parts of the Island due to the high costs of sensors and the fatiguing task of doing the work manually. We are challenging our team to develop a smart sensing solution to contribute to our Bali Water Protection Program.

Waste to Value Communities with Nusa Sentara

Nusa Sentara has been working to develop community hubs across the Gili Islands and Lombok to support the resiliency of local communities and ecosystems. Their challenge takes place across two islands and will focus on developing waste-to-value ecosystems for these small island communities by developing a platform and incentive system that allows the conversion of waste streams into valuable materials that serve the local community.

1000 Prosthetics with Printridi + FabCare

Can we bring together a distributed community across Bali to design and print 1000 prosthetics in just 10 days? With Printridi, international partner FabCare and our challenge team we will put distributed design and manufacturing to a real-world test for community, creativity and care.

Looking Closer with Prakash Labs

We are surrounded by a buzzing microscopic world that holds answers to some of the questions we seek in our everyday world that's visible to our eyes. This challenge will deploy microscopic solutions in water environments to explore questions of resiliency and dependency.

Floating Hydrogen Pods with Cesar Jung-Harada

This urgent energy-focused challenge proposes to prototype multiple floating solar to hydrogen floating pods, designed in collaboration with local coastal communities mainly with local materials to benefit the local environment and economy.

Precious Plastic

The Precious Plastic Challenge will be developed collaboratively will over 15 members of the Precious Plastic community from across the Island and Indonesia! It will be designed to respond to what the local organisations operating in Indonesia really need with the problem definition being the first collaborative action the of the challenge!

From Fab Labs to Fab Cities

Neil Gershenfeld (2022)

I consider the Fab City project to be one of the most important (and unexpected) realizations of the promise of fab labs.

Fab labs began with a modest goal of expanding access to digital fabrication; we never expected the doubling that followed to thousands of fab labs today. As the small network grew we began meeting annually, and after a few of these gatherings as a joke we began numbering them, again never expecting them to continue into and beyond the next decade (this seems to be a pattern). By the time we got up to FAB10 in Barcelona in 2014 it was clear that something larger was happening.

By then Vicente Guallart, who co-founded the Institute for Advanced Architecture of Catalonia (home of Barcelona's pioneering first fab lab), had become the chief architect of the city. The future Mayor Xavier Trias had previously visited MIT with Deputy Mayor Antoni Vives and an IAAC team in 2011. Barcelona had (and still has) high unemployment, particularly among young people, but also a fabulous history of design and urban planning. At that meeting we described its current operating model as Products-In-Trash-Out, and we articulated a goal of using digital fabrication to move it to Data-In-Data-Out -- digital bits of information traveling globally, while physical atoms stay locally.

This thought led to an initiative to set up fab labs across Barcelona, viewing access to the means to make as part of the urban infrastructure, as essential as providing access to electricity or water. That project in turn inspired a memorable moment at FAB10, when now Mayor Trias pushed a button to start a forty year countdown to urban self-sufficiency. This work continued in Barcelona with Mayor Ada Colau, and around the world with many more cities, regions, and even countries joining the pledge, with their leadership committing to this visionary approach to make technology more accessible and transformative for cities.

Forty years was chosen to be well outside most political and commercial planning horizons, but within individual lifetimes. The intention is for this to be a continuous transition rather than a step change, accumulating a few percent a year.

Smart cities are instrumented to provide services more efficiently; a Fab city looks beyond that to cross the boundary from digital to physical. This could start with making furniture, then progress from there to creating shelter, building wireless data networks, converting wind and solar energy, and producing systems to grow food. All of these things exist as fab lab projects in prototype form today; what's needed is to propagate them at scale.

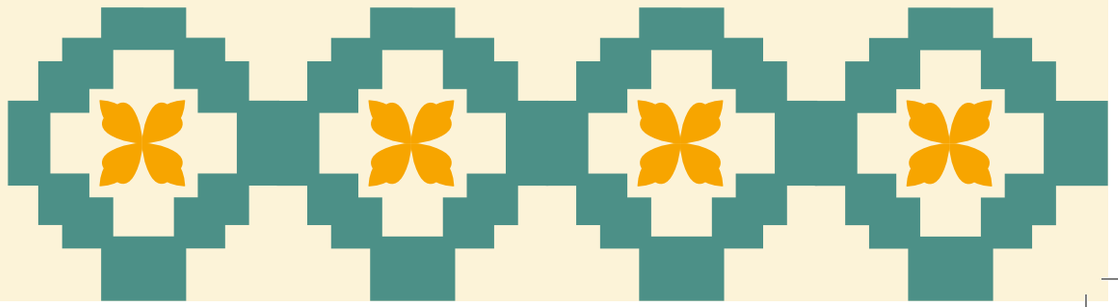
One of the first observations after the button-pushing event was the recognition that cities today don't even collect the kind of data that would be needed to quantify the fluxes of bits and atoms across their borders, and hence would need to collaborate on building the technology base to first measure and then move that ratio. That began to fill in as cities joined the Barcelona pledge at subsequent FABx gatherings, all sharing the same clock from that initial button press.

The Fab City initiative is now ably led by Tomas Diez, working with a globally distributed team. It's grown to host a Fab City Summit, including campuses showcasing the latest in Fab City technologies. 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.

One of the most interesting developments in Fab Cities has nothing to do with cities. There are a number of fab labs in rural locations that are finding that the combination they offer of growing local self-sufficiency with global connectivity is leading to what could be called "ruralization", reversing the drive towards increasing urbanization by providing rural amenities with urban capabilities.

Fab labs are now making a transition from the 1.0 stage (buying machines) to 2.0 (making machines). Led by a growing network of super fab labs with more advanced manufacturing tools, it's becoming feasible to locally produce fab lab tools that are not just faster and cheaper but also better than their commercial predecessors.

This is a key step in the forty-year countdown, to support continued scaling. As we look ahead to growing from 1,000 fab labs to 1,000,000, what matters is not their quantity but the quality of their impacts. Fab Cities are the engines both demanding and delivering this transformation from consumption to creation.



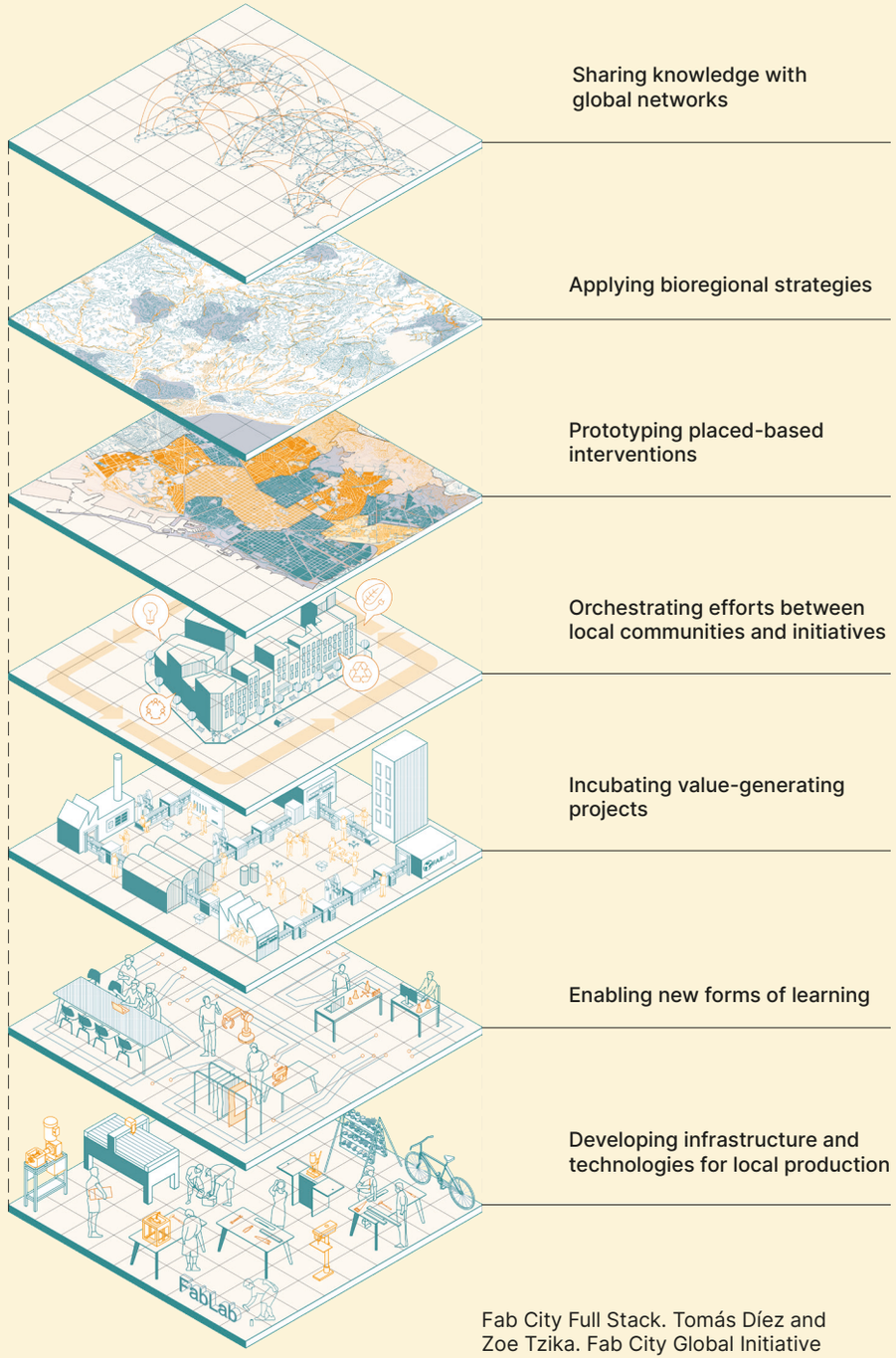
The Full Stack

Unpacking the Fab City challenge

Tomás Díez (2022)

In computer science, a series of programs or services work together as a stack to provide specific solutions in software applications (Bratton, 2015). Similarly, a series of articulated actions between actors can provide a framework to address a complex challenge such as the one Fab City faces. From neighborhoods in cities to systemic change, the Fab City Full Stack aims to provide the Fab City Global Initiative with an operation plan that can translate the Product In - Trash Out (PITO) paradigm into a new Data In - Data Out (DIDO) paradigm. Moreover, the Fab City Full Stack framework helps cities and regions to interpret the Fab City challenge and is also a tool that guides them to implement it in a multiscalar and ecosystemic approach and define their strategic action plan. By unfolding in seven specific layers that complement each other, the Full Stack aims to enable efforts between the global network of cities and regions and create open repositories of knowledge to advance a new industrial production model. This framework is now being used within the Fab City Global Initiative to articulate its distributed innovation and research roadmap.

Adopting a Full Stack strategy can unpack the major challenge of Fab City into smaller parts, which in turn facilitates the development of technologies for urban regeneration. As the challenges ahead are not only technical, political, social or economic but the sum of all operating simultaneously, a framework to articulate such complexity is needed. Moreover, the scale of the challenge is not nation versus city, nor centralization and decentralization or global versus local, but the complementarity of scales and strategies that allow the construction of more resilient, inclusive and regenerative sociotechnical systems. This is why, by using the analogy of the Full Stack, Fab City is employing this approach to orchestrate its efforts both locally and globally, as well as use it to identify specific action points to enable the transition towards productive cities.



Fab City Full Stack. Tomás Díez and Zoe Tzika. Fab City Global Initiative

The base layer from which the whole Fab City challenge is structured is based on the pillars of science and technology but also rooted in the life-supporting systems at the planetary scale. Hence, the fundamental objective for Fab Cities to thrive is based on the application of scientific knowledge in sustaining, regenerating, and nurturing life. The work done by the Center for Bits and Atoms (CBA) at MIT and the global Fab Lab Network in designing future machines, exploring alternative materials, and fabrication processes has been foundational to a new industrial paradigm, as it is the core scientific base for developing technologies and infrastructure for distributed production.

As the work of CBA is democratized through situated labs and open-source knowledge, it supports the development of the needed skills and knowledge required to incorporate a new production paradigm in our society, economy, and culture. Currently, the Fab Lab Network brings new approaches to education based on learning-by-doing approaches, as well as project-based learning, as seen in the Academy of Almost Anything and emergent educational programs of the network. By incorporating digital fabrication tools, principles, machines, and processes in existing formal education, as well as creating new programs, we are enabling new forms to learn the skills for the future. This enables a transition to educational models that foster the development of creative and critical skills at all levels. Fab City understands that learning to learn is fundamental to continuing evolving knowledge and, therefore, human capacity on a lifelong basis.

As skills are developed, they can be applied in creating novel ideas to solve local challenges by bringing ideas from the different distributed networks and turning them into projects that can have an economic, scientific, and social impact at multiple scales. A learning environment that incorporates the development of projects as part of the learning process itself allows the emergence of situated solutions to local challenges, which can be applied globally following the PITO-to-DIDO principle of Fab City. One of the future challenges for Fab Labs and Fab Cities is to create a support program to incentivize and help the development of projects from their global networks and become part of global repositories of solutions to some of the critical issues faced by many communities locally.

When such social and entrepreneurial projects that strengthen the principles of the Fab City Global Initiative are identified, they can be incubated and accelerated inside Fab Labs, as well as within other innovation hubs such as Fab City Hubs that are orchestrating efforts with local communities and organizations. Fab Labs, makerspaces, creative hubs, and hackerspaces need to engage with the local communities and ecosystems, recognizing and interacting with the context in which they operate. Fab City Hubs are community spaces that aim at enabling and facilitating the creation of a network between local communities. They act as physical interfaces to connect multiple actors (neighbors, citizens, makers, organizations, businesses, and public entities) and foster collaboration and exchange of skills and knowledge between local communities in a given territory, expanding the role of Fab Labs and makerspaces, as they broaden their reach.

To connect the projects coming out of the Fab Labs and Fab City Hubs closely with their local ecosystem, it's important to prototype the Fab City model on various scales, such as a neighborhood, but also the city itself. The objective is to create local strategies and governance models and influence policy-making to develop a favorable legal framework for the implementation of Fab City projects to enable the transition towards a new productive model. Moreover, Fab City prototypes set up an experimentation playground to implement, test and iterate innovative business opportunities at the local scale in neighborhoods and cities, and create open markets for products and services that support the development of a circular economy. These prototypes are developed by citizens at large and supported by the private and public sectors. The aim is to establish the necessary urban frameworks and lighthouses to guide policymakers to scale the results to metropolitan and bioregional levels.

The physical context in which labs, hubs and projects are placed shapes their work. As projects in the form of interventions coming out of these spaces are placed in local communities, they also have impacts at other scales, including the city, or the regions in which they are located. A bioregional approach to the transition to a new productive model can help improve humans' relationships with other species. Humans are not the only inhabitants of any given territory and include other non-human species, natural ecosystems such as watersheds, mycelium networks, and geological formations, and understand them as part of the same systems that recognize both nature's principle ruling in a space, as well as the human culture and organization around the same areas. Bioregions are defined by cultural relationships and natural systems in each territory (Van Newkirk, 1975). Bioregions allow us to operate on a territorial scale large enough to understand cities beyond their artificial, physical, or political limits. At the same time, bioregions operate within global logic, such as changes in climate and the interdependence of aquifer systems, transport of microorganisms through the air, or the influence of natural or artificial phenomena on changes in temperature on a local scale (Wahl, 2017). Due to humanity's influence on the ecosystems that make up the bioregions, it is impossible not to link this relationship between the biological and the synthetic within the same spatial and cultural dimensions that compose them. Any intervention we make in cities, towns, regions, or any other type of settlement, needs to recognize this multispecies approach.

Finally, enabling the mechanisms to share knowledge between local and global networks is fundamental, as it is key to understanding the transition from PITO to DIDO. The exchange of knowledge is produced in the local contexts, and that happens in labs, hubs, neighborhoods, or bioregions. It also contemplates the need to develop metrics to measure progress for cities to produce (almost) everything they consume before 2054.

In the current context of climate and territorial transformation by human activity, it is imperative to articulate efforts in the configuration of a better relationship between technology, communities and bioregions. The challenge is not only to achieve the sustainability of the material world in which we operate today but to use regenerative principles to recover much of the biodiversity sacrificed for the sake of economic and industrial development over the last two centuries. In this sense, it is essential to reconfigure our relationship with living systems that allow us to satisfy in a sustainable way the energy needs of the human species, such as electricity or food that serve cities and rural populations.

To achieve a challenge of these dimensions, we must be able to generate opportunities for learning and re-learning, as well as to generate cultural exchange that combines political, cultural and biological dimensions. We can do this by applying existing methodologies, tools, and skills in both local and global environments and through networking with and within bioregions, cities, towns, communities and individuals that share the purpose of transforming and evolving the way our current urban life works. Only by articulating efforts through collaborative networks on a global scale will it be possible to deal with the difficult task of solving highly complex problems.

It is not an easy task to replace a centuries-old colonialist logic based on artificial scarcity, competition, extraction and exploitation with new principles based on regeneration and justice, and on learning from experimentation in cities, bioregions and human settlements. The potential of distributed learning and innovation networks, such as Fab Labs, allows the construction of complementary layers for the sum of small-scale efforts to produce collaboration at scale. In the same way that the negative impacts of the daily actions of current urban life generate problems on a global scale, it is possible to think that the articulation of small efforts based on collaboration, open source and experimentation can lead us to the development of new answers to the questions that we will continue to ask ourselves about the concept of the city.

As we write, one of the most disruptive pandemics of all time has changed entire economies, a possible third world war is showing on the horizon, climate change is becoming more evident, and it seems we are still struggling to rebuild the world as it was. We might not want to return to the previous normal because that normality no longer makes sense. It made sense for a very small percentage of the world's population but not for any natural system or the planet itself. The previous normal has been too focused on searching for growth of the Gross Domestic Product, competition, extractive dynamics, and the exploitation of people and resources. As the privileged ones, we have the responsibility to enable inclusive and desirable futures for as many people and species on the planet through collaboration, open-source knowledge and ecological principles. We do not have time to fight the past. Instead, we must put our energy into enabling emergent scenarios that could allow us to test alternatives to (re)organize our world.

Contents

Enabling Emergent Futures

A constructive overview for the future of cities, technology and society

(Articles written in 2018)

Fab Futures: The Power of Networked Impact

Sherry Lassiter

In 2003, the first true Fab Lab was established in inner-city Boston. Politician, professor, writer, and community activist Mel King was its champion. Mr. King was constantly exploring new technologies for our inner city community, which was largely black, urban, and often left behind. "The rear wheels of the train never catch up to the front wheels, unless something radical happens." He believed that digital fabrication was a way for youth in his community to jump ahead and lead our technological future.

Just a few years later, Haakon Karlsen started a Fab Lab in northern Norway, 1,500 kilometers north of the Arctic Circle. He, too, was a community leader, the descendant of Vikings and Sami Herders. He built his lab in a Viking longhouse to bring advanced technical education to the children of rural Norway and to help local entrepreneurs bring their ideas to life. He believed that the growing Fab Lab network was a community of people who wanted to share knowledge and collaborate.

These two pioneers helped inspire the global Fab Lab network, a network that is about more than machines and technology. Yes, it is a community of people who want to share knowledge and collaborate. But the participants are change agents, who use technology as their catalytic platform. With common vision and a worldwide distributed technology infrastructure, the community is able to collaborate and act in broad and powerful ways—in education, humanitarian aid, and research collaborations.

"Fab Lab network, a network that is about more than machines and technology."

"The Fab Academy, is a distributed campus for advanced technical education."

"As Fab Labs mature and are able to produce better quality and innovative solutions."

The Fab Academy, for example, is a distributed campus for advanced technical education. Each Fab Lab that participates is a classroom in this global campus. Peers and mentors work together in their Fab Labs; connect to other Fab Labs to share knowledge and expertise; and together celebrate the ideas, the technical solutions, and the creativity of each student. Some of the ideas are big, and some are small, but they all are interesting, and in most cases just as exciting as the innovations we see coming out of MIT. There are about 80 Fab Labs participating in Fab Academy this year, with several hundred students from India, Kenya, Iceland, Spain, the U.S., Peru, Chile, as well as many other countries taking part. The people who teach and mentor the Academy are extraordinary technology innovators and are among one of the most impressive groups of people within our network—intimate, action-oriented, and definitely changing the world of education, as well as entrepreneurship.

Humanitarian aid has become a salient point of interest for many in the network over the past few years. As Fab Labs mature and are able to produce better quality and innovative solutions, the humanitarian sector is reaching out to the community, seeking easily deployable innovations for small-scale manufacturing and for makers who can become humanitarians in the field. Small, flexible aid organizations like Field Ready and Terre des Hommes, are putting Fab Labs into refugee camps and using digital fabrication to support field operations. While still in its early stages, this work holds great promise for large and impactful network action.

