Digital urbanization of remote rural cities through design as a catalyst for sustainable development: The case study of Puerto Williams, Chile.

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Abstract. This article presents the firsts phases of interlocking between community, city and digital manufacturing infrastructures, focused on the case study of Puerto Williams, Chile, the southernmost city of the world. Its process of digital urbanization for sustainable development based on technological education for the local school and community, by combining digital fabrication for the design and production of local solutions. Located in Navarino Island, Puerto Williams has no high-speed internet connection, and it does not produce any energy and goods, being utterly dependent on ships that bring liquid gas, products and raw materials. In January of 2019, a fully-equipped Digital Fabrication Laboratory opened, and fibre optic internet expected to arrive by the end of 2020. These conditions establish the basis of digital urbanization process for rural, pre-digital and isolated communities.

1. Introduction.

Digital production infrastructures and equipment placed in rural areas allow changing conventional paradigms of industrialized urbanizations, reconnecting settlements, communities and natural resources in closed and interconnected ecologies based on communities. When these communities are digitally connected and have access to digital manufacturing tools, they can catalyse internal changes in their social, cultural and environmental ecosystems. Creating an alternative and sustainable approach for their development through the design and production of local solutions, based on natural resources and citizen empowerment.

In recent years, capitals of Latin American countries have undergone major urban transformations, to become part of the global cities' circuits (Sassien, 1999), concentrating and enhancing their efforts to become developed countries. However, within each country, there are essential contrasts between capitals or large cities with medium and small scale rural and isolated cities or villages. Thanks to their particular contexts, some of these settlements have the potential to become global excellence
models of sustainable development, unveiling specific insights of successful processes.

This article exposes the transition of the pre-digital community of Puerto Williams, Chile. Describing the firsts two stages of implementation of Fab Lab Austral, a digital fabrication laboratory which works as an open innovation space for sustainable development, social engagement and educational transformation. Mobilizing the community to a sustainable development focused on processes rather than products.

2. Context.
Puerto Williams, founded in 1953 as a base of the Chilean Navy is located on the island of Navarino in Cape of Horn commune in Chile (Figure 1), has the category of being the southernmost city in the world.

It plays a critical geopolitical role as a gateway to the Chilean Antarctic Territory and as the southernmost territorial enclave in the world. With a population of 1,868 people (Chilean Census, 2017), is estimated that by adding the floating population, increases to 2,400 inhabitants. Its social structure is composed of members and families of the Chilean Navy, old civilian inhabitants, new civilian inhabitants, and the Yagan indigenous community.

The Fishing Industry is the main economic activity, focused on the collection of King Crab, followed by public services as the second sector. In recent years, the Chilean government has sharply increased its investment to consolidate Puerto Williams as a global city, while projecting Navarino as a sustainable global tourist hub.

In 2005 Cape Horn received the UNESCO recognition of the World Biosphere Reserve. At the same time, studies from the University of North Texas (2016) indicates that Puerto Williams has one of the purest freshwaters in the world, defining the Biosphere Reserve of Cape of Horn as a natural research laboratory situated in a pre-industrial era (Verbeck, 2016), i.e. it has not been affected by industrial development. Marine currents and the fact that is located at the end of the global supply chain, gives the condition of an isolated ecosystem, strengthening its pre-industrial identity. Nevertheless, since all the required goods and raw materials arrive by ship, and due it does not have a recycling system, isolation can be understood as a threat.

Figure 1. Location of Puerto Williams, Cabo de Hornos, Chile.
The lack of necessary infrastructure for social gather, medical specialists, networking and internet connectivity, among other factors, strengthen the insularity status, both at operational and perceptual levels of its inhabitants, which perceives, in some cases, a distance with centralized policies and decisions made in the capital of the country.

Besides, Puerto Williams is one of the few cities in Chile that does not have a direct high-speed internet connection, needing to connect to targeted signals directed from Ushuaia, Argentina, with a download speed lower than 2 megabytes. The long-awaited fibre optic channelled from the mainland will be operational by the end of 2020.

In January 2019, thanks to a donation from Dassault Systemes, the Center for Bits and Atoms of the Massachusetts Institute of Technology, Fab Foundation and the Pontifical Catholic University of Chile, the Fab Lab Austral Digital Manufacturing Laboratory was inaugurated, being the southernmost Fab Lab of the global network composed of more than 1,900 laboratories and the only one without an internet connection. The Lab, equipped with top-end machines for the digital and analogue fabrication of prototypes and products is open and available to the entire community, contrasted with the digital illiteracy of the community.

Do all these conditions, the idea of developing digital urban processes in rural territories raise. Can we build sustainable communities around the design and digital production of their own needs? How should be the design process to move towards a rural/digital sustainability model? Can, through an infrastructure that promotes design and production make a sustainable community?