Research collaborations are another way the network takes action. The Machines that Make Machines project started at MIT but has grown into a global project. Fab Labs all over the world are making machines: 3D printers, milling machines, routers, lathes, 5 axis wire cutters, scanners, paint droppers, cocktail mixers, even Zen garden designers. From the practical to the whimsical, there is no end to the types of machines that can be made in Fab Labs. What's more, most fabricators freely share their designs for others to follow. It costs around the order of $120,000 to buy a Fab Lab, but once you have one lab, you can then use the machines to make another. In other words, Fab Labs can self-reproduce for 1/10th of the original price, making digital fabrication far more affordable, and thus democratizing access to the technology tools for innovation. And it's not just a single individual doing this work; rather, it's a global community collaborating—a network of expertise and invention.

The Fab Foundation was established in 2009, largely as an effort to support the growth of the international network. We spent our first 10 years building Fab Labs in communities across the world, and developing the educational tools to help those labs and communities create new microenterprises and solve their own local technical challenges. We have largely achieved our goal: Today, there are more than 1,200 Fab Labs in more than 100 countries, and each lab shares a common set of tools and processes.

Today Fab Foundation supports regional networks and the promising projects and innovations that emerge from within these networks in order to help them reach their potential in the world in sustainable and impactful ways. We have seen extraordinary regional leadership emerge in many parts of the world, forming effective, collaborative local networks in countries and regions including the Netherlands, Spain, Iceland, Japan, India, Brazil, South and Central America (FabLAT), Asia (FAN), and China. These regional networks are becoming powerful voices and actors in our work, spurring innovation in programs and projects, such as the Fab Academy and Fab City, that are changing the way we educate and live in our world.

Fab Labs buck the traditional ways of running organisations, educational programs, and businesses. The way this network has grown, and keeps growing, empowers new generations that constantly push us to reformulate the way we learn, live, work, and play. The fundamental role we see for Fab Labs and Fab Cities is to catalyze this process in urban and rural areas, welcoming those who don't fit into traditional systems or formal educational programs, and offering enabling, empowering opportunities for those who've been left behind economically. New innovation ecosystems in cities, governments, and local industries will play a critical role in the transition toward a more inclusive and generative economy—one where technology is a key element, but not the central element. We take a holistic view of this future, our mission being to enhance human capabilities in such a way that we become the best version of ourselves.

We are poised at the transition between the 3rd and 4th Industrial Revolutions, moving from an industry based on automation, computers, and electronics to an industry that incorporates Cyber Physical Systems, the Internet of things and networks[1]. New technologies are developing so quickly

"Our work is to build a full-stack infrastructure to democratize access to digital fabrication tools."

"This research will help us establish new pathways for living and working in the 21st century city."

"Fab Labs buck the traditional ways of running organisations, educational programs, and businesses."

"How will we provide social security, health and financial well-being?"

that we really don't understand what the technologies will look like even just 10 years from now. It follows, therefore, that we don't know what skills the future workforce will need, either. How do we best prepare our youth for that future, and how do we retrain the current workers in the skills they'll need to play an active role in that future?

Education is one of the core pillars of the Fab Foundation's work and one of the pathways we use to bridge the digital divide. I believe the Fab Lab Network is uniquely positioned to support the kind of education needed to forge technically prepared, lifelong learners. Through the Fab Academy we are exposing adults to transdisciplinary knowledge and learning, to design, media literacy, computational thinking, collaboration, communication, and the technical skills to leverage digital fabrication for work and for entrepreneurship. With the SCOPES-DF project we are doing the same for our youth. This broad and flexible base of knowledge, along with the skills to learn how to learn, will be critical to participating in the work of the 21st century.

As we are pulled into Industry 4.0, we must carefully consider how to build the educational systems of the future; how to provide access to digital fabrication for al; and also how to establish sustainable, equitable practices and participation in industry. And thinking beyond the purely technical realm, we need to address what will happen to the social benefits and safety nets that support us all once the workplace becomes less centralized and more distributed. If we embrace a brave new world of decentralized industry, and more of us join the gig economy, how will we provide social security, health and financial well-being?

1 "Industry 4.0: Trade Rules for the Internet of things," by Ed Gerwin, June 22 2017, tradevistas, retrieved 6-01-2018 from: https://tradevistas.csis.org/industry-4-0-trade-rules-internet-things/

Blockchain
A global infrastructure for distributed governance and local manufacturing

Primavera
de Filippi

"We no longer need to live in the same area, or meet face to face, in order to collaborate on a common endeavour."

"New open source hardware and software tools fosters new modes of learning, designing, manufacturing."

The arrival of the Internet and digital communication tools have led to the emergence of new "paperless organisations" that operate without an office, schedule, or even employees. With the Internet, we can now work remotely, synchronously and asynchronously, without having to physically move from place to place. We no longer need to live in the same area, or meet face to face, in order to collaborate on a common endeavour. We simply need to connect to the Internet network to find colleagues, partners, or customers. The hope was that this global communication network would eventually lead to increased participation and greater opportunities for people all over the world to play a part in the global economy. And tosome extent, it did.

Yet, the shift was only a partial one. Over the past 20 years, we have progressively moved away from the traditional model of centralized organisations, where large operators (often with a dominant position) were responsible for providing a service to a group of passive consumers. Today, we are witnessing the emergence of new organisational structures in the digital domain that are much more distributed in nature. These so-called "crowdsourced organisations" are responsible for aggregating the resources of multiple people to provide a service to a much more active group of consumers. Indeed, if we look at the modus operandi of today's Internet giants—such as Google, Facebook, Twitter, Uber, or Airbnb—we see they have one thing in common: They rely on user contributions as a means of generating value within their own platforms. The problem with this model is that, in most cases, the value produced by the crowd is not equally re-distributed among all those who contributed to that value creation. Instead, the lion's share of profits ends up being captured by the large intermediaries that operate the platforms.

Conversely, in the physical domain, the development of new open source hardware and software tools over the past decades has fostered new modes of learning, designing, manufacturing, and collaborating that actually promote individual participation in an open ecosystem of value creation and re-distribution. Inspired by the Open Source movement in software, maker communities have been building new hardware-based technologies and tools inside new fabrication spaces. Today, millions of people are connected to the Internet through open source software and use digital fabrication tools (including 3D printing) to build the largest distributed design and manufacturing ecosystem in the world. This paves the way for a more

equal redistribution of production means, both digitally and physically. And yet, as occurred with the Internet a few decades ago, the value generated by makers is likely to be captured by rising manufacturing and distribution giants. How can these communities govern themselves without falling into the same centralized paradigm that has become so prevalent within the sharing economy?

Recently, a new technology has emerged that could help answer that question. Blockchain—the technology that underpins Bitcoin—facilitates the exchange of value in a secure and decentralized manner, without the need for an intermediary. As such, it enabled the emergence of virtual currencies and other distributed ledger technologies that look likely to disrupt existing intermediaries in the financial sector, and beyond.

But the most revolutionary aspect of blockchain technology is that it is also a means for individuals to coordinate common activities, to interact directly with one another, and to govern themselves in a more secure and decentralized manner. Indeed, modern blockchain-based networks make it possible for people not only to transact value between one another, but also to execute software in a secure and decentralized manner. With a blockchain, software applications no longer need to be deployed on a centralized server: They can be run on a peer-to-peer network that is not controlled by any single party. These blockchain-based applications can be used to coordinate the activities of a large number of individuals, allowing them to organize without the help of a third party.

There are already a few such applications that have been deployed on a blockchain. For instance, Steemit, Sapien, and Akasha are distributed social networks and media platforms that operate without a centralized authority. Instead of the content being stored on a centralized server, operated by a centralized organisation that can control and manage the content that is displayed to the public, these platforms stores content on a decentralized network, using blockchain technology to coordinate individuals and manage the content they contribute to the platforms through a set of code-based protocols and rules.

Similarly, OpenBazaar is a decentralized marketplace, like eBay or Amazon, that operates independently of any intermediary operator. The platform relies on the Bitcoin blockchain to ensure that buyers and sellers interact directly with one another, without passing through any

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"Blockchain-based applications can be used to coordinate the activities of a large number of individuals, allowing them to organize without the help of a third party."

centralized middleman. Anyone is free to offer a product for sale on the platform at a given price. Once a buyer agrees to the price for that product, an escrow account is created on the blockchain, requiring two out of three people (i.e., the buyer, the seller, and a potential third-party arbitrator) to agree for the funds to be released (a so-called multi-signature account). Once the buyer has sent the payment to the escrow account, the seller ships the product, and after receiving the product, the buyer releases the funds from the escrow account. Only if an issue arises will the system require the intervention of a third party (e.g., an arbitrator) to determine whether to release the payment to the seller or return the money to the buyer.

There have also been some attempts to create a generic infrastructure for decentralized organisations, such as DAOstack and Aragon, which provide the basic building blocks for creating decentralized crowdsourcing organisations, administered without a centralized operator. These organisations are governed by the code deployed on a blockchain-based infrastructure, which is designed to govern peer-to-peer interactions between multiple actors.

"Blockchain technologies can support a much more cooperative form of crowdsourcing."

Blockchain technology thus facilitates the emergence of new forms of decentralized organisations, which have neither a director nor a CEO, nor any sort of hierarchical structure. These organisations are administered collectively by all the individuals interacting on the blockchain. As such, it is important not to confuse them with the traditional model of "crowdsourcing," where people contribute to a platform but don't actually benefit from its success. On the contrary, blockchain technologies can support a much more cooperative form of crowdsourcing—sometimes referred to as "platform cooperativism"—where users are contributors too and shareholders of the platforms to which they contribute. And since there is no intermediary operator, the value produced within these platforms can be more equally redistributed among those who have contributed to the value creation. With this new opportunity for increased "cooperativism," we're moving toward a true sharing or collaborative economy—one that is not controlled by a few large intermediary operators, but rather governed by and for the people. Blockchain technology makes it possible to replace the model of top-down hierarchical organisations with a system of distributed, bottom-up cooperation. Ultimately, this shift could change the way wealth is distributed in the first place, enabling people to cooperate toward the creation of a common good, while ensuring that all involved are duly compensated for their efforts and contributions.

"Users are contributors too, and shareholders of the platforms to which they contribute."

While most of these blockchain-based organisations have so far been developed mostly to facilitate the coordination of individuals in the digital world, the possibilities resulting from these new organisational structures can also be found in the physical world. Cities, municipalities and local communities can leverage the power of blockchain technology in order to increase transparency and accountability in many sectors, while providing new opportunities for anyone to engage and participate in the local economy. Indeed, blockchain technology is currently being explored as a way to support local energy microgrids with peer-to-peer exchanges between neighbours (see, e.g. Grid Singularity), or to provide more transparency in the food supply chain (for instance, with projects such as Provenance) by recording information in the form of immutable cryptographic records on a distributed ledger.

Digital technologies create many new opportunities to increase the capacity of local production within communities, neighbourhoods, and cities through urban farming technologies (aquaponics, aeroponics, synthetic biology), solar panels or wind turbines, and digital fabrication tools (from personal 3d printers to flexible factories). These technologies could result in significant operational efficiencies by reducing production costs and unleashing new business opportunities for manufacturers worldwide. Yet, the question of governance remains a critical one that still must be properly addressed. Indeed, in the physical world, commons-pool resources are subject to the "tragedy of the commons": without a proper governance structure or incentivisation scheme, people are likely to free-ride, leading to over-exploitation and/or under-contribution to these common-pool resources. In order to increase the chances that these new technologies contribute to the flourishing of a healthy ecosystem of local production, we need to identity the proper incentivisation mechanisms that will encourage people to contribute resources, without being subject to the scrutiny of a centralized authority.

Enabling local processes of production to reduce the impact of the current industrial globalisation is crucial, but enabling mechanisms to incentivise, accelerate, and scale this process is fundamental and urgent. This is where blockchain technology could come in handy, by creating an open platform and decentralized incentivisation scheme that can be articulated between multiple stakeholders. Local communities have been experimenting with local currencies for a long time, but because of the limited scope, they haven't yet managed to reach a global audience. For instance, with a blockchain, multiple cities around the world could incentivise local communities to contribute to the commons and engage in productive and collaborative activities by rewarding these practices with a global social impact currency. This would enable local communities to coordinate on a global level, in order to promote a paradigm shift in terms of recycling, reuse, relocalisation of supply chains, and other practices that reduce the impact of the linear economy.

"There are new opportunities for anyone to engage and participate in the local economy."

"Enabling local processes of production to reduce the impact of the current industrial globalisation is crucial."

"Enabling mechanisms to incentivise, accelerate, and scale this process is fundamental and urgent."

"There is always the risk that behemoths will also eventually emerge in the blockchain space, just as it happened with the Internet."

"Engage and experiment with this emerging technology enable us to achieve the promises of a true collaborative economy within the context of new productive cities."

The opportunities are huge, and yet nothing should be taken for granted. The decentralized potential of blockchain technology does not necessarily mean that it will, in fact, be used in a decentralized manner. Just as the Internet has evolved from a highly decentralized infrastructure into an increasingly centralized system, controlled by but a handful of large online operators, there is always the risk that behemoths will also eventually emerge in the blockchain space. If we as a society really value the concept of a true sharing economy, where disparate groups of individuals can coordinate and cooperate on a peer-to-peer basis, and those producing value are fairly rewarded for their efforts, it behoves us all to engage and experiment with this emerging technology, exploring the new opportunities it provides and deploying large, successful, community-driven applications that enable us to achieve the promises of a true collaborative economy within the context of new productive cities.

Artificial Intelligence and Urban Community Memories

Luc Steels

The rapidly burgeoning human population, with its spiralling numbers of city dwellers living urban lifestyles, demands an extremely efficient use of resources, particularly for transportation, communication, food provisioning, and manufacturing. For many cities, the population explosion has already proven too much to handle, leading to unbearable pollution, chronic health problems, deep inequality, and political paralysis due to lost cultural coherence. It is within this context that the Fab Lab movement was born. The empowerment of citizens and equal-opportunity access to resources, manufacturing, and distribution are its key tenets. Information technology is a critical component to the Fab Lab strategy, and Artificial Intelligence is the icing on an IT cake.

Artificial Intelligence

Artificial Intelligence, or AI, has become a hot topic of late, as the pendulum has swung from widespread underestimation (the dismissive notion that AI will never work and is useless) to near-universal overestimation (the idea that AI will soon lead to superintelligence and overtake the human species). The truth lies somewhere in the middle. Yes, AI can be very useful. But that doesn't mean it's going to lead to superhuman intelligence anytime soon. Proponents of the latter theory either totally underestimate the human mind and the force of human collaboration, or they're wildly mislead as to exactly what AI can achieve today—probably due to a dangerous cocktail of limited technical competence and overexposure to propaganda from companies with large stakes in AI.

"AI is not a single object or process but a large and growing arsenal of insights, methods, and techniques for adding intelligence to information systems."

It's important to keep in mind that AI is not a single object or process but a large and growing arsenal of insights, methods, and techniques for adding intelligence to information systems. Deep Learning is just one of these techniques. Other examples include reinforcement learning, the representation and acquisition of vast knowledge networks (such as Google's Knowledge Graph, with its more than 70 billion facts); grammars and dialogue strategies for conversational agents (such as SIRI); sophisticated implementations of logical inference; and many others. Each application requires different AI components, some of which already exist and others that are yet to be developed. Components must always be adapted to the task, through processes including machine learning of statistical models on big (and small) data; "reading" texts, such as Wikipedia or scientific papers; and through careful design decisions to determine which algorithms should be used and how they will interact. In any case, a critical component of AI is the availability of data and knowledge. There's no magic!

Obviously, AI has potential applications across the entire manufacturing process. It can help in defining functionalities such as what to produce, in what quantities, by better tapping into the customer base and recognizing feedback patterns among users of existing devices. It can help in design by making it possible to search through a huge set of existing solutions, or propose adaptations that fit with the intended purpose of a new design. It can help in the manufacturing process itself by automatically programming machine tools with high-level specifications,

or by controlling flexible robotic tools. It can also help in quality control—and, in fact, quality control has become AI's main application in manufacturing today. Finally, it can help in orchestrating the distribution and transportation of products. AI is already being used in centralized manufacturing for all these functions, and there's no doubt it will play an ever-larger role in the kind of distributed digital manufacturing that's practised by Fab Labs. Many in the Fab Lab community will particularly applaud AI's increasing role in designing objects and automatically programming Fab Lab tools.

But in the rest of this essay I'll focus instead on the other aspect of the Fab Lab strategy—namely, how to make better, more liveable cities by empowering citizens. Today, the term "smart city" refers largely to gathering more data about the activities of citizens and the state of the urban environment. However, all this data is useless if it's not followed up on with powerful data analytics, in which AI is playing an increasingly important role. Moreover, a lack of citizen understanding about the type and extent of data gathered on them will lead to a sense of disempowerment. Citizens must be able to visualize this data themselves and see the consequences of their actions. It's obviously preferable that citizens themselves engage in data gathering and provide computational resources or expertise in data interpretation, rather than the data being gathered behind their backs, via hidden sensors, and processed by private companies without any oversight.

Community Memories

Quite a few projects in several Fab Labs have been trying to make this vision a reality. Here, I'll hone in on case studies about pollution, which in its many iterations (air, water, soil, food) of course constitutes one of the main worries of big-city residents. Pollution, however, is a largely invisible and a silent killer—that is, until it's quantified and made public. Systematic measurement is more complicated than it sounds. Not all players want the numbers to be made public: Revealing the extent of pollution affecting a given neighbourhood could have palpable consequences for economically powerful entities. Also, concrete facts and figures can help shape public opinion and, thus, political consensus on such sensitive subject as car use or whether to allow the docking of cruise ships. So how can citizens be empowered to pressure their government to be concerned with the common good? How can a consensus be established?

"A lack of citizen understanding about the type and extent of data gathered on them will lead to a sense of disempowerment."

"So how can citizens be empowered to pressure their government to be concerned with the common good?"

Around 2005, I introduced the notion of a community memory (Steels, 2007) as a fundamental information structure to help in the collective management of "commons"—the things we share, such as water, air, oceans, fertile land, space, money, and resources for handling mail. The Nobel Prize-winning economist Elinor Orstrom (1999) has argued that it's neither the state, nor the market that are the best-suited for managing the commons, but rather those who are directly affected. But putting that principle into practice is difficult. The tragedy of the commons occurs all too readily: Often, there are members of the community who take more than their fair share; there are those who are only users, and not providers; those who are, in effect, destroying the commons. All cases of pollution boil down to a tragedy of the commons. When people decide to take their car to work, they're effectively using the air—a common resource—and partially compromising its quality for everyone else. Those drivers are also taking up space on roads and parking spots. If too many others are doing the same, the air quality gets to a point where nobody can breathe, where the roads are so clogged that nobody can move, and where critical green spaces are paved over for parking.

A community memory is designed as a tool to help communities manage their commons. The term "community memory" dates back to the 1970s, in reference to the first electronic bulletin board set up in Berkeley, California (Colstad and Lipkin, 1975). The system became a forerunner for many shared networks and information sources, such as the World Wide Web, or social media like Facebook. The term came up again in the 1980s, when the focus of AI began to shift away from reaping knowledge from an individual expert to harnessing the encyclopaedic knowledge of a community (Steels, 1989). At that time, however, the term community memory didn't yet refer to a tool for managing a commons.

Over the past two decades, community memory came to be seen as a distributed information structure, crowd-sourced with data, commentaries, and knowledge provided by community members for keeping track of their commons—thus instilling a sense of responsibility so that everybody takes better care of the commons and coordinates its production and usage. It now routinely uses AI to create insightful maps, detect trends, predict the future evolution of the commons and the consequences of certain actions, as well as explanations for all this through

natural interfaces, like human language. A community memory should be public and accessible, at least by the community members, through a continuously updated web page, for example.

Although the dream of community memories was already in existence at the beginning of the 21st century, turning it into a reality has required a number of non-trivial enabling technologies, in addition to the software tools for setting up and running the community memory itself. Many of these technologies are now in widespread usage; others still have to mature. Those that are already readily available include the following:

1. Near-universal Internet access, and the democratization of the tools for setting up and maintaining websites. This has largely been achieved, due, in part, to the availability of the web and other Internet tools on mobile phones.

2. Tools for social networking among community members. This has also been largely achieved through the exponential rise of social media, which began around 2005 and exploded in 2010.

3. Facilities for geomapping, which is an important aspect of many common resources that include spatial location. This has also been achieved thanks to the widespread availability of maps and geolocation embedded in a variety of devices, including mobile phones.

Enabling technologies that are not yet so widespread include:

A. Ways to access large computing resources without the cost (and pollution) of centralized supercomputing centres. Such computer resources are needed for data processing, data storage, AI, and simulation. I'm not able to discuss the issue further here due to page limitations, but See Hanappe (2010) or D'Hondt et al. (2012) for concrete experiments in how communities can harvest huge computer resources by banding together and using laptops, mobile phones, game stations, and even television sets.

B. Devices for participatory sensing, so that members of a commons are able to perform measurements and upload them to the community memory. The remainder of this essay delves into this aspect, partly because Fab Labs have played a significant role in it. My focus will be on examples of air pollution monitoring.

"The dream of community memories was already in existence at the beginning of the 21st century, turning it into a reality has required a number of non-trivial enabling technologies."

Participatory sensing of air pollution

Around 2005, the first consumer-oriented smart phones started to appear, and with them, the possibility of using them for participatory sensing. There are official institutions measuring air quality in all cities, such as airparif in Paris (https://www.airparif.asso.fr). However, such sites are often hampered by drawing on too few measuring points. (Pollution levels can differ greatly from one side of a city to another.) Therefore, the prospect of using distributed participatory sensing was welcomed by many, including action groups that were frustrated by sluggish government action. Several projects began to take shape, such as the Participatory Urbanism Project, from Intel Research Berkeley, or the DAPPLE project at UC London. Together with Eugenio Tiselli, who already worked on community memory-like projects with artist Antoni Abad in Barcelona, we developed a first prototype for using smart phones for participatory sensing of pollution at the Sony Computer Science Laboratory in Paris in 2006, attaching a low-cost Nitrogen Dioxide (NO_2) sensor to a phone using an Arduino Bluetooth microcontroller that could send sensor data to a Symbian NOKIA smartphone. The phone was able to log the data, along with time and geolocation information, and send it via MMS to a web server. Users could also add tags to record their own experience. The data was then aggregated and projected on maps.

However, experiments in the streets of Paris throughout the course of 2007 made it clear that it was not possible to get scientifically reliable measurements to the standards required by official institutions. The measurements were certainly not admissible in the kinds of lawsuits that citizens are now increasingly launching against city governments that fail to act to curb air pollution. The main issue was finding reliable but not-too-expensive sensors and consistently calibrating them properly. Like most other sensors, NO_2 sensors are sensitive to many aspects of the environment, and getting relevant data requires those other factors to be reliably measured, as well. In addition, sensors may demonstrate spurious behaviour, requiring constant supervision, and they also need to be used in conjunction with top-down modelling, in order to reduce noise and avoid erroneous outliers. Measurements need to follow standardised protocols to allow for comparison across locations and time points. Furthermore, the data has to be interpreted in categories that are meaningful to citizens—and not only graphically.

Our initial experiments taught us that to be of any value and to get the measurements right, citizen science projects must adhere to proper scientific principles and procedures. This requires the use of sophisticated AI techniques to bridge the gap between scientists, experienced in physical measurement, and citizens dealing with signal processing, detection of patterns, categorization of data, prediction of future data based on simulation, and data visualization. Because attempts to secure European project funding to carry out the foundational research and scale up testing failed, the efforts at Sony CSL Paris and its various partners—experts in local air simulation, sensor technology, measurement strategies, etc.—were put on hold.

A decade later, the dream of participatory sensing using mobile devices remains largely a dream, even though the technological resources for participatory sensing (for example, the availability of sensors or AI systems for analysis and prediction-making) have improved, and Fab Labs have made it possible to release designs in open source for digital fabrication. One of the best-known examples is the Smart Citizen kit, which was developed by Fab Lab Barcelona in cooperation with De Waag Society in Amsterdam. The specifications of the device, as detailed on their website (https://smartcitizen.me/about#hardware) are as follows: "The Smart Citizen Kit is a piece of hardware comprised of a sensor and a data-processing board, a battery and an enclosure. The first board carries sensors that measure air composition (CO and NO2), temperature, humidity, light intensity and sound levels. Once it's set up, the device will stream data measured by the sensors over Wi-Fi using the FCC-certified, wireless module on the data-processing board. The device's low power consumption allows for placing it on balconies and windowsills. Power to the device can be provided by a solar panel and/or battery. The Kit is not another black box compatible with Arduino." The major step forward lay in the relative ease of fabrication. All the design files are open-source (schematics and firmware) and can be produced digitally and simply assembled.

Unfortunately, testing in real world circumstances showed that the Citizen Science Kit did not fare better than the phone-based air quality assessments like the ones we carried out in Paris. (See the evaluation report by van den Horn and Boonstra, 2014). The NO2 sensor turned out to be unusable in outdoor environments, and similar problems plagued sensor calibration, data interpretation, measurement protocols, etc. Many participants reported

"Citizen science projects must adhere to proper scientific principles and procedures."

"The dream of participatory sensing using mobile devices remains largely a Dream."

"Fab Labs have made it possible to release designs in open source for digital fabrication."

having had trouble connecting their kit or making it work reliably. Nevertheless, the project again underscored citizen's enthusiasm and eagerness to take part in measuring their environment. Participants reported a very strong uptick in their willingness to hold governments and official institutions to account.

Do the difficulties of these prototype experiments mean that the dream of empowering citizens to tackle pollution in their urban environment through participatory sensing should be abandoned? Certainly not.

First of all, the experiments described above demonstrate that achieving this goal will require a much more thorough scientific approach; the collaboration of official institutions tasked with measuring air pollution; as well as more sophisticated technology, particularly AI, to bridge the gap between expert knowledge and citizen action. This of course means securing more funding, and the past decade has repeatedly shown just how hard getting such funding can prove. There are also other aspects of air pollution that can be measured. Take, for example, a very successful, on-going project measuring fine particles: It's based on attaching an add-on in front of the smartphone camera that transforms it into an optical sensor, suited for measuring the macro- and microphysical properties of atmospheric aerosols. The add-on measures the (intensity) spectrum and the degree of polarization for visible light (Snik et al., 2014).

"Do the difficulties of these prototype experiments mean that the dream of empowering citizens to tackle pollution in their urban environment through participatory sensing should be abandoned? Certainly not."

Secondly, there are now a number of projects in participatory sensing of NO2 air pollution that have been successful, although they no longer use mobile phones or special kits but rather more traditional means. One is a Belgian/Flemish project "CurieuzeNeuzen," or "Curious Noses," (https://curieuzeneuzen.be/) established by official institutions dealing with air pollution in collaboration with environmental scientists of Antwerp University and the Flemish Institute for Technological Research, experts in air quality measurement and environmental simulation. A pilot project involving 2,000 citizens took place in 2016 in the city of Antwerp, and a more extensive project involving 20,000 citizens (selected out of around 50,000 volunteers) was completed in May, 2018. The high levels of public interest and participation resulted from a finely tuned media campaign, as well as the decision to mark measuring points very visibly. A similar smaller-scale project took place in Brussels in May, 2018, and the results, particularly near schools, were so disturbing that they triggered outrage

and protests among teachers, parents, and even the schoolchildren themselves.

In the Belgian projects, participants "installed a simple, standardized measurement device on a street-facing window of their house, apartment or building. Two diffusion tubes determine the mean concentration of nitrogen dioxide in the ambient air over one month. The samplers are attached to a V-shaped window sign commonly used in advertising real estate in order to establish a standardized measurement setup. The data collected from the diffusion samplers are quality controlled and calibrated with NO2 measurements at reference monitoring stations operated by the Flemish Environment Agency." (https://curieuzeneuzen.be/) Data was centrally extracted from the tubes, aggregated, and visualized, and the results were then made public. The impact clearly demonstrated the kind of effect participatory sensing can have, touching off citizen demands for government action.

Participatory sensing of air pollution

Finally, participatory sensing using mobile phones has proven quite successful for noise pollution monitoring—another major citizen concern. Right after completing the air pollution experiments at Sony CSL in Paris in 2007, I started working with Matthias Stevens, Nicolas Maisonneuve, and Peter Hanappe on another approach—namely, to use phones as mobile sensors for noise (Maisonneuve et al. 2009). Given that phones already have built-in microphones, this seemed like a natural focus. Nevertheless, once again it quickly became clear that you could not simply feed the recorded sound into signal processing algorithms to determine exposure to noise because sound processing in phones is highly optimized for human speech. But still, such hurdles proved easier to overcome than the technical obstacles for air pollution.

A system, called NoiseTube, was launched in 2008, in the form of a freely downloadable app and various web-based visualisation tools. Around 2010, the NoiseTube project moved to the VUB Artificial Intelligence Laboratory (Stevens, 2012) and later to the VUB Software Programming Group, where physicist Ellie D'Hondt further fine-tuned the quality of the measurement to make it scientifically adequate. The NoiseTube system was progressively extended to contain other tools one would expect for a community memory, such as social tagging, collective

"The impact clearly demonstrated the kind of effect participatory sensing can have, touching off citizen demands for government action."

"Participatory sensing can achieve similar levels of accuracy to the "official" scientific instruments."

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city-wide noise maps, AI-based sound classification, tools for feedback and opinion exchange, mechanisms for securing users' data privacy, and the inclusion of volunteer distributed computing (D'Hondt et al. 2012).

Around the same time, the NoiseTube system became part of a large-scale project set up by Catherine Lavendier, of the Univesity of Cergy-Pontoise, that brought together the official organisation for monitoring noise pollution in Paris, Bruitparif, and the city of Paris. This project also has been able to prove that when done properly, participatory sensing can achieve similar levels of accuracy to the "official" scientific instruments.

Conclusions

AI methods and techniques are very relevant to the goals of the Fab Lab network. They can partly help to make tasks like design and the programming of machine tools more doable for less-experienced citizens and can also play a major role in setting up a community memory—an information resource where citizens can upload data, comments, opinions, and knowledge in order to manage and define their commons. I focused here on examples from the domain of air and noise pollution, although this approach also has wider applications. AI can play a role in interpreting sensors; for prediction aimed at improving sensory interpretation or informing the community about the future state of their commons; for finding patterns in data; for structuring and querying based on social tags; as well as other applications. Much work remains to be done, but there is a sense of urgency, informed by a need to act before the environment is irredeemably destroyed.

Building Bridges for Circular Networks of Fabrication

Stephan Sicars (UNIDO)

The mandate of the United Nations Industrial Development Organization (UNIDO) is the support of Inclusive and Sustainable Industrial Development (ISID) in developing countries and economies in transition. For 50 years UNIDO has worked towards a truly sustainable industry and recently it has embraced the circular economy concept as a strategic topic consistent with its mandate.

Circular economy is a way of creating value and ultimately prosperity, where products are designed for durability, reuse, remanufacturing and recyclability, and where materials for new products are derived from old products. The circular economy will offer opportunities for networks of small, flexible enterprises for exchange of concepts and knowledge across borders, as well as possibly sharing of manufacturing tasks locally.

The transformative potential of a new wave in digitalization covering technologies of computation, communication, automatization and innovative local fabrication offers the opportunity to enable a transition towards a circular economic model based on a global and distributed flow of data (and knowledge), and local flows of materials.

These technologies have the power to connect global networks of hyper-local infrastructures for fabrication, production and distribution of goods and resources.

Cities, by nature being connected to industrial value chains, can radically transform production and consumption patterns within their metropolitan regions. This could be achieved by adopting strategies that focus on smart customisation, interconnected processes, and most importantly: empowering citizens and communities.

This article looks to the growth and potency of digital technologies as the creative hub of the so called fourth industrial revolution as a transformative force to realise the circular economy. The article also describes UNIDO's commitment to work with the international Fab Lab and Fab City networks consistent with the organization's mandate.

Context

The urbanisation process is closely related to the first industrial revolution, which on one hand created locally large amounts of highly specialised jobs, and on the other hand allowed for the rapid reproduction and replication of largely standardized infrastructure and products around the world. Mainly, urban dynamics in cities of today reflect this standardization and the associated linear economy of manufacture-use-waste. This urban model consumes most of the world's resources and generates most of world's waste.

In many periods of history, urbanization and industrialization have proven to be complimentary drivers for development. Industrialization has acted as a catalyst for urbanization by stimulating economic growth and creating jobs, attracting people to move to cities. Likewise, urbanization has created socio-economic benefits from concentrating people, resources and investment, increasing the potential for economic development, social interaction and innovation.

Similarly, the Fab Lab and Fab City networks can be seen as an innovative way to link urbanization and industrialization in today's world. Several advanced economies are already implementing the concept of Industry 4.0, marking the Fourth Industrial Revolution. Increasingly, companies are applying innovative solutions, including the "Internet of Things" (IoT), cloud computing, miniaturization, and 3D printing that will enable more interoperability and flexible industrial processes and autonomous and intelligent manufacturing.

Using these and other concepts of Industry 4.0 for circular economy purposes has the potential to improve competitiveness, labour conditions and local community well-being. In addition, using Industry 4.0 this way will substantially increase energy and resource efficiencies and hence decrease the use of natural resources and protect the environment. UNIDO's mandate, to support inclusive and sustainable industrial development (ISID), is fulfilled very well by applying industry 4.0 to circular economy. The structures that Fab Labs and in particular Fab Cities form, with groups of SMEs cooperating matching innovation with experience and capacity, help to create "inclusive" development because many persons with diverse backgrounds participate and benefit, and "sustainable" development since their activity helps to reduce natural resources use and negative environmental impacts.

Inherent to industry 4.0 technologies is the power of open source hardware and software solutions. Recently, 'blockchain' based applications have shown their transformative potential to provide authenticated data communication between each player in a supply chain without the intermediation of a trusted central organization. With that comes transparency and material traceability, reduced administrative costs, lower risk of fraud and grey market trading and better control of outsourced contract manufacturing.

Constantly evolving digital technologies have the capacity to support UNIDO's work and its projects, such as: circular economy initiatives, eco-industrial park developments, and contribution to sustainable cities. Collectively, these developments will lead to the emergence of more sustainable production and consumption patterns, and could thus provide opportunities for developed and developing countries alike to achieve economic growth in line with the 2030 Agenda for Sustainable Development.

Opportunities for collaboration

As mentioned, FabLabs and Fab Cities can be agents of change towards a more inclusive, environmentally friendly way to operate the economy. UNIDO's Department of Environment wishes to explore the possibilities to collaborate with the network of Fab Labs. We see interesting and promising options for developing relations and interactions between Fab Labs, normally located in urban areas, with nearby artisans and small-scale conventional manufacturers, as well as with industrial facilities located in peri-urban areas. Collaborations in industrial applications of eco-design, and industrial processes of acquisition, reprocessing and remarketing could be explored.

The main focus will be on the circular economy principle, which will be catalyzed by the use of new digital technologies and logics of production that are part of the Industry 4.0 paradigm. UNIDO believes that the use of robotization, artificial intelligence, 3D printers and other innovative technologies for production, as well as the raising of open source and distributed knowledge

management will most likely have a major impact on the development of circular economy. Circular economy faces widely distributed goods far from their original manufacturers, which need to be to be renewed and improved for better experience wherever they are; this needs facilities and networks in and around urban centers, but the necessary know-how can be blended from different sources, either local or over long distances. We therefore see working with industry 4.0 and digitalization solutions in developing countries to have a significant potential to support UNIDO in fulfilling its mandate.

UNIDO related environmental work supports circular economy models, in particular for developing economies. Many of our projects already address various building blocks of a circular economy and can be linked with industry 4.0. Some projects support cleaner manufacture of products, others help develop safe, easy-to-recycle products with longer lifetimes and still others deal with resources recovery. Future projects will focus substantially on extending product life and innovative solutions for upcycling. UNIDO projects contribute to the restructuring of value chains towards a circular flow of materials, achieving reduced resource consumption.

Another good example of this linkage is the UNIDO works on eco-industrial parks (EIPs), where industrial synergies between different companies are fostered and could greatly benefit from open source and distributed knowledge. EIPs are also strongly interrelated with UNIDO sustainable cities programme. The role of cities in the context of the circular economy and the Industry 4.0 paradigm is paramount, as they are the most important beneficiaries and actors of the linear economy and, at the same time, the biggest centers where circular economic solutions are currently developed.

In this respect, the city will have to redefine its relationship with the industries located in the surrounding or peri-urban areas, in order to maximize the efficiency in resources and wastes management. Here, the link between SMEs, normally located in urban areas, and facilities or industrial parks, placed in peri-urban areas, will be of high importance.

UNIDO is in support of the Fab City initiative, involving citizens in a more sustainable urbanization, where ecological systems are developed around the whole life cycle of products, where the flow of materials is circularized and energy more efficiently consumed. This initiative is a great opportunity for participating cities to advance their transition towards circular economy. It will create new types of jobs and professions related to the knowledge economy and the development and implementation of new approaches and technological solutions. The circular economy is the sustainability framework that supports the emerging fourth industrial revolution, and UNIDO is the partner for Fab Lab and Fab City networks sharing this vision.

Decolonizing Digital Fabrication Case studies in generative justice

Ron Eglash

Why do pressing social problems—environmental degradation, labor insecurity, ethnic and gender inequality, and so on—look so much alike in both capitalist and communist societies? Systems designed to extract value—whether that value is delivered to private corporations or centralized states—are inherently flawed: Once value has been alienated, it's nearly impossible to restore. But defining what it means to nurture value mobility in unalienated form—circulated rather than extracted—is by no means obvious. By collaborating with indigenous communities, urban artisans and others, our research group has explored "generative justice" as both theoretical framework and experimental intervention. Here we report on our results with computational, thermal, and mechanical systems that expand the circulation of unalienated value in three domains: labor value, ecological value, and expressive value. From heritage algorithms for STEM education to solar ink for West African fabrics, generative justice can guide us, bottom-up, towards a just and sustainable future.

"From heritage algorithms for STEM education to solar ink for West African fabrics, generative justice can guide us, bottom-up, towards a just and sustainable future."

Introduction

The Fab City international initiative represents an exciting call to move towards a just and sustainable future. At the same time, it's impossible not to hear echoes from the colonial past. The Gershenfeld brothers' recent Fab Lab manifesto is entitled Designing Reality, and it would be hard to imagine a name that would more vividly invokes a "Masters of the Universe" vibe. The word "universal" occurs 47 times in the book, usually describing the importance of standardizing a single universal set of machine communications across the globe. The colonial undertones are not restricted to the metaphorical realm: In light of the fact that Chevron Corporation's activities have caused billions of dollars in environmental damage in Ecuador, Brazil, Angola, Nigeria, and elsewhere, what should we make of their $10 million dollar donation to Fab Labs? How might the $2.8 million in Fab Foundation funding from the Department of Defense diminish the network's educational efforts and activism aimed at fabricating products and promoting practices that oppose the U.S. military's hyper-inflated budgets, saber-rattling aggression, slick youth marketing, and covert drone killings?

"The Fab City international initiative represents an exciting call to move towards a just and sustainable future."

"it's impossible not to hear echoes from the colonial past."

To clarify: I'm a firm believer in the Fab City vision and an enormous fan of the Gershenfeld brothers' work. Neil's focus on "generative design" puts his finger squarely on the crux of the issues. Joel's brilliant analysis of

the contributions that unionized workers made to the resurgence of the U.S. auto industry (Cutcher-Gershenfeld et al. 2015) is a firm rebuke to anyone who suspects that Fab Labs are an anti-labor conspiracy. Alan's role in the acclaimed Iñupiaq game Never Alone represented a breakthrough in replacing the thin ethnic veneer so commonly masquerading as "inclusion" in digital media with a deep collaboration that included native writers, artists, elders, and the first indigenous-owned game developer and publisher. But if Fab Cities are to achieve their goals, we cannot afford to be naïve about the lengths to which multinational corporate giants and militant nationalism will go to hold onto power.

One might be tempted to think that if the problem is corporate power, then Marx's communist framework could represent be the solution. But the history of state communism—from Stalin to the Stazi; Ho Chi Minh to Hugo Chavez—has been unrelentingly bleak. Marx and Engels set the tone in 1850: "A revolution is certainly the most authoritarian thing there is... and if the victorious party does not want to have fought in vain, it must maintain this rule by means of the terror which its arms inspire in the reactionaries." Replacing the corrupting force of banks, corporations and Wall Street greed with central planning, secret police, and state bureaucracy creates no change at all.

Where did Marx go wrong? His initial concept was sound. In his 1844 "comment on James Mill," Marx includes a portrait of a traditional, pre-capitalist village artisan: a woman whose pride is derived from the fruits of her labor, and whose feeling of belonging comes from being enmeshed in a rich social network of exchange. In his later "Ethnological Notebooks" Marx showed particular interest in the descriptions of Iroquois life, as related by anthropologist Lewis Morgan, whose work shed a great deal of light on their communal sharing and gender-egalitarian relations.

When Marx contrasts these traditional ways of life with the scene within a capitalist factory, we see immediately how labor has become alienated from workers. There's no pride of craft in simply turning the same bolt on an assembly line all day long, and little source of identity or social connection, either. A bit of the value that's extracted from these factory workers is returned in the form of wages, and so they attempt to fill the hole in their lives through consumption: We move from Homo Farber, man the maker, to Homo Emptor, man the shopper. At first only the means of production was transformed to

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"Leaving value in its unalienated form and allowing it to circulate in a commons, as was done in the indigenous tradition, is actually far better for both people and the planet."

maximize capitalism, but once commodities become our identity, "subsumption" takes over, and all social functions are sucked in. Our relations with people, nature, built environments, religion—all become transactional.