These factors present us a unique- and historical — opportunity to research, study and prospect the future of sustainable development of the city and community of Puerto Williams, and to serve as a global case study in on how to develop a sustainable digital urbanization model with digital tools a rural and isolated territory.

2.1. Urban era and industrialization.
For cities to maintain their urban phenomenon in time, they require territorial and material support that extends over urban boundaries, equipping territories — apparently lagged behind urbanization processes — of physical and spatial equipment as services. This phenomenon defined as the exponential growth of cities (Brenner, 2016) describes the global phenomenon (Sassen, 2006) of cities where virtually the entire territory of the planet is available to the functioning and growth of cities (Figure 2).

This conventional urban processes, based on industrialization, increase the environmental impact of global cities over rural territories and shaped the model of production of objects and goods (Diez, 2018). Transforming an economy based on agriculture by one based on industrialization, mass production and consumption (Jaune, 2006). In this process, constituting modern cities, individuals are no longer governed by history or by a particular tradition, being attracted by opportunities, consumption, and services offered. The hyper-sensory stimulation that modern cities offer defragment time by inciting constant change and flow of information as conditions supporting urban experience.
Centralized manufacturing, with highly optimized taylorist processes under the Ford model, is the direct response to the market's need to produce consumer goods at high speed. Bringing significant contributions to engineering processes, standardizing components, manufacturing processes for products. Speed and efficiency of tasks required to minimize errors, by performing repetitively one task optimizing productivity, impacting in educational and training models to feed to the productive system.

One of the consequences is a lag of speeds between the economy of cities and the regeneration of natural resources, generating a delay in the action/reaction relationship, where the socio-environmental complexity is not able to react in time to the demands of a dynamic market (Arboleda, 2015). Breaking local ecologies and forcing the market to seek for new territories (Urban Theory Lab, 2013) to expand the productive areas increasing the entropic bill (Rifkin, 2009), breaking the underlying structure which supports any sustainable development. The construction of world society (Morin, 2010) has led us to the homogenization of, among other things, culture, identities, production, and economy. The capitalist economy, supported by the globalized model, has fractured the potential of developing sustainable communities.

2.2. Physical prototypes in the digital era.
Digitization through the Internet has been one of the key players for global economic reforms. China, for example, thanks to the exponential growth of e-commerce with Taobao and Alibaba as buying and selling platforms, together with Wechat pay and Alipay as payment platforms have energized territories that were previously invisibility by urban logics Conventional. (Quartz, 2017).

Hyperconnectivity and its impact on our personal lives (Cheok, 2015), have been placed as means of socialization and communication of information, but it has not been validated as a medium that
allows solving, on its own, urban issues (Sassen, 2017). Urban planners, architects and designers cannot solve complex problems than the same infrastructures or objects in themselves can. There is no need to build massive and large-scale projects to make a widespread impact on cities or communities.

The idea of distributed design (Vivanco, 2017) is related to the dematerialization of physical infrastructures and objects to create new types of relationships based on information and communication systems (Castells, 1995) centred on people and its value of collectively detect, design and produce their own solutions.

2.3. Towards digital urbanization.
The application of digital processes in rural or isolated territories allows the generation of new typologies of socio-territorial transformations in pursuit of integration to global networks sustainably, connected with their natural environment and social complexity (Kotler, et al. 1984). New information technologies allow us to modify the time lag (Ibañez, Katsikis, 2014), reconnecting demand and supply with the territory, reformulating the conventional capitalist model, reconnecting citizens with producers and productive capacities with those of environmental regeneration (Ghosh, 2017) in cities. Consolidating a people-centred ecosystem, supported by an ecological and social floor.

Open Laboratories for developing objects and technologies through participatory design process (Hyysalo et al., 2014), any person with or without prior knowledge can learn and connect so that they can explore and develop potential solutions to solve local needs.

3. Towards Sustainability.

3.1. Fab Lab Austral
Making ideas into tangible prototypes involves the activation of design processes, which its result is to build symbols and artefacts, but framed in a social, cultural, environmental and political context, to generate some degree of meaning — and impact — in individuals and within their communities. Transiting from symbols to products, products to services and services to systems (Buchanan, 2001) enables the construction of meaning, value, and capacity of action.

In the context of the design process, questions are not just answered only by the outcome of a methodological process, but also answered by the design process itself. In this sense, design is understood as a chemical reaction that manages to change individual states (Vivanco, 2016) or conditions of the context where it is produced. Moving towards meeting any of the Sustainable Development Goals involves the action of movement and not stabilization. It is there where design as a discipline can trigger the transition from one state to another.

Fab Lab Austral as a digital manufacturing laboratory has gradually changed into a space of social convergence of the local community, which does not have meeting places or community centres for interaction, conversation, production, experimentation, and education. Funded as an open space for the creation, design, and production of prototypes, projects or entrepreneurship products, something unprecedented and unique in the southernmost city in the world.