Marx mistakenly believed that the problem was not extraction, but rather the fact that the value begotten from extraction was delivered to capital. He proposed that a communist state could gather this extracted value and redistribute it, according to needs of the people. But it turns out that mindless bolt turning in "the people's factory" isn't any more enjoyable (Burawoy 1985). The misplaced optimism that a centralized bureaucracy, run by elites, would know how to make working class environments empowered and enjoyable seems naïve in retrospect. But Marx felt he had no choice: In the absence of value extraction by a centralized state, the only alternative to capitalism would be indigenous life in the village, teetering on the verge of starvation and perennially unable to rise beyond what he called "nature's paltriness" (natur-bedurftigkeit).

Despite his radical political stance, Marx held a colonial, hierarchical view of cultural that placed Europeans at the top. Marx was not only wrong about the health implications of indigenous economies—their dietary habits were often far better than Europe's penchant for fat, sugar and white flour—but also about their relation to nature. Figure 1 (p.52) shows a satellite image of the border between the USSR and Mongolia. The centralized communist economy—armed with the latest science and technology and organized for "winning a war against nature"—led to massive desertification. The indigenous herders on the other side of the border, on the other hand, prevented a "tragedy of the commons" by relying on centuries-old collaborative relations that circulated value in unalienated form—milk, dung, brush reduction, sacred ritual, crafted artifacts and so on—among one another and with their fellow non-humans in the local ecosystems.

Thus Marx's error was assuming that the only way to meet modern needs in health and human services was to require that both labor value and ecological value be alienated, extracted, and centrally redistributed. On the contrary, leaving value in its unalienated form and allowing it to circulate in a commons, as was done in the indigenous tradition, is actually far better for both people and the planet. This essay describes our experiments in merging these unalienated forms with Fab Lab-style production

techniques. The hybrid of the two—a sort of cyborg ecosystem—is not a "tech fix." It requires innovation in social, technical, and environmental domains, as well as the restoration of diminished histories.

Before leaving the counterexample of the USSR, it's helpful to look at a third form of value, the semiotic realms of spirituality, sexuality, media, arts, and other forms of expression. Some scandals of wanton capitalist environmental destruction in the U.S. resulted in books, like Silent Spring, and protests, like Love Canal, that ended up mitigating some of the damage. Communist suppression of human expression not only created a crisis in human rights, it also encouraged environmental destruction by suppressing public scrutiny. Bottom-up liberation of expressive value is just as crucial as the emancipation of labor and the flourishing of nature's non-humans.

Thus, the fundamental principles of generative justice extend across all value forms, with a particular focus on labor value, ecological value, and expressive value. They are:

The universal right to generate unalienated value and directly participate in its benefits; the rights of value generators to create their own conditions of production; and the rights of communities of value generation to nurture self-sustaining paths for its circulation.

Ethnocomputing and generative justice

Applying generative justice to Fab Labs means that contemporary fabrication techniques are facilitating, nurturing, or extending the ways in which labor value, ecological value, and expressive value are able to circulate in unalienated form. Elsewhere (Bennett 2016, Eglash 2016a, 2016b, Kuhn 2016, Lokko and Eglash 2017, Lachney 2018) we have reviewed these concepts in greater detail, but due to space constraints, a few words will have to suffice here.

At its core, the word "generative" in the term "generative justice" refers to a self-generating system. Neil Gershenfeld provides wonderful insights on precisely this recursion in chapter 3 of Designing Reality, describing life as self-evolving and humans as self-aware—hence, the need to establish Fab Labs in the near future on the basis of a self-assembling process he calls "generative design." But he misses an opportunity when celebrating John von Neumann

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"A far better connection between algorithms, social justice and sustainability can be found in various indigenous traditions around the world, rather than in computational systems."

as the father of self-reproducing automata, stating that it was simply because von Neumann was "interested in understanding life."

Heims (1980) details how von Neumann's precarious survival as a young Hungarian Jew evolved into a lifelong quest for imposing mathematical order on the world. He invented game theory to prove that politics was a zero-sum competition, and his work on the Manhattan project—where it was his calculations that showed how to create fission by implosions, and his calculations for maximizing civilian casualties that determined the locations and altitudes for Hiroshima and Nagasaki explosions—led von Neumann to call for an immediate nuclear first-strike against the USSR during the cold war. "If you say why not bomb [the Soviets] tomorrow, I say, why not today? If you say today at five o'clock, I say why not one o'clock?" (Heims p. 247). During the Hixon symposium (Jeffress 1951) he stated that in the event of "air raids," "there is no doubt that one can design machines which, under suitable circumstances, will repair themselves." It doesn't take much to see that von Neumann likely considered how his self-reproducing mechanical progeny would populate the earth after humans were wiped out by radiation. He died relatively young age, of a cancer that had almost certainly resulted from his proximity to the nuclear test explosions he loved attending. Neil is wrong when he states that von Neumann took the path to self-reproducing automata because of an interest in life: On the contrary, it was being a merchant of death that drove him there.

Therefore, it follows that if we are in search of a guide on how to keep the value generated by labor, ecosystems, and expression from becoming extracted, and to use computational systems to nurture its circulation in lively, unalienated forms, grim reapers like von Neumann are the last place we should be looking for inspiration. A far better connection between algorithms, social justice and sustainability can be found in various indigenous traditions around the world. For example, in the late 1980s, I observed that aerial photos of African villages looked like fractals: rectangular houses were in nested rectangles-within-rectangles; circular houses in circles of circles, and so on (figure 1). A Fulbright scholarship allowed me to travel around Africa conducting interviews, and I gradually accumulated a casebook of the fractal designs in native textiles, sculptures, adornment and other material forms; as well as in their recursive cosmologies and underlying social mechanisms (Eglash 1999). In the Ba-ila simulation,

(figure 1) we start with a single house and its sacred altar near the back. In the next iteration, the self-replicating line representing the altar becomes the human habitation towards the back of the corral; in the next iteration that becomes the chief's extended family compound; within that, the immediate family, and within that, a village that is only a meter across; it holds the ancestors, who have further recursions in their own realm.

Such representations of the generative power of life are commonly found at the heart of African fractals—whether in sculptures, reminding us of our feedback loops with nature; textiles, as the emergent effects of networks of sociality; or built environments, celebrating ancestral bonds. Take, for example, the difference between my small house and the New York governor's gigantic mansion. It's hard to even put them in the same class of structures; the differences are meant to reinforce our difference in social class. The self-similarity of African architecture, in contrast, ensures that the chief's home is essentially just a slightly larger version of the commoner's homes. The fabrication of artifacts also helps reinforce egalitarian relations. Hunter-gatherer groups in the Kalahari Desert, for example, use the hxaro gift exchange system, which stipulates that meat belongs to the maker of the arrow, not the one who shot it. That means that even those who don't hunt—women, elders, and people with disabilities—can still "bring down game" (although that also comes with the responsibility of "gifting" meat to others).

Inspired by the African fractal tradition, architect Xavier Vilalta created two contemporary fractal buildings in Ethiopia in 2013. A new school vocational school, the Melaku Center, used fractal layouts to create clusters of clusters of buildings, allowing for a more humane, more welcoming campus, with nooks and crannies that can be used as spontaneous meeting places, outdoor spaces for workshops, and microenvironments for plants. A shopping center in Addis Ababa used fractal perforations on the exterior walls, creating a breathable "skin" that reduces the energy needs. And a fractal array of solar cells on the rooftop turns a potentially alienating space into a pleasant outdoor market, generating enough electricity to keep the building powered during blackouts, thus making it more attractive to local merchants. Other applications for African fractals have been showing up in Afrofuturist fashions, arts, and even black literature like Nnedi Okorafor's Binti and Erna Brodber's Nothing's Mat.

Perhaps the most important applications of this "ethnocomputing" approach are to be found in education. We created a suite of these simulations, "Culturally Situated Design Tools," (CSDTs: open access at http://csdt.rpi.edu) which include not only African fractals but also native American weaving algorithms, Latino drum cycle ratios, urban graffiti curves, and so on. In each case, we began by working with tribal elders, community activists, and others to ensure that we made respectful use of the materials; tapped into authentic, unalienated aspects of the practices; and that we were not imposing our own computational or mathematical ideas on their indigenous knowledge. Using controlled studies in which one group of students use typical classroom methods, and the others learn math, computing and other STEM topics by creating designs with these "heritage algorithms," we found a statistically significant improvement for the culture-based group (Eglash et al. 2011; Babbitt et al. 2015; see https://csdt.rpi.edu/publications for a full list).

The scripting interface for CSDTs looks a lot like MIT's Scratch (and, indeed, we share the same codebase, Google's "blockly"). But there is a huge difference. Our research of youth-uploaded projects on the Scratch community (Lachney et al. 2016) showed an overwhelming presence of animations, art, games, music, and stories featuring commodities: 2,960 results for Barbie; 6,530 results for McDonald's; 4,600 for Disney Princess; 8,210 for Transformers; 17,400 results for Call of Duty; as well as numerous others, such as Bratz, American Girl, Strawberry Shortcake, Power Rangers, Care Bears, My Little Pony, Adidas, and Pokemon, which garnered 3 million search hits. The Scratch motto, "We turn children from consumers into producers," seems oblivious to how thoroughly corporations have colonized childhood.

The alternative is not censorship, arm-twisting, or didactic preaching. Rather, we simply start students off with rich cultural connections. Where they take it from there is up to them. On some rare occasions, we've seen students using CSDTs make commercial references—something along the lines of turning a West African adinkra curve into a Nike "swoosh." But that simply confirms that the system is open enough to avoid being censorious. More commonly, we see users creating cultural hybrids: African American students using the native bead loom CSDT to create graffiti tags; Latino students using graffiti curves to create symbols from Mexico; and so on. One Navajo student, looking at beadwork simulations, spotted a

Jamaican flag design, created by an African American student whose parents hailed from the Caribbean. The Navajo student then made her own rug simulation that incorporated Navajo aesthetics. Black students simulating quilts often remark upon our section of white Appalachian quilts, where they find the “radical rose” pattern used in auctions to raise money for the abolitionist cause during the Civil War—a discovery that challenges their assumptions about white working class history. Far from static forms of “identity politics,” cultural algorithms can encourage cross-cultural connections. Rather than being content-agnostic, we need these kinds of “content aware” systems as a means of facilitating paths for generative flow from the bottom-up.

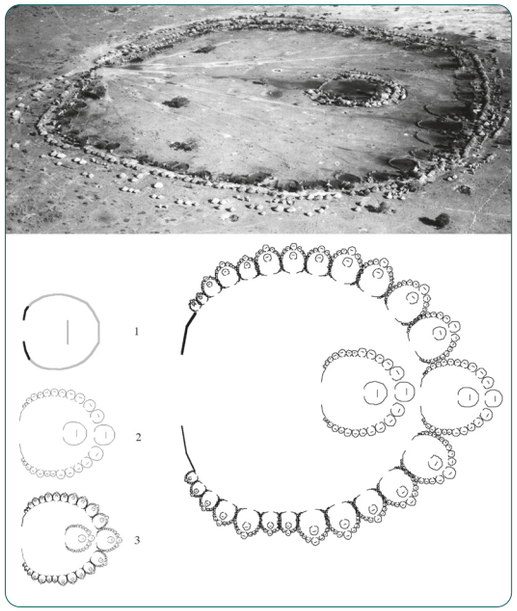

Figure 1: Traditional Ba-ila architecture and its fractal simulation.

In sum, we needn’t think of “unalienated” as a synonym for “natural” or “pure” or “simple”. Appeals to what is “natural” are often harbingers of homophobia, just as calls for “purity” rarely end well. It is only modern agriculture that insists on reducing soil to simplicity. Indigenous agroecology is deeply complex and innovative. Indigenous algorithms can be unleashed in ways that expand their reach, while at the same time retain their power to regenerate communities of origin. But how do we route this flow through the networks like Fab Cities?

Fabricating with Generative Justice

One of the unfortunate tendencies in digital fabrication is to approach the process similar to a kind of universal digestive acid: it eats everything, shits out 1s and 0s, and reconstitutes them, as either homogeneous blobs of plastic or laser cuts, that are oblivious to whether they’re slicing through birch or butter. In contrast, while working with Native American artisans, we noticed their remarkable attention to material microstructure, especially in wood. One Athabascan group was able to distinguish between

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wood from northern and southern sides of the same tree, based on its hardness. Much of our work was carried out with Anishinaabe collaborators (a group which includes the Ojibwa, Potawatomi, Algonquin, and several other Northeastern nations). They made detailed observations about annual rainfall and its effects, noting that tree harvests (in this case, creating strips of bark for lashings) would need to be done closer to the stream than usual because it had been a dry year, thus affecting pliability. The discussions over modulus of rupture led our Anishinaabe language teacher, Kenn Pitawanakwat, to create a new word for it, epiichiiyimigak (which toughly translates as “how much weight it can take.”) As language survival is a major concern, this and other terms have been recorded and can be heard on the CSDT for this activity: **https://csdt.rpi.edu/culture/anishinaabearcs/materials.html.**

It is crucial to understand that these “translations” to Western science are always in some way incomplete. For example, the understanding that trees have “personhood” (Naagidewnjigon) helps ensure ecologically sustainable harvesting (for example, limiting the harvests to a single branch allows the tree to continue to grow; removing one sapling makes room for others to grow larger.) That personhood is also closely tied to these mechanical properties in complex ways. One can be an atheist and still understand the connections, just as one can hold spiritual commitments and still understand the science. In either case, a generative approach to Fab Cities will require the same kind of dedication to egalitarian relations with both human and non-human allies that the Anishinabe have mapped so well.

One of the heritage algorithms that emerged from this work with the Anishinaabe was the persistent use of arcs: bending wood into the ribs of canoes, snowshoes, baby carriers, and, above all, wigwams. While “arcs” might seem simplistic, wood-bending curves can be quite complex (think of the S-shape curls in Ojibwa black ash baskets). The numerical mathematics of wood bending requires Bézier curves (a way of specifying control points, where the wood is anchored, that are acted upon by “blending functions” such as Bernstein polynomials.) Wood bending can be thought of as an analog computer, creating its equations by physical instantiation. We tend to think of mathematics as abstract equations that, once solved, can then be physically rendered as forms. But the mathematicians in this case, Pierre Bézier and Paul de Casteljau, were actually employees of French car

manufacturers Renault and Citroën. Before either went to work there, the beautiful curves of these cars (who can forget the Citroën DS?) were created using wood “splines”, which had been used centuries earlier to model curves for ship construction. In other words, the math first appeared in the form of wood, not equations, both the among the Anishinaabe and among Europeans. The only difference is that while the Anishinabe embrace the connection—trees have personhood and, hence, agentic knowing—Western traditions of intellectual property and egotistical competition strive to erase the connections (which is why have “Bézier curves,” when Casteljau actually developed them first.)

Native students in our workshops begin by reviewing the indigenous understanding that the act of bending stores energy. In the case of bows and arrows, or spring traps, it’s released; in other cases it performs what Buckminster Fuller called “tensegrity,” the structural elements pushing against each other to fill out and stabilize a form. Following the review, students simulate 3D wigwams, reverse-engineering the traditional algorithms by trial and error. Then they begin to creatively elaborate these designs, often ending up with something that looks nothing like the traditional form—a kind of heritage of the future. At this point, we could use a 3D printer or laser cutter, but that would destroy the intimacy with materials. Since the virtual structures all have intersections with virtual ground (thanks to their origins as wigwams), we mark those points on physical boards. A printout of the design provides a list of the required lengths, as well as their points of intersection. Therefore, the students are empowered by the translation to virtual forms, but still reap the benefits from unalienated hand-crafting. Some decide to take the technological path a step further and render designs with electroluminescent wire. Anishinaabe students further advanced their work by writing about new applications they imagined, from flexible room lights, to wigwam-like structures for Martian habitation. One theme of great interest that emerged was the greenhouse. In the next phase of this work, Anishinaabe students will design and build an aquaponics system, bringing structural design together with their “decolonizing diet” program.

A generative justice approach typically starts with a source of unalienated value, but these are easier to identify in some cases than in others. Low-income African American communities have a hair braiding tradition, and their cornrows possess extraordinary algorithmic properties. High school students again began by exploring these designs virtually, but in this case they splintered off into

“A generative approach to Fab Cities will require the same kind of dedication to egalitarian relations with both human and non-human allies that the Anishinabe have mapped so well.”

several directions. One group used 3D printers to create custom mannequin heads that were installed in local salons in a bid to attract more customers. Another group explored the pH of hair products using Arduino-based sensors, which allow them to develop and market their own natural alternatives. Other projects still in exploratory stages include a hair strength meter; laser interferometry for hair damage metrics; and the use of braiding algorithms to explore new forms of carbon fiber structures.

Our most complex example was adinkra, a West African stamped cloth tradition. Our examination revealed that adinkra symbols for living things tended to have logarithmic spirals in their structure—a wonderful connection between the exponential growth patterns, as we would refer to them in the West, and indigenous African knowledge. Ghanaian students being taught the distinction between linear and log spirals not only appeared to grasp the concept better through this model but also displayed unusual enthusiasm. (Many of the students requested to remain after school—a rarity in the math class.) We doscovered that the ink used to make the stamped patterns was derived from tree bark, and that places in which the bark was harvested were not being deforestated. And because the traditional method of boiling bark down to ink generally consumes prodigious amounts of firewood, we proposed a solar alternative. Adinkra symbols also conveyed understandings of health and well-being and were, therefore, an obvious choice for graphic elements in an HIV program. That lead to the development of a DIY condom vending machine, with some parts recovered from electronic waste dumps. Further experiments included using physical scripting blocks, together with miniature stamps, so that students without computers could still learn about algorithms. The network as a whole shows how value can circulate through many different forms while retaining a relatively unalienated character.

Adinkra symbols have also been used in a Batik process in Ghana. The Global Mamas clothing line, which caters to serves an international clientele, trains local women to carve latex foam into wax stamps. However the latex wears out, and because it’s not biodegradable, a noxious pile of synthetic foam bricks has accumulated. We originally approached them about using the CSDT simulations to add an additional skill-set to local training, with the idea that laser cutting foam would nicely link the virtual and physical designs without affecting the hand-stamped character of the product. But concerns about waste send us back to

the drawing board. Figure 2 shows our modified process. The artisans start with an adinkra simulation, in this case, Dwennimmen, the ram's horns (which is yet another lovely case of log spirals). There's a saying associated with this symbol: "It is the heart and not the horns that led the ram to bully," which in contemporary parlance might be taken to mean something along the lines of "just because you are a tech genius does not mean you are relieved of accountability for your impact on the world." The next step prints a 3D mold of the form, which we fill with a mix of fungus spores and sawdust (the creation of a company started by our students here at RPI, Ecovative). Once fully-grown, the stamp can be used just like latex, but has the distinct advantage of being biodegradable.

Pathways to generative fabrication

Indigenous contexts are not the only places where it's possible to bring fabrication techniques and generative justice together. Open source can be thought of as an example of generative justice: its code often leans toward less alienated forms of production, (for reasons more complex than we can describe here; see Eglash and Garvey 2014) and its value is circulated in a commons. Open source models have moved beyond software; they now include open source pharmaceutical research; open media; architectural blueprints; and so on—constituting every bit as as much a "commons" as any indigenous village's pooled resources. Figure 2 shows a value flow network for Arduino, the world's most popular open source microprocessor. It's no coincidence that Arduino was born in Northern Italy, an area of a rich design tradition that economists Piore and Sabel (1984) identified as a center of the rise of "flexible economic networks." (Olivetti typewriters, for example, used to be based in the same city where Arduino is now). Just as African culture can contribute fractals in generative circulations, the traditions of Northern Italy's contributed to the rise of Arduino. In the diagram above, I mapped alienated value flow using single lines and unalienated with double lines.

The upper left quadrant shows the chips making up Arduinos, still sourced from relatively alienating factory conditions. The lower right shows the commons-based "peer production" of lay people's craft: for the most part free from alienation, but also free from income. The critical intersection in the system is the upper right: in this case I showed the LilyPad Arduino created by Leah Buechley.

"Just because you are a tech genius does not mean you are relieved of accountability for your impact on the world."

"Just as African culture can contribute fractals in generative circulations, the traditions of Northern Italy's contributed to the rise of Arduino."

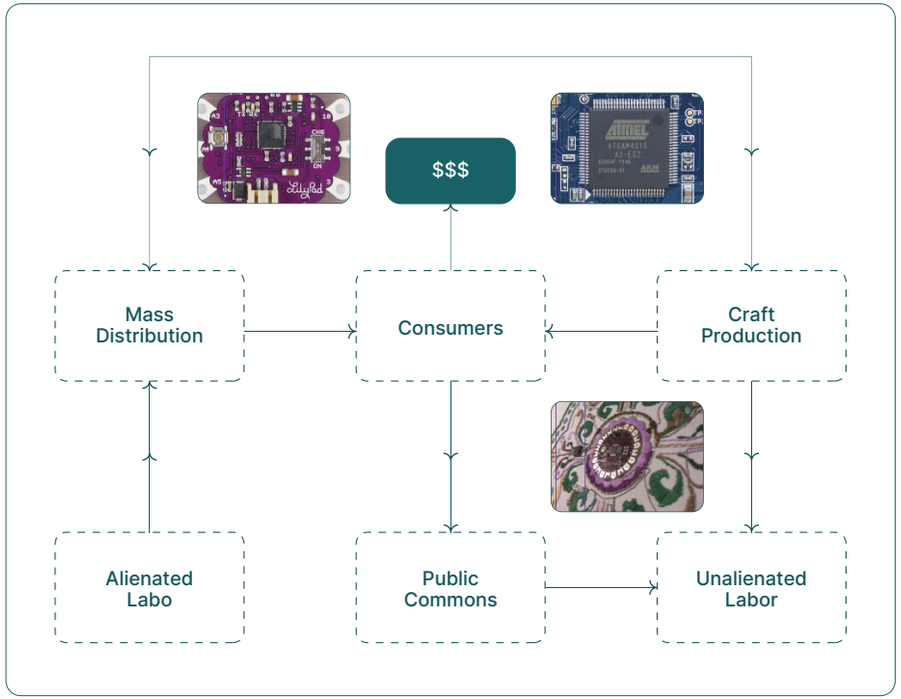

Figure 2: Alienated flow to LilyPad Arduino at left; unalienated at lower right; hybrid at upper right.

Because the Arduino hardware is open source, Buechley was able to redesign it in a form that is more amenable to e-textiles. Her study showed greater numbers of female purchasers of her version of the board, (Buechly and Hill 2010) and it's here that the system gains the most "traction," as it has one foot in the non-profit world of communal sharing, and the other foot in the for-profit (albeit still open source) world of entrepreneurship. The more the right side can be expanded, and the left diminished, the closer we move toward generative justice.

Our team has found that this analysis is generally applicable in many different domains. It's particularly illuminating to examine the lower right quadrant: a "spiritual commons" of shared belief. The pre-existing commons is always a fundamental engine for these systems, but they are not always obvious.

The root and the water

In describing the process for connecting digital fabrication to unalienated value, we often use the metaphor of root and water. The temptation for engineers is to ask for a list of problems they can solve, but such an approach is rarely helpful in expanding creative visions. "Problems" are already understood in terms of existing technological frames. "We need free cell phone minutes" does not create much opportunity for innovation. And proclaiming that we are here to solve your issues encourages over-promising.

A better description is that of root and water: Water gradually percolates through soil; and the root similarly gropes its way underground. Eventually the two will meet, but where, exactly, cannot be predetermined. It's a matter of each side exploring a space of possibilities; seeking promising interstices; and conducting trial and error iterations. Developing an eye for unalienated value is as crucial to the needed skill set as programming or CAD. In some cases, it's simply a matter of spotting artisanal labor—the kinds of occupations that allow capabilities and well-being to flourish. In other cases, it may be unrecognized ecological value. (The entire urban agriculture movement, for example, is largely based on seizing the long-ignored potential of vacant lots.) And expressive value can be overlooked, too. Who knew that rap music would be spun off into spoken word poetry?

"Water gradually percolates through soil; and the root similarly gropes its way underground."

But it is important to see the commons itself—and not just the value flowing through it—as a crucial component. We are used to thinking of the commons in terms of an open source repository, but can be also a kind of spiritual repository. Elsewhere, we've described how Vienna's love for coffeehouses was a kind of circulated value that enabled a project for the homeless; and how a fanfiction commons helped to force a switch to fair trade chocolate (Eglash 2016a). We need Fab Labs that can be conduits for generative ecologies.

"We are used to thinking of the commons in terms of an open source repository, but in the Aravind case it was a kind of spiritual repository."

In mapping out a vision that extends Marx's concept of unalienated labor value to unalienated ecology value and unalienated expressive value, we can begin to gather a more fundamental vision for how generative justice and high-tech fabrication can merge to offer new pathways for just and sustainable futures.

"We can begin to gather a more fundamental vision for how generative justice and high-tech fabrication can merge to offer new pathways for just and sustainable futures."

Is There a 21st Century Ideology?

Thomas Ermacora

The 21st Century has thus far proven a turbulent period for global capitalism. The economic system that emerged victorious from the ideological tug-of-war of the Cold War—and widely regarded, in the aftermath of the telegenic fall of the Berlin Wall, as something akin to a panacea for the world's ills—hasn't fully delivered on its promises. Francis Fukuyama's End of History never happened.

The century started off with the spectacular 2001 burst of the dot-com bubble, and no sooner had the economy found its footing again than the 2008 subprime crisis struck, triggering the lingering malaise of the Great Recession that dragged onfor the better part of a decade.

The meltdown of the financial system and spiking inequalityushered in a period of widespread mistrust of the veryinstitutions that long made up the bedrock of contemporarycapitalist societies: From governments, to corporations, tointernational organizations, a deep disbelief in their ability to address global issues has set in.

"The real and present danger of climate change has raised the stakes exponentially."

Making matters worse, the real and present danger of climate change has raised the stakes exponentially. We've known for decades about just what a serious threat climate change represents. Already in 1973, the Club of Rome in its seminal work The Limits of Growth warned that business as usual could put the very existence of our species and all life on earth at risk. But our reaction over the intervening more than four decades has been tepid and, the scientific community has long insisted, grossly insufficient.

The Paris accord of 2016, in which 193 countries agreed to curb emissions, was a step in the right direction, demonstrating the potential of diplomacy and consensus. But still, such natural disasters as Hurricane Katrina, the centennial floods in Pakistan and the droughts in Syria—which many observers see as fueling the bloody conflict there—are all vivid reminders of the grossly insufficient pace of change.

"Climate change could drive as many as 300 million people out of their homes."

The drama playing out in Syria looks likely to be just the tip of the iceberg: The United Nations estimates that climate change could drive as many as 300 million people out of their homes by 2050. By way of comparison, that's close to the current population of United States.

It has been amply and pointedly demonstrated that the continuation of business as usual is putting the continuation of life as we know it at risk. And still, our battered

institutions have shown themselves to be woefully ill-equipped to deal with these challenges.

From our current vantage point, it would appear that maybe Karl Marx was right, after all: Market capitalism does seem to contain the seeds of its own destruction. But what if capitalism also held the formula for its own salvation? What if the very system that has generated inequality between the global north and south and unleashed a wholesale environmental devastation of life-threatening proportions could be recoded to put the welfare of people and the planet at its very heart?

That's the bold—but no longer unrealistic—proposition that global innovation hubs should be working on: The world of distributed everything, or "swarmonomics," is coming online at an exponential pace. Already, a host of different initiatives are exploring ways of re-engineering capitalism, global supply chains, and mass empowerment. I'd like to discuss two I've been a core player in.

The first emerged from the reach and power of one of the world's most august institutions, the Vatican....

The audacious question was: What if combining the ability to design for scale of the Silicon Valley-style start-ups and the wisdom of a millenary institution such as the Roman Catholic Church could heal the wounds of neo-liberal capitalism? Pope Francis' bold leadership proved the perfect moment to put the idea to the test, particularly in the wake of the 2015 release of his second encyclical, entitled Laudato Si': On Care of Our Common Home. The nearly 200©page-long document casts environmental destruction as a "sin" and calls for a "new way of thinking about human beings, life, society and our relationship with nature."

The time was ripe to bring together two of the world's most powerful drivers—Silicon Valley and the Roman Catholic Church, with its billion-strong flock—to try to find marketbased solutions to the challenges enumerated in Pope Francis' encyclical. There's no reason that companies aiming to do good in the world shouldn't also be angling for huge profits. In fact, skyrocketing profits are exactly what would help strengthen the solutions that are the right ones for both people and the planet. By throwing its weight behind an accelerator, Silicon Valley's tried and true method

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of fostering start-ups, the Vatican could become a partner for the kind of deep societal shifts the pontiff has urged. Thus, the first annual Laudato Si' Challenge came to was born.

The first edition of the challenge targeted startups proposing innovative solutions in seven key areas: energy, food, water, conservation, industry and finance, urban solutions and human potential. More than 300 companies from 20 countries applied for the accelerator, which included an eight-week-long residency in Rome and a $100,000 equity investment. Nine were accepted, including a startup that transforms agricultural waste into clean cooking fuel, a scooter ride-share app and a company producing cheap, portable filters that fit over taps and make contaminated water into potable.

The 2018 edition of the Laudato Si' Challenge will focus on startups spearheading solutions on climate change and addressing the refugee crisis. The goal is that the goods, services and solutions imagined by the companies selected to participate in the accelerator impact the lives of at least 10 million forcibly displaced people by 2020.

"The only real global device we have capable of ushering in such a change is market capitalism."

In order for world's rich, developed nations to make up for the harm they've caused and prevent a global catastrophe, they need to lead the charge toward a radically update of our current systems, revolutionizing our energy supply, technology, supply chain management and wealth distribution. But neither governments nor the third sector can catalyze such a momentous shift this alone. The only real global device we have capable of ushering in such a change is market capitalism. We need many more of this type of accelerators to equip eager Millennials to use the tools of profit-driven capitalism to solve the planet's most pressing problems.

The second is the emergence of a unified maker-for-change collective focused on cities...

Thanks, in no small measure to Benjamin Barber's creation of the Global Parliament of Mayors, consensus has grown over the crucial role cities must play in forging a common route to solving the seemingly intractable challenges that nation states have failed to address—particularly, climate change. At the same time, the pace of technology's

penetration and transformation of society is so great, it has spurred renewed interest more citizen-centric Smart City initiatives.

How ‘makers’ are keeping it local

When the Maker Movement burst onto the scene at the dawn of this century, it was widely seen as a DIY phenomenon that brought bricolage into digital age, providing enthusiasts access, in so-called Fab Labs, access to 3D printers, laser and vinyl cutters, computer numerical control, or CNC mills, and other similar machines.

Over the past decade, though, the Movement has morphed into a global ecosystem for prototyping software-hardware integration. What used to be an informal testing ground for advanced production methods is rapidly becoming the place where next-generation technologists—who can both code and build sophisticated electronics—are honing their skills: Going forward, Fab Labs will be the spaces where everything from the Internet of Things to renewable-energy power stations are conceived, refined and pushed forward.

This shift in the essence of the Maker Movement is very significant, given the lightning speed with which the versioning of technology now moves and the critical role that the ability to beta test and develop new tools plays in the flowering of competitive markets. Through its unorthodox “geek houses,” the Maker Movement has become a key partner in the Fourth Industrial Revolution, helping propel both the digital fabrication industries and the wider digital economy forward. The Movement has also helping counteract widespread urban decline, bringing state-of-the art manufacturing back to the very city centers from which industry fled a half century ago and offering citizens the novel chance to make the items they consume in situ. Not only is on-site manufacturing an effective way of cutting down products’ carbon footprint—much of which results not from making stuff but rather from shipping it—it’s also a way of building enduring employment opportunities and giving resident the skills for success in the Fourth Industrial Revolution.

“The maker movement has become a key partner in the fourth industrial revolution.”

“Not only is on-site manufacturing an effective way of cutting down products’ carbon footprint.”

Multiplying maker districts and the example of London...

London’s Maker Mile represents an interesting case study in the power unleashed when the maker community joins forces in service of its local community. It’s a creative cluster of fabricators, studios and workshops in east London, all located within a one-mile radius. Spearheaded by the Machines Room, the UK’s first Fab Lab, the maker spaces of London’s Maker Mile have been working on collaborative prototypes aimed at analysing local inflows and outflows and streamlining the delivery of services to residents.

Opendesk[1] is an example of one of the Maker Mile supported startups, an online furniture purveyor that uses open-source design and manufacturing to circumvent the dysfunctional global supply chain. Opendesk allows customers to select furniture via an online catalogue and matches them with a local lab in there own city where their design can be 3D printed, thus cutting most of the costly and highly polluting logistical link out of the supply chain.

The Fab City Global Initiative shows how cities, working in concert with local communities and global business partners, can blueprint the next generation of nimble and reactive public service solutions; provide residents with the skill-set to succeed in the Fourth Industrial Revolution; attract business clusters to raise general competitiveness and build urban resilience and, in time, reduce environmental footprints. Indeed, although these are still early days in the Fourth Industrial Revolution, the Fab City Global Initiative offers an opportunity to get in on the ground floor of the movement that is spearheading the shift to a circular economy and more resilient communities.

1 https://www.opendesk.cc

The Science of Making Self-sufficient Cities

Vicente Guallart

2017 marks the 150th anniversary of the publication of the General Theory of Urbanization by the engineer Ildefons Cerdà, author of the Plan for the Reform and Extension of Barcelona. It was the first text in history to present urbanization comprehensively, as a science, and posit that it belonged among the great categories of human knowledge, apt to be included the sorts of rational descriptions that were being outlined at the time.

The technological revolution as a driving force for urban policy

"The General Theory of Urbanization is important because it represented the first internationally published attempt to consolidate a general theory on building and cities."

Cerdà has been studied in detail—his texts, his plan for transforming Barcelona, and his role as founder of the discipline of urbanism having attracted significant scholarly attention. But very rarely has his work been examined through the prism of the technical and social debates that were taking place during his time. Because he wore different hats—as a designer, as a theoretician, and as a manager—his best writings are scattered among different documents, written over the course of a 20-year period (from the memorandum of the preliminary plan for Barcelona's extension to the letters dating from his later years). The General Theory of Urbanization is important because it represented the first internationally published attempt to consolidate a general theory on building and cities.

Cerdà is a faithful reflection of his time, an era when the incipient effects of the Industrial Revolution were changing social, economic and cultural relationships in society. Notions about housing also had to be redefined because cities could no longer accommodate the thousands of people who were flocking in from the countryside, attracted by the new forms of industrial employment.

"The new technologies associated with the advent of the steam engine had a great impact on Cerdà's interest in the future of the city."

In fact, the new technologies associated with the advent of the steam engine had a great impact on Cerdà's interest in the future of the city. In the introduction to his Theory, Cerdà recognizes the decisive impact of an 1844 trip he took to the French Midi, at the age of 27. He recalls already being aware of the significance of the steam engine within the fields of industry and transportation. But it was only when he experienced the railroad for the first time, and fully grasped its ability to move entire populations territories, that he realized that cities were unprepared. And with that realization came the understanding that it was imperative to rethink how we would inhabit cities in the future.

Cerdà also mentions that he looked around for books about the effects these new technologies were having on cities, but to his surprise he discovered that nothing had yet been written on the subject. There were other urban plans for the expansion of cities, such as the plan for New York, approved in 1811, the reforms of London and Paris, and the plan for Vienna, which was in development at the time. But none of them was accompanied by a general theory.

Cerdà had an entrepreneurial spirit. Following the 1848 death of his elder brother, which made him the sole heir, Cerdá put the family's resources toward realizing his vision of expanding Barcelona and contributing to global science. It is surprising that the first draft of the preliminary project for Barcelona's Eixample was presented, through Cerdà's own initiative, to the magazine of the College of Engineers in 1856, accompanied by a small report—despite the fact that Cerdà had only been commissioned to carry out a topographical study of the area.

Throughout his career, Cerdà's ideas developed between two complementary poles: one technical, and the other social. On the one hand, as an engineer he was a techno-optimist, recognizing in science and in the new landscape ushered in by the Industrial Revolution an opportunity to improve people's lives: Technology applied to mobility, housing, construction, and urban policy could be transformational, he believed. Cerdà was also an eminently practical man who based his plans on humanistic principles, aimed at achieving common welfare for all.

The social project: Urbanism or revolution

The other great debate concerning Cerdà's work has to do with the social commitment that comes through in all his work. The beginning of the Industrial Revolution touched off a widespread urbanization process that saw great numbers of people flocking to cities, drawn by the promise of jobs in industry. As many authors have written about extensively, the traditional relationship between landowners and peasants from the rural sphere and the feudal tradition was revamped into the equally hierarchical relationship between the emerging bourgeoisie and the industrial working class. These new social relationships lay at the origin of the French Revolution and social movements in the later decades, as well as the class struggle that gave rise to the Communist movement, for which Marx and Engels

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"The beginning of the Industrial Revolution touched off a widespread urbanization process that saw great numbers of people flocking to cities, drawn by the promise of jobs in industry."

"Marx and Engels published the Communist manifesto in 1848."

published the manifesto in 1848. (It's indeed a coincidence of history that Marx published his Capital the same year that Cerdà published the General Theory of Urbanization.) Some three years earlier, Engels had carried out statistical studies of the working class in London using a similar approach to the one Cerdà would later apply in Barcelona.

As asserted by many authors, Marx authored a foundational theoretical text for Materialist philosophy, economics and politics. It's a brilliant text that explains the history and internal relations of the industrial economy in order to demonstrate need for social revolution as the foundation for a new more just society. While it's a great theory, built no doubt on well-meaning hypotheses, we are all too well aware of the results of its subsequent application in various countries around the world.

"Cerdà belonged to a school of thought that aimed to put technical knowledge at the service of progress, for the betterment of people's lives."

Cerdà, on the other hand, belonged to a school of thought that aimed to put technical knowledge at the service of progress, for the betterment of people's lives. One of its first proponents was Henri de Saint Simon, a French philosopher and social theorist who came of age during the French Revolution whose proposals included founding a state led by scientists and industrialists as an alternative to the tradition, nobles- or church-led model. Saint Simon, along with Owen or Fourier, was later classified as a "utopian Socialist," in contrast with Marx and Engels' "scientific Socialism."

Construction of the sciences

Science and scientific thought as we understand it them today constitute recent phenomena, dating back to the mid-19th century. Where scientific thought had its origins in research on astronomy carried out sequentially by Copernicus, Galileo, Newton, the ideas of structuring any domain of knowledge in a global way, writing scientific treatises, aspiring to find laws and general theories were all new ones.

"Charles Darwin published On the Origin of Species in 1859."

One of the great scientific contributions of those decades came from the naturalist field. In 1859, the same year that Cerdà published his first Theory on the Construction of Cities and approved the plan for the Eixample, Charles Darwin published On the Origin of Species, which represented an authentic revolution in the field of science, with profound religious and existential implications. Darwin proposed the theory of evolution rooted in natural selection,

meaning that a living beings' environment offers limited resources, resulting in the survival of the fittest.

Darwin's work spread quickly across Europe and found a faithful defender in the German botanist Ernst Haeckel. It was Haeckel who, in 1866, in his Generelle Morphologie der Organismen coined the term "ecology" from the Greek oikos (house) and logos (study or treatise). He defined ecology as "the study of all those complex interactions referred to by Darwin as the conditions of the struggle for existence."

The science of ecology, a branch of biology that studies the relationships of different living beings with each other and with their environment, has, over time, proposed a structure of knowledge similar to the ones championed by Cerdà in his Theory. In the same way that ecology analyzes ecosystems that are made up of the non-living components of the environment, the communities that integrate that environment, and the interactions of all the parts with the organisms, in the Cerdà's Theory, he examined the Container (which he defined as the physical manifestation of the city), the Content (people) and Function (essentially, the relationship between Container and Content.)

Since the mid-20th century, ecology and urbanism have begun to converge, as people began to study the impact of urban phenomena on the planet. And with climate change now being felt by people, cities, and the planet as a whole, the integration of urbanism and ecology is accelerating.

The Self-Sufficient City

Everyone configures their own particular habitat through their daily actions and the resources they generate and consume, whether in an aboriginal community in the jungle, a mountain village, a neighborhood in a European city, an American suburb, or an Asian megalopolis. Each person, each community, each society, each generation throughout history has built its own habitat, aimed at serving a particular way of life. At the dawn of the 21st century, we have the unique chance of rewriting our history and the history of our urban habitat using the knowledge and the resources at our disposal in order to produce the resources—energy, food, goods—we need to live locally.

A new human being emerges as a result of access to universal knowledge, used for individual purposes and

"With climate change now being felt by people, cities, and the planet as a whole, the integration of urbanism and ecology is accelerating."

"A new human being emerges as a result of access to universal knowledge, used for individual purposes and for the good of the community."

"With strong citizens, comes strong societies."

"Connected self-sufficiency allows for better resistance to global collapse."

"Distributed systems, which are the result of the interaction between self-sufficient units, are more flexible and adaptable to change."

for the good of the community. This universal knowledge allows for producing resources locally, while participating in global social networks of knowledge and economy. The strongest societies are made up of individuals with strong leadership abilities and the desire to share.

The Self-Sufficient City is an attempt to define the conditions in the urban environment that will allow the cities of the 21st century to be inhabited through networked self-sufficiency. Those conditions will make it possible for human beings to take charge of organizing their existence. The project is centered on rehumanizing cities based on efficiency in the generation and consumption of resources, as well as fostering quality of life and promoting local culture from a global technological and economic foundation. All this constitutes a new economy of urban innovation.