The mission of Fab Lab Austral is to create a community around making and prototyping sustainably and collaboratively, based on local resources. It also seeks to activate technological urbanization processes through the digital transfer of content and information for the development of prototypes, biomaterials, products, and systems. Its implementation process is structured in three phases (Figure
which will gradually involve different actors in the community, and impacting and developing different types of projects.

3.2. Community production as a catalyst for change.
During the first phase of implementation, the work focused on digital illiteracy by transferring knowledge and digital fabrication training to children of the Liceo Donald McIntyre Griffiths, the only educational establishment, through workshops where they learn to use machines, along with design methodologies. During these activities, about 280 participants were registered in the activities (Figure 4), corresponding to almost 60% of the school population of Puerto Williams.
During workshops, a schoolchildren group with much interest in participating in all the activities of the laboratory was identified, proposing ideas of possible projects to develop. Schoolchildren aged 12 and 13 years old were the most active, on the other hand, from 15 years old and onwards there is a disinterest in participating in activities. Besides, some schoolchildren with problems of adaptation and integration into the traditional educational model of the Liceo have found in the Fab Lab a space to develop their skills differently, based on horizontal and collaborative learning. In a second phase, workshops were developed for adolescents and their parents, extending the impact to the rest of the community, where the participants themselves proposed an action agenda linked to relevant Navarino Island issues to address with digital design and manufacturing tools. By the appropriation of the creative and productive capabilities of the Fab Lab so that, from design, issues can be addressed to have a positive impact on the island. Sustainably taking ownership of their context and, at the same time, generating new and unique interactions between the community.

In addition to the function of being a manufacturing laboratory, Fab Lab Austral transformed into a meeting and socialization place. While the main activities carried out in this first stage of implementation were aimed for children, in numerous activities their parents participated, generating social links between them and also among other adults belonging to different groups of actors in the community (Figure 5). In this same vein, one of the central projections identified in this first stage is to focus in a second stage the work with the adult community, for the generation of collaborative and associative networks, of local organizations or entrepreneurs and local businesses with a focus on reducing inequalities (SDG 10), cities and sustainable communities (SDG 11) and industry, innovation and infrastructure (SDG 9).
Results.
Methodologically the workshops were led through a co-design process between the different actors of the community together with a group of designers, for the detection of natural resources available on Navarino Island and its subsequent link with local needs. In this sense, the main issues detected was the local production of energy and, given the geographical context, for its transformation into heating systems (Figure 6), together with the development of new materials, based on waste or resources to supply plastics or other harmful materials to the environment entering the island.

Figure 6. Domestic heating from organic waste using the Berkeley method. Developed by students of the Master of Advanced Design form the Pontifical Catholic University of Chile.

The development of biomaterials, on the part of the community, meant a holistic and systemic understanding of the island and its processes, recognizing and highlighting the stagnant energy of materials and resources, which could channel towards the generation of new low-cost raw materials or products.

For example, the 8-hectare Puerto Williams Landfill has an occupancy of about two-thirds of its area. Only by maintaining the increasing occupancy rate implies that in less than 13 years, its storage will...
complete its capacity. The fishing industry of Puerto Williams' primary economic industry provides 35 m$^3$ of organic waste yearly, waste with high productive and nutritional potential. Chitin, found in shells that are considered waste, is the main ingredient to produce producing types of bioplastics. The generation of a low-cost technology to extract the Chitin from shell, and a process to produce of bioplastics (Figure 7), allows not only to generate a new sustainable and biodegradable material as input for the design of products (Karana, 2015) but also directly attack the increase in the volume of the landfill and the environmental pollution by bad odours that this material generates.

![Figure 7](image)

**Figure 7.** Do It Yourself system for the extraction of Chitin and prototyping process for the generation of bioplastic based on Chitin extracted from King crab shells.

**Conclusion.**
Co-design is an exercise that integrates and overlays individual knowledge (Tironi, 2018), to create a collective goal of knowledge. Therefore, a community with the ability to co-design their solutions could be defined as a sustainable community.

The connection of the Fab Lab with local resources and the community of Puerto Williams offers a unique opportunity in the near future to decrease the number of physical importations by ships and to increase the digital transfer of information distributed by fibber optics to produce in the FabLab digitally. Developing novel and replicable model of sustainable digital urbanization for remote rural settlements.

As a first stage, the gap of digital illiteracy was shortened by enabling the community the access, equipment and knowledge to produce ideas with digital tools, under the idea of cutting the isolation perception, producing a docking process (Lee, Yoon, 2004) in between the community. At the same time, the emergence of new objects in a rural settlement is framed in a multi-scale, transiting from technological devices to meaningful actions.

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