Cities, which in recent years have obscured their obsolescence behind spectacular formal artifices, in the form of architectural icons, have the ability to rewrite their history using new principles that emerge from the distributed systems favored by the information society. This model surpasses the centralized systems of industrial societies by building new functional structures and social structures based on the relationship between multiple entities, acting as a network.

Connected self-sufficiency allows for better resistance to global collapse. In times of crisis, like the present, guaranteeing the supply of resources and the safety of the development of urban processes is as important as the processes themselves. Distributed systems, which are the result of the interaction between self-sufficient units, are more flexible and adaptable to change. Because they draw on local resources, they make less of an impact on the territory, on mobility and the consumption of systemic resources. And with increased self-sufficiency in the multiple layers of the management of our habitat comes increased decision-making capability about what kinds of habitable spaces we wish to develop, and at what pace.

Fab City Global Initiative

Locally productive, globally connected cities and regions

The Fab City Initiative is organised to have a maximum impact on social equality, environmental regeneration, digital skills development, cultural heritage at the local and global level. It includes the Network of cities and regions, a collective of stewards and the Fab City Foundation. Together these moving parts support the global implementation of the Fab City agenda.

Timeline

Events that led to Fab City

2003

First Fab Lab was set up at the South End Technology Center in Boston in a collaboration between the National Science Foundation and the Center for Bits and Atoms at MIT.

New Fab Labs are set in Costa Rica, Ghana, India and Norway. Following labs are open in South Africa and Iceland.

2007

Fab Lab Barcelona was set up inside the Institute for Advanced Architecture of Catalonia.

2011

Barcelona, then Amsterdam, became the first EU based Fab Labs of the global network in 2007. Few years later some of the founding members of IAAC became part of the city government in Barcelona. The team from Barcelona (IAAC, Fab Lab Barcelona and City Government) announces Fab City at FAB7 Lima.

The city of Barcelona changes the political leadership, which requires a reconnection with the new team in the city, which ends up launching the Maker District in Poblenou.

Barcelona opens the first two labs (Les Corts and Ciutat Meridiana) of a public network of Fab Labs run by a city, the Ateneus de Fabricació. Sao Paulo follows this path, opening the Fab Lab Livre network (12 Labs in the city).

2014

6 The city of Barcelona hosts the FAB10 conference. At the end of the main symposium, the mayor publicly commits for the city to produce (almost) everything that it consumes in 40 years (by 2054).

Barcelona is chosen to host the 10th International Fab Lab Conference under the moto: from Fab Labs to Fab Cities.

2015

The Fab City global network starts to grow in an unexpected way. During the FAB11 in Boston, 7 new cities pledged to become Fab Cities.

The growth of the Fab Lab network in Barcelona goes beyond Fab Lab Barcelona and the public network of Fab Labs, forming a mixed ecosystems of innovation in digital fabrication, circular economy and social innovation.

2016

The Fab City Campus is organised in Amsterdam by Pakhuis De Zwigjer as part of the events in celebration of the Presidency of the EU by The Netherlands, it also takes place the first Fab City summit. Amsterdam joins the Fab City Global Initiative.

Space10, IKEA, Fab Lab Barcelona and IAAC organise the Made Again Challenge and launch The Fab City Prototype at Poblenou (now a public policy by the city council under the name Maker District) in Barcelona.

The FAB12 conference takes place in Shenzhen, 6 new cities join the Fab City Global Initiative in China, 7 in total for 2016.

2017

The Danish Design Center organises the Fab City Summit Copenhagen.

2018

The Fab City Summit Paris is organised by the local Fab City Grand Paris Association, the City Council of Paris, the European Union and the Fab City Global Initiative.

The Fab City Foundation setup process starts at Volumes, during the Fab City Summit Paris, and at the Danish Design Center, during the Techfestival Copenhagen.

The founders of Fab City Foundation gather to sign the funding agreement and the statutes of the foundation at Nurkse Department in Tallinn, 12 December 2018.

2019

Pakhuis de Zwijger organises the Fab City Summit Amsterdam.

2022

Bali Fab Fest 2022 in Bali, Indonesia, organized by Fab Foundation, Fab City Foundation, and the Meaningful Design Group. The Fab Island Challenge brings over 100 makers, designers and other multidisciplinary creatives to work on solving 10 locally oriented key challenges for Bali.

2021

Montreal hosts Fab City Summit 2021 - Fabricating the Commons, an event in hybrid online/in-person format; 42 cities, regions and countries in the Fab City Network.
REACT-EU funded project Interfacer to develop Fab City OS kick-off in Hamburg, September 2021.

Fab City Whitepaper

Locally productive, globally connected self-sufficient cities

Fab City Collective

More than 200 years since the Industrial Revolution, global urbanisation keeps accelerating. United Nations projections suggest that 75% of the human population will be living in cities by 2050. Newly created cities and the urbanisation process in rural areas replicate a lifestyle based on consumerism and the linear economy, causing destructive social and economic impact while compromising the ecology of the planet. We are losing livelihoods through both offshoring and automation, and this in turn leads to the demise of dynamic hubs of practical and cultural knowledge, at the sites where things are made. Extreme industrialisation and globalisation have turned cities into the most voracious consumers of materials, and they are overwhelmingly the source of carbon emissions through both direct and embodied energy consumption.

By now, it's become clear. We need to reimagine cities and the ways they operate.

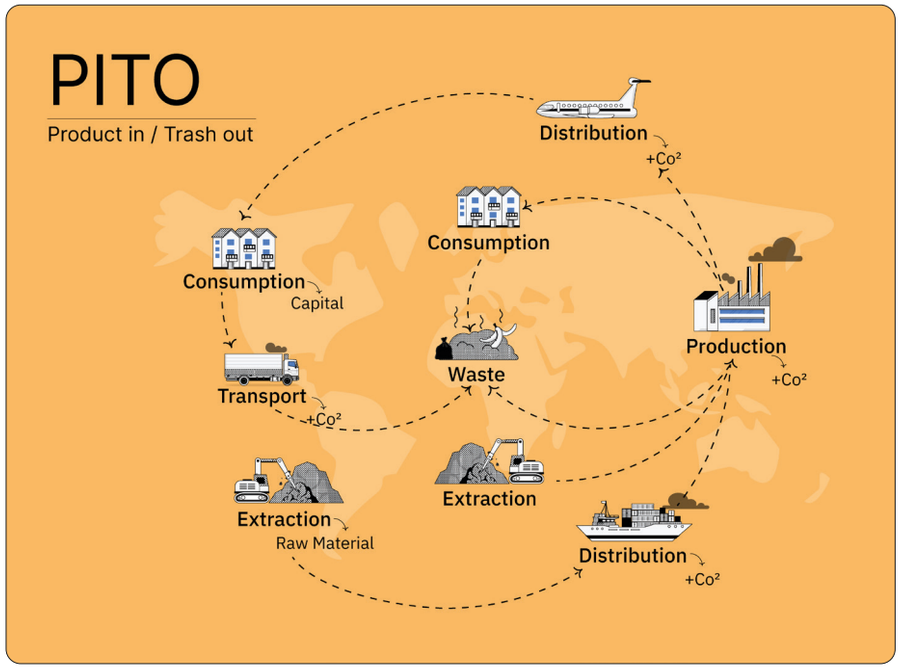

Figure 1. Where do we make things? The industrial paradigm is structured around complex global supply chains that move "Product In and Trash Out" of cities, hence "PITO". Source: Fab City.

The Fab City is an international initiative started by IAAC, MIT's CBA, (I would put the names, not acronyms, in the first reference and then use the acronyms from then on.) the Barcelona City Council and the Fab Foundation to develop self-sufficient cities that are at once locally productive and globally connected. The project is connected to the global network of Fabrication Laboratories, or Fab Labs, and made up of an international think tank of civic leaders, makers, urbanists and innovators working on changing the paradigm of the current industrial economy. Under the model, the city operates in a linear fashion, importing products and producing waste. Our aim is to move to very different model—to an ecosystem of spiral innovation in which materials flow within cities, and information about how things are made circulates globally. Fab City is about building a new economy based on distributed data and manufacturing infrastructure.

Introduction

We need to reinvent our cities and their relationship to both people and the planet by re-localising production so that cities are generative rather than extractive; restorative rather than destructive; and empowering rather than alienating; where prosperity flourishes; and people have purposeful, meaningful work that they enjoy and enables them to use their passion and talent. We need to recover the knowledge of how things are made in our cities and the capacity to put it into practice by connecting citizens with the advanced technologies that are transforming our everyday lives.

Background

For more than 10 years, Fab Labs (We need to have a unified style on the capitalization (or not) of Fab Labs. I have left the remaining references as they are until we decide on what our style is.) have provided widespread access to modern means for invention and production. They began in 2003 as an outreach project from MIT's Center for Bits and Atoms (CBA). From inner-city Boston, they quickly spread across the globe, mushroom up everywhere from rural India to South Africa to northern Norway. All sorts of things go on in this global network: Fab labs play host to everything from technological empowerment initiatives to peer-to-peer project-based technical training to local problem-solving to small-scale high-tech business incubation to grass-roots research. Projects being developed and produced in fab labs include solar and wind-powered turbines, thin-client computers and wireless data networks, analytical instrumentation for agriculture and healthcare, custom housing, and rapid-prototyping of rapid-prototyping machines.

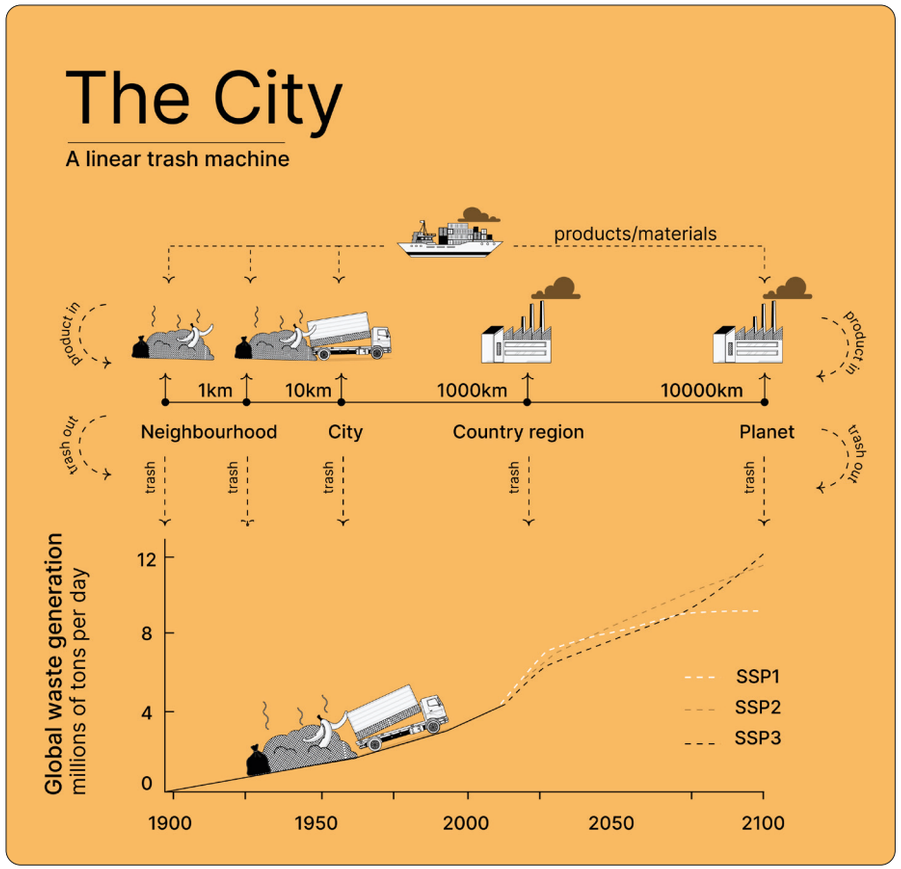

Figure 2. "Three projections to 2100 for waste generation spell very different futures. In the first Shared Socioeconomic Pathway scenario (SSP1), the 7-billion population is 90% urbanised, development goals are achieved, fossil fuel consumption is reduced and populations are more environmentally conscious. SSP2 is the 'business-as-usual' forecast, with an estimated population of 9.5 million and 80% urbanization. In SSP3, 70% of the world's 13.5 billion live in cities and there are pockets of extreme poverty and moderate wealth, and many countries with rapidly growing populations." Graphic source: Fab City. Data source: Organisation for Economic Co-operation and Development / Interpretation by Daniel Hoornweg, Perinaz Bhada-Tata & Chris Kennedy for "Environment: Waste production must peak this century" published in Nature, October 30/2013 at http://www.nature.com/news/environment-waste-production-must-peak-this-century-1.14032.

Fab labs share core capabilities among the nearly 1,2781 labs in operation as of May 2018, (should we get a more recent number?) meaning that people and projects can be shared across the network. These labs work with components and materials optimized for use in the field and are controlled with custom software for integrated design, manufacturing, and project management. This inventory is continuously evolving towards the very meta goal of one fab lab being able to make another fab lab.

Since 2001, the Institute for Advanced Architecture of Catalonia (IAAC) and the MIT's Center for Bits and Atoms (CBA) (If we're going to keep repeating entire name of each entities, we should take out the acronyms in brackets, as it's distracting.) have been working together to develop a new approach to architecture and urbanism by understanding how the use of digital technologies will impact our cities. Founded back in 2007, Fab Lab Barcelona at IAAC was the first fabrication laboratory in the European Union, and is now the headquarters for global coordination of the Fab Academy program, the fablabs.io platform and the Smart Citizen project—making it the world's leading lab for the Fab Lab Network, in collaboration with the Fab Foundation.

In 2011, at the seventh annual International Fab Lab Forum in Lima, Peru, IAAC, the MIT Center for Bits and Atoms, the Fab Foundation and Barcelona's City Council launched the Fab City project. Seven years later, at the FAB10 conference, Barcelona's mayor invited other leaders from across the globe to join his city and accept the challenge of becoming at least 50% self-sufficient by 2054. Since then, more than a dozen cities—including Shenzhen, Santiago de Chile and Paris—as well as several regional governments and even a whole country, Bhutan, have joined what has come to be known as the Fab City Global Initiative, with more signing on all the time to collectively build a more humane and habitable new world.

Details

FAB City takes the ideals of the Fab Lab—the connectivity, culture and creativity—and scales them up metropolitan scale, to meet the needs of entire cities. It has become a new model for urban transformation that radically overhauls how cities they source and use materials, moving from a 'Products In Trash Out' (PITO) paradigm to the infinitely more efficient 'Data In Data Out' (DIDO) system. This means that more production occurs within the city itself, as does recycling and urban mining of materials to be reinserted in supply chains. Meeting local needs through local inventiveness becomes one of the city's core strengths, and under this model, the lion's share of imports and exports are found in the form of data (information, knowledge, design, code).

The Fab City project will help civic leaders develop locally productive cities in collaboration with local communities, companies and institutions, revitalising manufacturing infrastructure and incentivising a new economy. As spaces of learning, where new skills are developed and honed, Fab Labs are giving people the know-how they need to remain employable in this fast-evolving economy and also providing businesses with the on-point workforce they require. Fab Lab and makerspaces are also giving local businesses a boost by helping develop solutions to local problems, while reactivating metropolitan and regional manufacturing ecosystems. And with their longstanding ethos of slashing carbon emissions and creating zero-waste systems, the Fab City approach can help cities reach a whole range of objectives, from environmental goals to human development targets.

In this way, cities and their citizens are empowered to be the masters of their own destiny: Both become increasingly resilient, even as their ecological footprints diminish with the decrease in the carbon-spewing movement of goods and materials.

In order for this to be possible, the city must be locally productive and globally connected to knowledge,

Figure 3. A multiscalar and complementary fabrication ecosystem. Source: Fab City.

economic and social networks, making cooperation between cities, citizens and knowledge centers the basis of the scientific knowledge.

To become a FAB City requires having a more precise understanding of the ways cities work and developing metrics to measure progress towards the established target of 2054. The evolution of the project will make it possible to create better systems for capturing and analysing data, thus allowing for a more granular picture of any given city. It will also require the implementation of an evaluation system and detailed monitoring.

The Fab City strategy is unique in that it addresses a range of environmental, social and economic objectives (carbon reduction, waste minimisation, relocalisation of manufacturing and employment) within a systems approach by harnessing new technology and production approaches. All of this is brought to a practical level by tapping into the existing Fab Lab Network, a vast source for urban innovations being shared already globally by makers in some 1,278 labs in more than 90 countries. In this way, Fab Labs and makerspaces are catalysts for the transition towards the Fab City objectives. They do not replace industry or businesses but instead reactivate local production by creating new demands for shorter supply chains while accelerating innovation by creating the new technologies needed for this new style of productive urban living.

The first city to become self-sufficient—simultaneously increasing employment by creating opportunities through open innovation and radically reducing carbon emissions by re-localising production—is sure to become a global trailblazer for urban development across the planet.

Strategies

The core Fab City strategy is to develop a global network of cities that are part of a sustainable ecosystem of production and knowledge: from the 3D printer at home, to the neighborhood Fab Lab, to the city factory to global production infrastructure. A new manufacturing ecosystem to rescale globalisation and provide the means of innovation and production to citizens, who in that way become empowered to lead the transformation of their cities.

Becoming a Fab City involves working in the following **specific strategies**:

- **Advanced Manufacturing Ecosystem:** Being part of a global network of cities that share knowledge and best practices on urban solutions emerging from citizens, companies, educational institutions, and governments. Local networks of Fab Labs and mid-scale production centers connected to the larger global network of supply chains, sharing knowledge, best practices and projects.
- **Distributed Energy Production:** With the advent of domestic batteries and efficiency improvements in solar and other means of clean power generation, energy distribution itself will face enormous changes. Distributed grids will change the role of households and businesses in power, water and resources distribution.
- **Cryptocurrencies for a New Value Chain:** Cities creating their own trade markets connected to a global economy, using a multi-currency and value system based on the blockchain and similar technologies.
- **Food Production and Urban Permaculture:** Urban farming will scale up from experimental practice to large-scale infrastructure. Local production of foods at the domestic, neighbourhood and city scales will create a closed loop system for food production and harvesting.
- **Educating for the Future:** Incorporating a stronger emphasis on learning-by-doing in education systems and curricula, engaging all levels of education in finding solutions for local needs through digital fabrication technologies, and sharing them with global networks.
- **Building the Spiral Economy:** Reduce the amount of imported goods, food and resources such as water or energy. Increase the use of recycled raw materials for the production of objects in cities. Create added value in every iteration of a new product.
- **Collaboration between Governments and the Civil Society:** Local government and civic organizations, start-ups, universities, and other organizations must work together in order to make a cultural shift that promotes the empowerment of cities and their citizens.

All these efforts will be supported by technologies such as digital manufacturing, the rehabilitation of buildings and neighbourhoods aimed at making them more energy efficient, smart energy networks, electrical mobility, urban permaculture, intelligent infrastructure, and related policy and regulatory approaches, among other solutions to be shared globally between cities.

Benefits

This initiative offers a multitude of valuable economic opportunities for participating cities. It will create new types of jobs and professions tied to the knowledge economy and the development and implementation of new approaches and technological solutions. The Fab City initiative will develop a set of associated services:

- **Mapping** the existing innovation and production ecosystems in cities. Understanding the existing manufacturing infrastructures, networks of knowledge, initiatives, communities and other organisations that are pursuing systems change in participating cities.
- **Establishing metrics** to evaluate impact in each participating city. Developing common standards and sharing best practices in terms of local production. A Fab City data dashboard.
- **Developing products** that can be produced locally and shared globally that include everything from objects to food to waste management or even energy harvesting solutions. A global Fab City repository.
- **Deploying interventions.** Running a Fab City Blockchain amongst the participating cities as a decentralised autonomous organisation.
- **Articulating** with other groups of interest and networks. Fab City is not the only initiative looking into the future of cities. We aim to build bridges with existing research and initiatives that have long been contributing to forging a better understanding of urban life.
- **Organising** a yearly event at Fab Conferences and complementary events in different cities of the world.

These associated services should lead to a business model for Fab City to exist as an international organisation, which will be established by its founding members (IAAC, MIT's CBA and Fab Foundation) and by inviting associated members to share rights and duties.

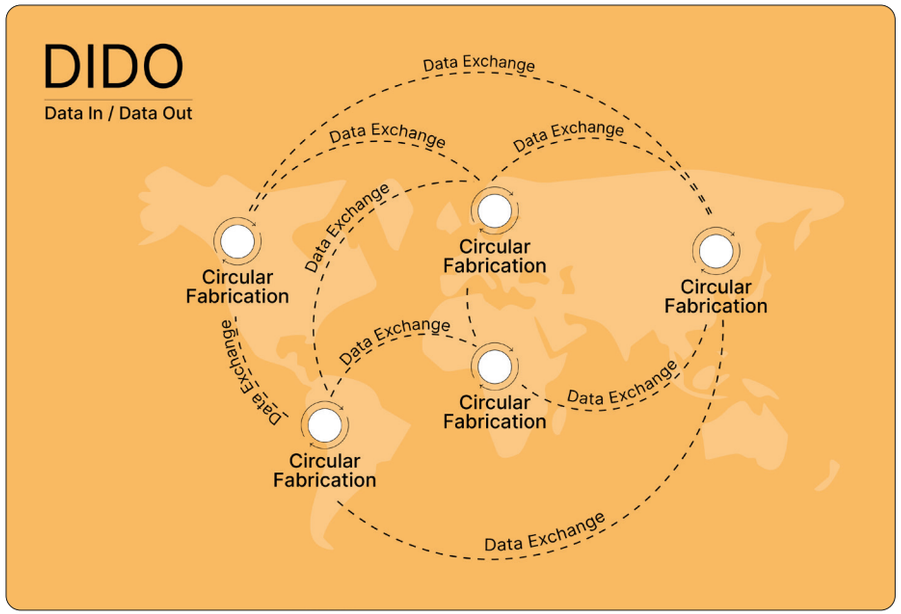

Figure 4. Globally connected production. Materials stay within accepted distances in cities and regions, information travels on how things are made. We share the recipes for how to construct our world. Source: Fab City.

Conclusion

A concerted and coordinated response must be made to reimagine what we make, and how and where we make it, if we are to live harmoniously within the limits of our planetary resources. We are proposing a model for cities to be resilient, productive and self-sufficient in order to respond to the challenges of our times and recover the knowledge and the capacity to make things, produce energy, harvest food, understand the flow of matter, and empower citizens to become be the leading agents of their own destiny. We have a unique opportunity to build cities from the ground up by synchronising philosophies, visions and objectives together with existing distributed innovation ecosystems, to consolidate and nurture the knowledge-based economy that's been developing over the last decade in Fab Labs, Makerspaces and open communities around open source innovations, digital fabrication technologies and distributed digital networks. We want to create a global database of recipes for how things are made, from what and why. The Fab City is about radical transformation—about rethinking and changing our relationship with the material world so that we as a species can continue to flourish on this, our precious planet.

The Fab City Manifesto

"We, as signatories, commit ourselves to implement the ten principles to enable the urban transition towards locally productive and globally connected cities. We embrace circular economy and digital social innovation strategies and foster collaboration between a global network of worldwide cities and territories to meet the planetary challenges of climate change and social inequalities."

Ecological

Inclusive

Life-centered

Open Source philosophy

Locally productive

Holistic

Sustainable development

Glocalism

Participatory

Experimental

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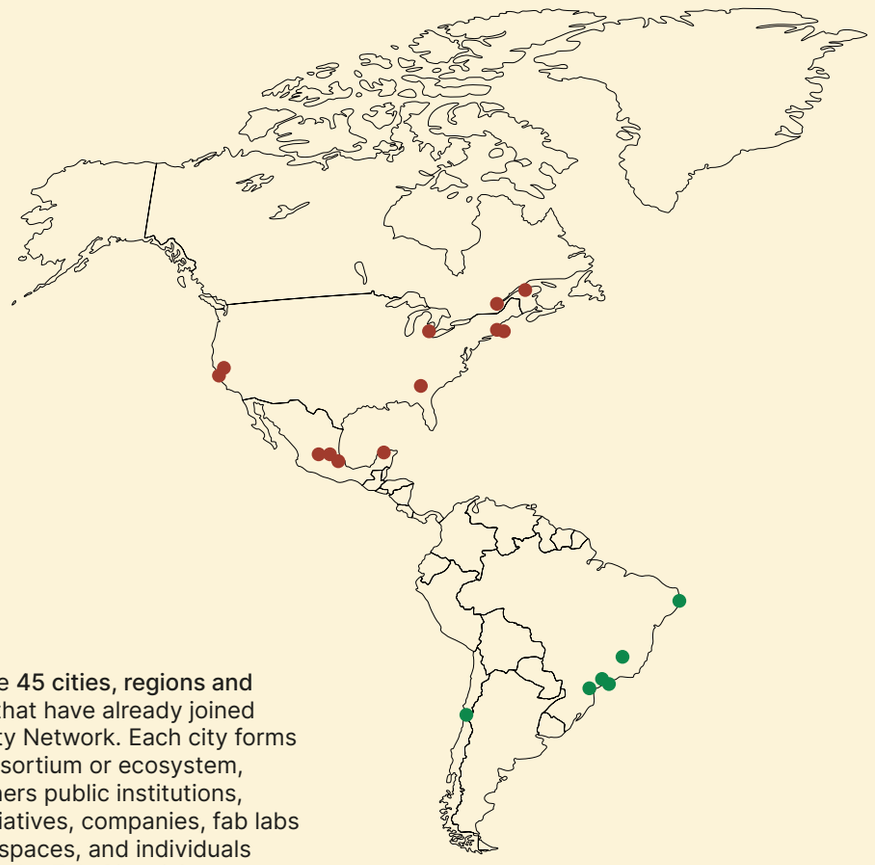
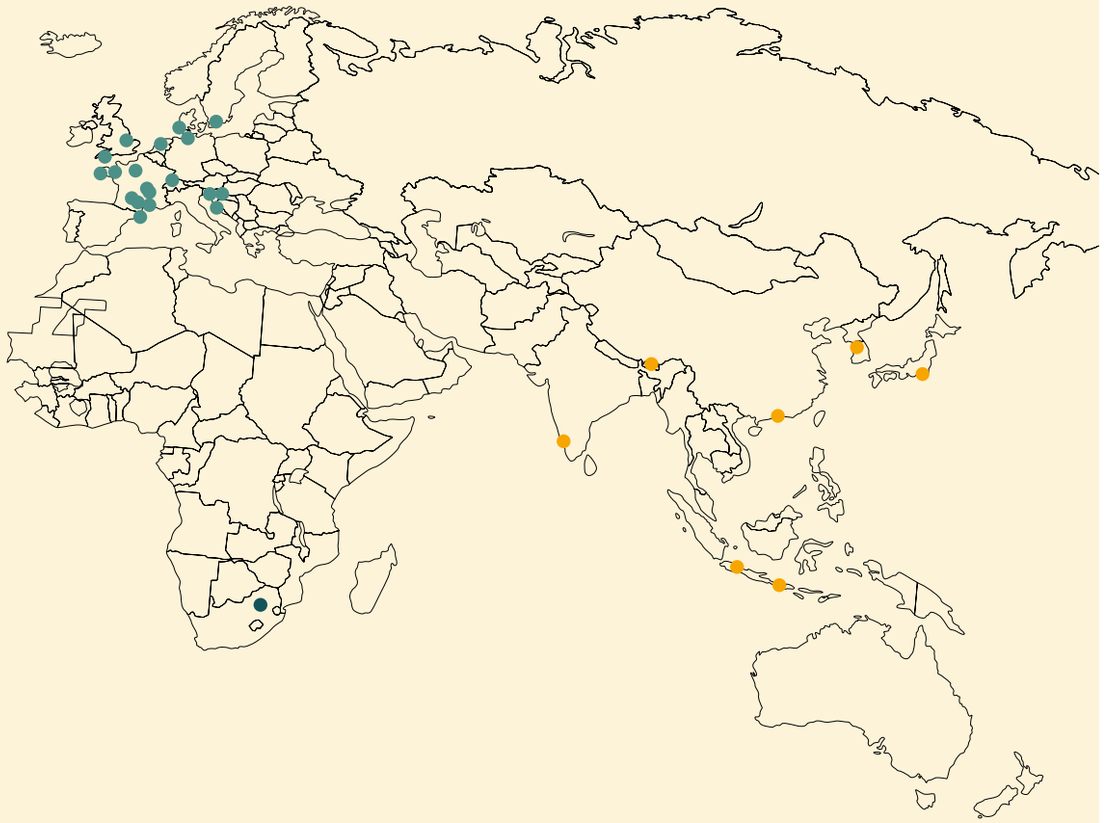
The Fab City Network 2022

Barcelona, Zagreb, Thimphu, Shenzhen, Georgia, Curitiba, Occitanie Region, Puebla, Mexico City, Auvergne-Rhône-Alpes, Amsterdam, Cambridge, Kerala, Sacramento, Plymouth, Hamburg, Yucatán Region, Belo-Horizonte, Ekurhuleni, Brest, Boston, Toulouse, Paris, Santiago, Velsen, Seoul, Oakland, Somerville, Detroit, Kamakura, Sorocaba, Rennes, São Paolo, Recife, Zadar, Valence Romans Agglo, Bas-Saint-Laurent, Linz, Montreal, Montpellier, Veberöd, Bali, Sumedang, Guanajuato and Ljubljana.



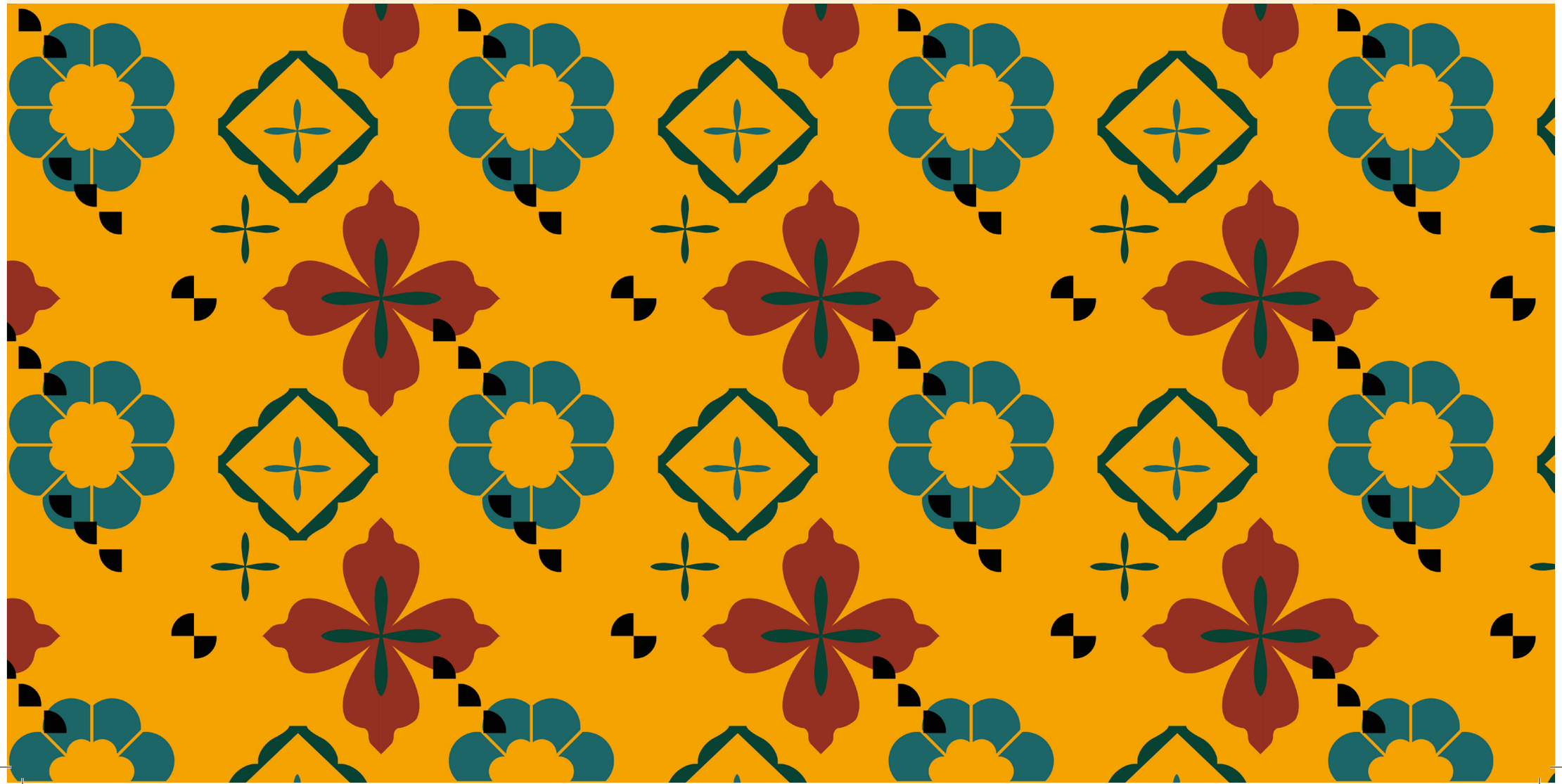


There are **45 cities, regions and countries** that have already joined the Fab City Network. Each city forms a local consortium or ecosystem, which gathers public institutions, private initiatives, companies, fab labs and makerspaces, and individuals developing the Fab City vision locally, while connected to the global network.

Network number updated at time of publication.

Fab City case studies

Fab City case studies share concrete examples of interesting local initiatives which have been implemented by Network members. This section of the book report on the interventions by Network cities and regions that have contributed to the roadmap towards 2054. It includes practices, products, systems, spaces and services that reflect the multiscale approach of the Fab City Full Stack. The case studies aim to be inspirational for current and future cities looking to make the transition towards regenerative economy and help guide their own decisions about similar projects. Together, the case studies are a collection of best practices that connect real Fab City experiences to the principles of the Fab City Manifesto.



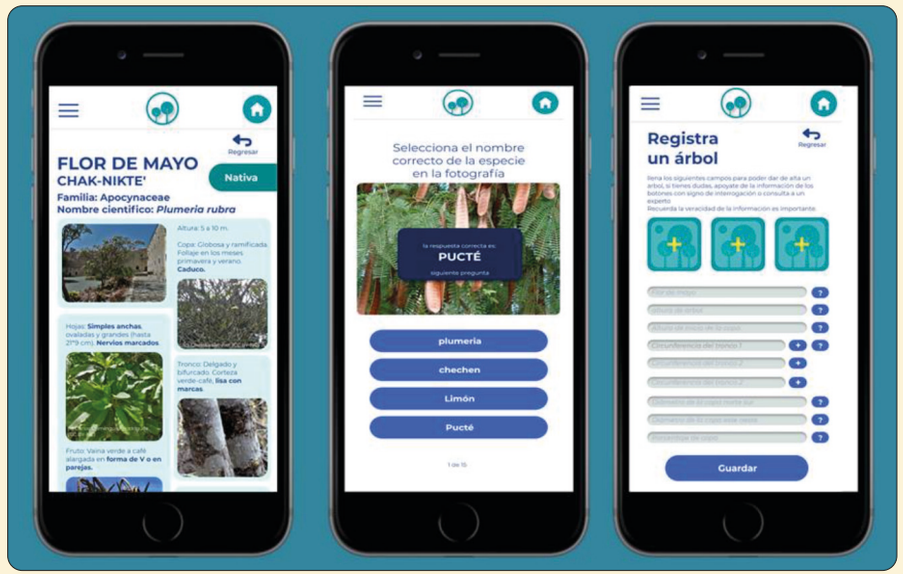
Yucatán Region Mexico

Year Joined Fab City Network	2019
Co-author of the case study	Ileana Ceron Palma and Oscar Diaz (Fab City Yucatan Association)

The Yucatan region has geographical, cultural and social characteristics of great value, hosting the capital city of Mérida, which is an international benchmark for life quality, security and tourism. It is currently characterized as a pole of contemporary investment and development that merges cultural wealth with the future.

Arbolado Urbano, an urban tree management app

Arbolado Urbano is a mobile application that gives citizens of Mérida the opportunity to be involved in urban processes. Developed within the framework of the agreement to strengthen digitalisation processes in Cities, signed between the German Cooperation for Sustainable Development (GIZ) and the Fab City Yucatan Civil Association, the app uses gamification, codification, citizen data collection and literacy in order to empower citizens in urban tree identification and care. For example, the app includes a catalog of trees that provides technical information about local vegetation and information about the important role these trees play in the ecosystem of the city. Citizens can learn how to identify trees and map their location on the mobile app. The application seeks to highlight the status and effort made in greening the city while meeting sustainable development objectives such as: quality education, sustainable cities and communities, climate action, and life of terrestrial ecosystems.



Barcelona

Spain

Year Joined Fab City Network	2014
Co-author of the case study	**Marion Real and Milena Juarez (Fab Lab Barcelona)**

Historically, Barcelona is a global leader in the field of urbanism. The city has been a testbed for innovative urban models and in 2014 pledged to become the first Fab City. Today, it builds on 15 years of action research at Fab Lab Barcelona and collaborating entities to test ways to support productive activities and increase urban resilience.

Platform connecting designers, makers and markets

Fab City Barcelona has been developing Make.Works, an ecosystemic platform that uses mapping, community building and profiles to create an online-offline network of manufacturers, makers, designers and consumers in an effort to connect small-to-medium scale productive businesses and make them more visible in the urban fabric. A prototype of Make.Works has been deployed in the neighbourhood of Poblenou, Barcelona led by Fab Lab Barcelona. It currently lists 11 local manufactures including LOV Ferments kombucha manufactures and LIKEN woodworking studio. The project builds on the legacy of fablabs.io, a digital mapping and social network for the Fablab network which was developed by Fab Lab Barcelona at the Institute for Advanced Architecture of Catalonia (IAAC), and is co-funded by the Distributed Design Market Platform; a European Union funded project, which acts as an exchange and networking hub for the European maker movement.

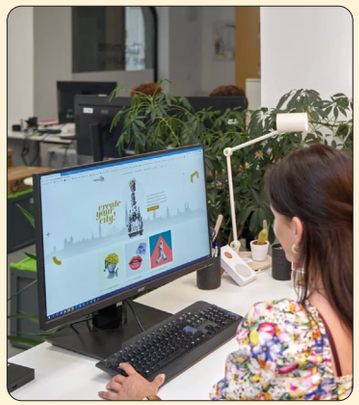
Remix Ecodesign, Food Waste Biomaterial Makers

Remix Ecodesign is a collective of designers that was established after an 18-month co-creation programme initiated by Fab Lab Barcelona, that sought to co-create creative solutions to reuse neighbourhood food leftovers. “Remix El Barrio” took place in the neighborhood of Poblenou in Barcelona with the ambition to create a learning space to nurture circular practices based on food-waste crafts and community engagement. In 2021, Remix el Barrio won the Starts Prize 2021 and following the project’s success, Remix Ecodesign collective formed to keep exploring connections with local services, activating circularity and shared infrastructures, and scaling up processes by collaborating with open-minded and visionary industries that share their values. Since its founding, Remix Ecodesign collective has participated in international exhibitions (Ars Electronica, “Biotopia” in Namur, “In Transfer, A new condition” in Esch 2022, Bozar, Brussels)), facilitated several workshops and developed a set of video tutorials explaining the process of making biomaterials for emerging DIY makers and enabling circular glocalism. The learnings and outputs of the project have been replicated in different European and local initiatives, such as the Remix the School project, an iteration, targeting primary schools.

Linz
Austria

Year Joined Fab City Network	2020
Co-author of the case study	**Kathrin Oberhumer and Franz Dörfler (Magistrat Linz, Innovationshauptplatz Linz)**

A city committed to the values of humanity, Linz sets the course for a new and ever-changing digital society. Digitalisation activities have always been guided by the question of what new technologies mean for our lives and how to make our city inclusive, safe, resilient and more sustainable. Their empowerment approach is characterized by free and open spaces for interdisciplinary discourse, initiated and driven by visionary partners, companies and citizens. Linz has actively pursued this approach since its transformation from an industrial steel city to a city of digital arts.



Climate education and citizen participation

ECOPOLIS (Establishing Climate-related Opinion-voicing and Political participation via Online Learning and Interactive Scenarios) is among several initiatives developed by the city to use digital tools to engage the voice of its citizens in climate change topics. Developed by the University of Applied Sciences Upper Austria and the SORA Institute for Social Research and Consulting Ogris & Hofinger GmbH and funded by the Austrian Climate and Energy Fund; ECOPOLIS aims to explore how communication between political representatives and the target group of 14-16 year-olds can be facilitated by an online platform that combines both game-based educational scenarios and opinion-voicing functionality. It uses relatable, real-world urban data to create customised interactive scenarios that address climate policy using a transdisciplinary approach to engage the consumers and decision-makers of tomorrow. Linz has also launched the Innovationshauptplatz Linz, for older citizens who wish to submit or collaborate on community projects. In 2021, 26 ideas were submitted by citizens on the topic of a climate change adaptation concept that the city is working on. Linz City also offers a climate fund with a unique budget of 1 million per year to support many public and private projects focusing on climate protection, climate change adaptation, and sustainable development.

Green hydrogen

Linz wants to become a climate-neutral industrial city by 2040, which requires action on all scales. Next to emission reductions in buildings, mobility and energy production, one particular challenge comes with the decarbonisation of the local industry. In this sense, Linz has launched its own hydrogen initiative in 2021, bringing together knowledge from politics, industry and science. It is recognised that hydrogen is the simplest chemical compound that can be used as a resource in the steel and chemical industry, as well as in the energy and heavy transport sector. The city has, thus, established a hydrogen board with renowned technical experts and governmental leaders. Supported by the hydrogen project manager from the climate office, this board develops measures and aims to build a local hydrogen marketplace step by step. One field of action includes the use of hydrogen in steel manufacturing. The voestalpine AG has built a 6 MW PEM demonstration plant for upscaling electrolysis technology for green hydrogen. Another activity refers to mapping the greater hydrogen ecosystem around Linz, which is crucial to identifying key stakeholders and fields of application.

Curitiba

Brazil

Year Joined Fab City Network	2017
Co-author of the case study	**Alessandra Reis (City of Curitiba)**

Curitiba is considered the ecological capital of Brazil, a model city by its urban planning and development. With Jaime Lerner, former mayor, architect and urban planner, the city became world-famous by the implementation of the BRT (Bus Rapid Transit) system, and for being a city that takes care of the environment and develops in a sustainable and innovative way.

Urban farming: food and waste management

Curitiba was the first Brazilian city to join the Fab City Network in 2017. In an urban area called Cajuru, the city's first Fab Lab was launched in 2019. In this same area, in May 2020, the City Hall inaugurated the "Fazenda Urbana" (Urban Farming) program, the first one in Brazil. In an area of 4,435 square meters, it is a reference centre in urban agriculture where more than 60 organic agricultural varieties are grown, encompassing the most modern planting methods, use of renewable energies, reuse of rainwater and bioenergy. The Urban Farming program is constantly growing. In 2020, there were 24 areas cultivated by 950 families, spread 428 thousand square meters under energy supply lines, public lands and areas of private initiative. The spaces are complemented with Honey Gardens, eight across the city, aiming to increase the bee population in the town to ensure the continuity of native forests and food plantations through pollination, raising people's awareness about the importance of bees in the planet's biodiversity balance. In addition, Curitiba is the first city in Brazil to implement a Food Bank within the Municipal Market to redistribute unsold products to entities that serve people in need.

Bas-Saint-Laurent Canada

Year Joined Fab City Network	2020
Co-author of the case study	**Rachel Berthiaume (Open Innovation Laboratory)**

The Lower Saint-Lawrence region is rooted in a strong legacy of regional collaboration supporting a sustainable transition. Lower Saint-Lawrence is known for its natural resources and unspoiled nature. Majestic rivers, lakes, forests, plains and mountains coexist in symbiosis with villages, small-sized and medium-sized cities.

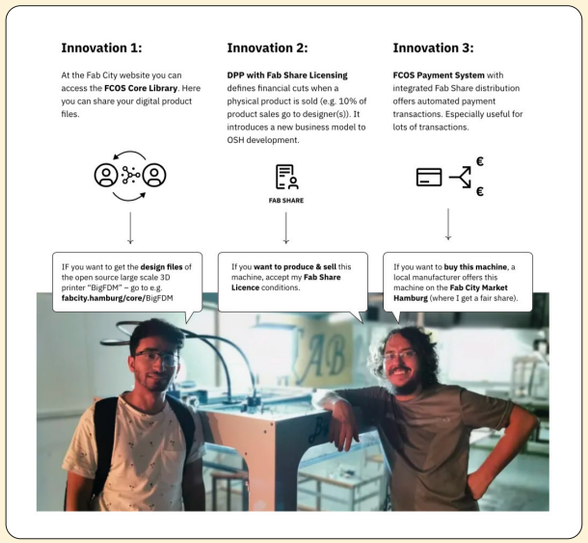
Co-created visions on food, mobility, housing and clothing autonomy

The region of Bas-Saint-Laurent developed an action-research project into the possible scenarios for a more autonomous region by 2054. The public consultation phase ending in 2022, collected 96 ideas from 235 people related to the areas of food, mobility, housing and clothing. The collective ideation session was transversal across all sectors of the local economy and represented an effort to bring various actors together. Experts from the biofood, energy, eco-construction, manufacturing and textile crafts sectors collaborated with elected officials and citizens to ensure the formulation of realistic visions that are concrete and adapted to the shared trajectory of sustainable autonomy, by 2054. The action-research undertaken also included the development of regional portraits of the production and consumption of energy and bio-food to understand where the region of Bas Saint Laurent is in relation to the Fab City local production objective. Some initial outcomes from the research suggest: 42% of theoretical autonomy in bio-food, 20% in vegetables (without potatoes), 16% in fruits, 93% in fish and seafood, 35% in energy, and 80% of energy consumption used in residential, commercial and industrial electricity comes from wind production.

Hamburg
Germany

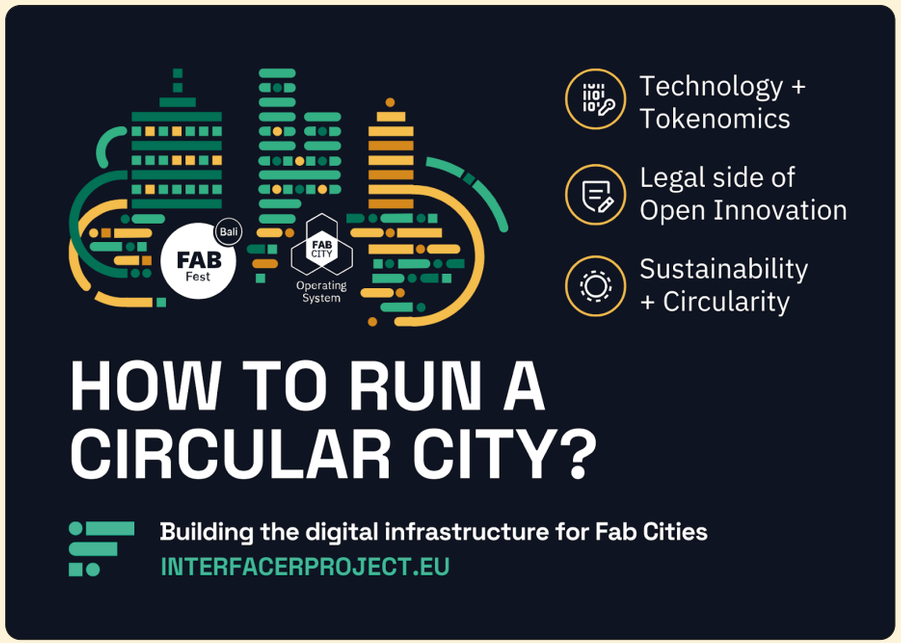
Year Joined Fab City Network	2019
Co-author of the case study	**Raphael Haus and Wolf Kühr (Fab City Hamburg)**

Hamburg is known for its harbor, which is Germany's main physical infrastructure and the currently predominant economic model of shipping products (atoms) around the globe. For new bits-based economic practices arising with the digital revolution, Hamburg aims at providing digital and physical infrastructure as well, which shall be governed as commons.



Design and manufacturing platform

The European Union EFRE-funded project INTERFACER started in 2021 and will go until 2023. The project aims to build this open-source digital infrastructure as a federated network. Along the concept of commons-based peer production and throughout the product life cycle, the proposed Fab City OS (Operating System) shall enable cities and regions to bundle, systematize and share data, information and knowledge generated in global knowledge networks and communities of practice in order to produce physical artifacts locally in a decentralized, green and resilient manner. The core of Fab City OS aims to connect hardware designers and producers and provide economic incentives for collaboration on a global scale. Based on distributed ledger technologies (DLTs) and a git-based versioning system of hardware design documentation, inventors and contributors may benefit financially any time physical artifacts based on this documentation will be sold in a Fab City. Part of this backbone is also a digital product passport (DPP) with two dimensions, namely, to track and trace material and design flows. Any contribution and enhancement will be tracked, and the value captured will be distributed among the people involved in the design process. Fab City OS empowers citizens to participate in value creation and sustainably consume by giving them full access to the documentation and thus control over the products they may buy, build, adapt, use or repair.



Veberöd

Sweden

Year Joined Fab City Network	2021
Co-author of the case study	**Jan Malmgren (Byutveckling AB)**

Veberöd is a rural research village in Sweden, that empowers local citizens and democratization processes. As a village with a warm feeling, where people know each other, they are pioneering a ‘digital twin’ approach in the hope to inspire other villages and cities to boost their social sustainability.

Digital twin

The small village of Veberöd in Lund municipality are engaged in thinking about how a small society like a village can prosper and produce in a sustainable way. In Veberöd, this idea can now be tested to scale up to cities and other areas as Veberöd, with its neighbouring villages, is Sweden’s first test bed for “Smart Villages.” Fab City Veberöd has developed a 3D model of the entire village, a so-called “Digital Twin.” A digital twin is a digital copy of something that exists in reality. It can be a machine, a house or, in this case, a municipality! The purpose is to facilitate operation, simulate floods, traffic flows, and noise, and open up data for residents who want a better overview of their immediate environment. Due to a collaboration with a partner called Sensative and their data platform, Veberöd can insert live data directly into the 3D model. Students and researchers have free access to be able to insert their own sensors in the village. Then, they can follow their projects virtually and, at the same time, contribute with research to everyone about what is actually smart and sustainable. Think about the possibility of inserting artificial intelligence and observing connections that we otherwise don’t think of. For example, are you happier if you use less water?

Zagreb
Croatia

Year Joined Fab City Network	2018
Co-author of the case study	**Roberto Vdovic (Fab Lab Zagreb)**

Nature-based solutions

Fab City Zagreb is working on prototypes using the natural island landscape of Croatia to inspire the urban landscape. The “Adriatic Greenlab” initiative was established and shaped by a new greenlab island concept on Biševo Island. Residents of this remote island reported intense touristic exploitation at the cost of their livelihoods; the history, memories, traditions and identity of Biševo are being lost. To address this challenge, in September 2019, the 1st Makers Island Workshop was organised as an Adriatic GreenLab Initiative pilot activity. In a 5 day workshop, makers from all around Europe creatively confronted local issues in collaboration with local needs. The event brought a diverse group of makers to work together, using their simple technological skills and creativity to solve local problems (water, waste, island mapping). They left their projects as a legacy to the local community, while sharing findings globally.

Hub_S:
A community hub for all

Fab City Zagreb and its Fab City Hub_Sesevete called Hub_S is one of the pilots of the EU project CENTRINNO, a research project focused on industrial historical sites under transformation.

Sesevete is a large peri-urban area in the southeast part of Zagreb. The area underwent a process of urban transformation and is a key part of the city development plan. However, in their neighbourhood, the local community is missing a centre to gather and identify with. The local community, based in Sesevete, reached the Zagreb University of Architecture asking for help to save the old meat factory, Slijeme, from abandonment and destruction. The old meat factory was identified as the ideal location for a new community and innovation centre, where young and old generations could meet and experience new creative ways of producing (in) the city. Starting in 2015, a team of engaged people from academia and local NGOs have been working toward building a community centre where citizens will prototype new ideas for effective and meaningful solutions for city-wide transformations. The implementation of the Hub_S is currently undergoing. In the plans, the old meat factory will be renovated into an energy-efficient building that will foster creative and entrepreneurial approaches for sustainable business and projects.

Puebla
Mexico

Year Joined Fab City Network	2017
Co-author of the case study	**Aristarco Cortés (Instituto de Diseño e Innovación Tecnológica - IDIT, Universidad Iberoamericana Puebla)**

With its 492 years, Puebla is a 2-million population colonial city of great contrasts. On one hand, it has a powerful automotive cluster headed by VW and Audi plants, while on the other, it is the municipality with the highest number of people living in poverty in Mexico.

Social economy iniciatives

"Yo compro poblano" is an innovative project that promotes the local economy through the incubation and personalised support of business initiatives, applying the Social and Solidarity Economy methodology, which is governed by three fundamental principles: Solidarity, cooperation and reciprocity; Relationships formed and managed in an associative manner; and Solve collective needs through participation and democracy. The social and solidarity economy project considers the implementation of a methodology for incubating social economy companies and strengthening those that have been generated. It is aimed at people or social groups that wish to organise themselves and develop their activities in a collaborative, participatory and democratic manner, prioritizing well-paid employment, increasing collective wealth and operating under the principles and values of cooperativism. In 2018, for instance, Fab City Puebla incubated 300 small cooperatives, and the program helped over 600 small and medium enterprises.

Belo Horizonte Brazil

Year Joined Fab City Network	2018
Co-author of the case study	**Carolina Marini (Instituto Fab Lab Brasil)**

Belo Horizonte is a city keen on traditions such as gastronomy, but at the same time is becoming a city that has a holistic management model that brings productive inclusion with projects to promote and attract socially and environmentally responsible investments.

Creative Horizon programme

The Creative Horizon Programme is planned to encourage the development of companies and professionals of the creative industry in Belo Horizonte. With the funding of the Minas Gerais Economic Development Bank (BDMG, according to his initials in Portuguese), the program grants several lines of credit for the diverse agents performing in the Belo Horizonte creative industry. In addition, Belo Horizonte created 22 new crafts, food, beverage and plants trade fairs with the objective of generating employment opportunities and establishing a strong bond between communities and the local producers to foster the Belo Horizonte culture.

Ladybugs and Chrysopidae Biofactory: Biological control for urban agriculture and green areas

In Belo Horizonte, ladybugs and chrysopidae, which are common in the local fauna, are being used to combat pests that cause damage to the city's green areas, in order to reduce the cost of removing and replacing trees, besides enables biodiversity maintenance and even increasing in the city. The biofactory is a controlled environment for the breeding of ladybugs and chrysopidae, which promote the control of pests. The insects are released into urban gardens, green areas of the city, and also donated to homeowners who cultivate plants at home. The goals of the projects is to promote the service of regulation of pest populations using biological control, distribute larvae and adult insects to the general population and in schools and to promote environmental education with a focus on knowledge and training in the identification and management of natural enemies.

Paris
France

Year Joined Fab City Network	2018
Co-author of the case study	**Michael Araujo and Alexandre Mézard (Fab City Grand Paris)**

Fab City Grand Paris is a local network of creators, designers, architects, urban farmers, innovators, Fab Lab, think tank and research office engaged in the rise of the circular and collaborative economy in the Paris area.

Foodtrack: revealing urban agriculture heritage and traditions (by Alexandre Mézard)

Through the research program CENTRINNO, Fab City Grand Paris (FCGP), is focusing on the topic of alternative urban food systems. Besides running a dedicated training program (Agriculture XYZ), the team also wanted to tackle the urgency to rethink the way we produce, transform and deliver food in the city. Paris is the cradle of modern alternative farming that favours small parcels of land, called the “french method” by Elliot Coleman between 1850 and 1920. To promote and stimulate this cultural heritage, FCGP launched Foodtrack, a digital platform allowing any contributor to add some know-how, places, events or individuals that highlight the bind between the XIXth century Parisian market garden heritage and modern alternative urban agriculture. The platform aims to explore patterns, through timelines and streamgraphs, to reveal what led to it’s demise as well as when and how it has been rediscovered and reused. FCGP will ensure a public-facing outcome of the platform by editing an annual booklet and creating a tangible and mobile exhibition.

Local learning ecosystem for changemakers (by Michael Araujo)

Territory empowerment means citizens are empowered through hands-on training for new production methods. FCGP is combining crafts knowledge and digital technology and appling this to a real transition towards a regenerative, productive and inclusive economy. The main goal is to develop a common learning platform for the changemakers of tomorrow such as fablabs, foodlabs, creative and productive hubs, urban agriculture sites, SME of local manufacturing. The system is based on three pillars : 1) a digitalized network framed in several communication channels and mapping tools (such as Kumu) that aims to synchronize both people and knowledge, 2) educational programs related to emergent fields such as urban agriculture, circular design, 3) formal government certifications (Qualiopi) that gather experts, curious minds and unemployed people, 4) infrastructures such as the Fab City Hub which becomes the physical receptacle of each course but also the connection spot with the local community, as well as the productive sites of the network and, above all, a common place to gather all the knowledge and prototypes shared. The interconnection of current issues means that solutions will only be found through experimentation and learning in the field, but also learning from other cities and communities.

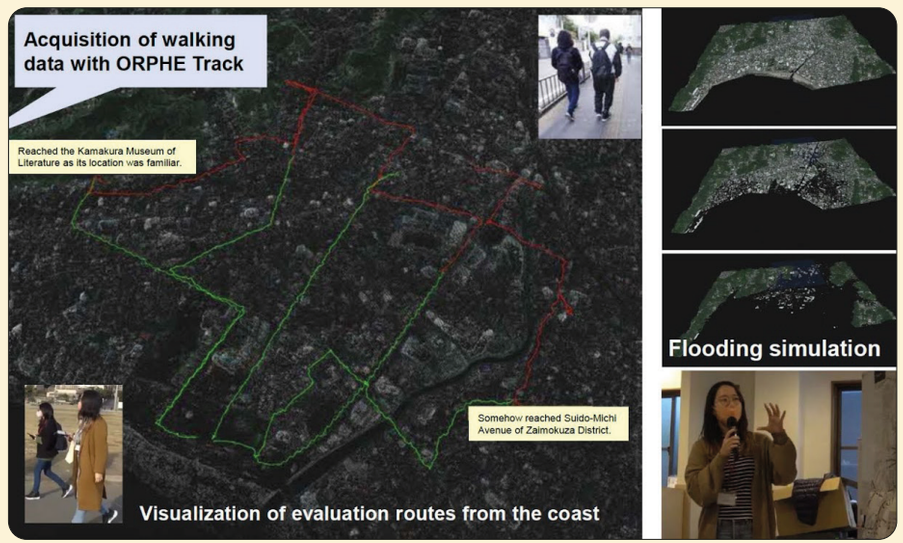
Kamakura
Japan

Year Joined Fab City Network	2018
Co-author of the case study	**Youka Watanabe** **(Fab Lab Kamakura)**

Kamakura City is located close in proximity to Tokyo. The political center of medieval Japan, modern-day Kamakura is a prominent resort town with dozens of Buddhist Zen temples and Shinto shrines. Kamakura is located next to Enoshima, one of the sites of the 2020 Olympics and Paralympics. Today it houses many IT companies and businesses.

Data Walk
@ Kamakura

Kamakura City is an area subject to tsunamis in the event of a strong earthquake. Therefore, the citizens are interested in creative ways to ensure disaster prevention efforts. The local Fab City community organized the Data Walk @ Kamakura. In the activities, participants wore smart shoes equipped with sensors to simulate evacuation from a tsunami. The groups gathered at a park on the beach and asked the participants to evacuate to a place they thought was safe in 12 minutes without using their smartphones, assuming a tsunami had occurred. After the evacuation, We shared the walking data and visualized the walking route on a 3D map of Kamakura City. By simulating flooded areas according to altitude, we could clearly see the safe and unsafe places and speculate more informed routes to safety with the participants.



Amsterdam
Netherlands

Year Joined Fab City Network	2016
Co-author of the case study	Thais Costa (WAAG)

Fab City Amsterdam joined the Fab City Initiative in 2016, to promote decentralized manufacturing and empower citizens to build a circular economy. Our focus has been on putting citizens at the center of sustainable transformation, building on the skills needed for circular local production and creating regenerative solutions considering our city's historical and cultural value.

Reflow

Reflow is a European Union-funded project that seeks to understand and transform urban material flows and co-create and test regenerative solutions at business, governance, and citizen levels to create a resilient circular economy.

Textiles have been a critical and polluting industry since the Industrial Revolution. Thus, the Amsterdam Reflow pilot, called Textile Life(cycling), aims to increase the percentage of home textiles that are recycled, through redesigning diverse methods for collection with citizens. This in turn provides feedstock for the recycling industries, transforming the textile stream from linear to circular in the Amsterdam region. Reflow focuses on increasing the clothing, home and leisure (hotel linen) textiles collected at a city level by engaging citizens in a series of hands-on educational experiences, lectures and expert talks which provide iterative learning entry points. The Amsterdam pilot aims to create an exchange system platform in the long term. This platform will track and trace materials, valorise the achievement of circular flow and cycles, and incentivise business opportunities through promoting and mapping businesses involved in material recycling.

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16
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The first Fab City book “Fab City: The Mass Distribution of (almost) everything”, was published in time for the Fab City Summit Paris. It was a book about the power that human-centered technology can have in transforming urban environments and our socioeconomic systems. This is the same book, but revisited for 2022. Four years on, a global pandemic, catastrophic weather events, new and on-going wars and a looming global energy crisis are reshaping the urgency for Fab City thinking. The potential that “The Mass Distribution of (Almost) Everything” has is more profound than before and only becomes more so. This edition is a major contribution to the Bali Fab Fest 2022; the first ever Fab Fest which brings together the Fab City global initiative and Fab Lab Network on the island of Bali to accelerate the transition to a regenerative economy on the island of Bali.

The first version of this book was made possible by the support of
Distributed Design Market Platform, a Eu-funded project under the Creative Europe Platforms program, the City Coucil of Barcelona and the United Nations Industrial Development Organisation.

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