

# When Residents Are Makers:

## *Using Additive Manufacturing for Rehabilitating Modernist Housing Heritage*

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*French colonial authorities realized numerous Modernist housing projects in the city of Algiers in the 1950s. Residents, mostly of low-income local communities, have modified these buildings over time to fulfill updated needs in overpopulation. While the government relocated the residents of some complexes to new settlements and demolished the buildings, in some, residences continued to live in and adapt the physical properties of the dwellings for new generations. These residents are already active agents in housing rehabilitation. Their modifications are almost systemic and have a language, inspiring sustainable approaches that are alternative to complete abolishment of architectural heritage. The efforts of the residents can be organized and enhanced with digital fabrication and open source sharing platforms of the maker culture. In pursuit of a rehabilitation strategy to these sites, we formally analyze the dweller modifications and assess the residents' competencies in order to formulate a context-oriented resident-driven do-it-yourself support framework.*

**Keywords:** *DIY, 3d printing, user empowerment, modernist housing heritage*

### **DESIGN TECHNOLOGY COMMONS AND USER EMPOWERMENT IN ARCHITECTURE**

Resident modifications are efforts in homemaking and vernacular interpretations of designed spaces (Attfield 1999). The role of architects in user-oriented design has come to be more and more explored in design studies since the 60s. Computational analysis and predictive decision-making techniques are effective in detecting deficiencies in design by mimicking the user (Jones 1963) while collaborative design processes often define users as active participants of decision-making (Vardouli 2015). Lately,

an increased interest in the maker culture and do-it-yourself communities have become a part of open source architecture (Ratti & Claudel 2015) and related design technologies are potent towards sustainable and humanitarian practices.

Open source architecture is linked to both the open source culture and user-driven design methodology. The open “source code” of architecture can be the building information that consists of the drawings and models of the design in a literal translation (Vardouli & Leach, 2014). The outcome is dependent on the mediator. Following a user-driven method-

ology, House\_n developers introduced a responsive model for creating places to live in where users are designers at the center of the process (Larson et al. 2004). In open building, the end user can adapt and transform the space they live in through systems of software and interactive electronics (Habraken 1972).

User-oriented design methods in housing projects have two central tendencies: one introduces the user to the design process, the other focuses on activating the user in a prolonged construction phase. More in the focus of our study, examples to the latter are Correa's PREVI Experimental Housing (Khan 1987), Architecture for Humanity [1], Elemental (Aravena & Lacobelli 2012), and Building Haiti (Stoutjesdijk 2013). Recent recognition of 10 Houses on Cairn Street by Assemble with the 2015 Turner Prize [2], Alejandro Aravena's socially conscious approaches to housing with the 2016 Pritzker Prize [3], and the refurbishment of a 1960's slab block with the 2017 Mies van der Rohe Award [4] show that user-oriented dwelling, whether newly designed or renewed heritage, is a present issue for sustainable communities.

## **BRIDGING THE ACTIVE AGENTS AND DIGITAL FABRICATION**

Focusing on one building complex in Algiers, namely 200 Colonnnes in Climat de France, we have analyzed in detail the resident modifications in order to propose a supportive framework for a local DIY culture. In reference to the notion of Ingold's taskscape (1993) to articulate the spatial and temporal dimensions of the architecture, our analysis categorized the residents' dwelling activities and identified the skills, cost and the impact resulting modifications have on the existing structure. Data collection included archival documents, on-site interviews, and on-site photography. The analytical drawings and visual rules based on this data are the subject matter of another upcoming publication.

Data showed that most resident modifications in Climat de France have a low impact on the building. Residents continually adapt the building and its

spaces according to their needs with minimum or no harm to the existing structure. Low impact changes are made mostly using basic hand tools and common hardware, or through contracted basic skill such as the kind utilized in building a partition wall. Following indoor and outdoor partition walls, the most popular resident modifications were awnings, laundry racks, outdoor curtain holders and fences. Satellite dishes and air conditioners are other common additions but are excluded in our study as they require professional skills for installation.

Figure 1 lays out the modifications on (evenly numbered) 24 adjacent blocks that form the South wing of the 200 Colonnnes building at Climat de France. All modifications, illustrated as grey fields, are visually linked to the general type of activity they respond to, the taskscape they serve, the level of skills required, the estimated cost to build them and the degree of their impact on the existing building. Based on these outcomes we propose to channel the residents' energy and building skills into a more efficient, self-sufficient way of doing modification with minimum harm to the building using digital fabrication. In the scope of this paper, we present our investigation on how their activities can be supported by on-site production with local and reusable materials for the possible use of additive manufacturing. As low-income residents cannot easily obtain sheet materials that CNC and laser cutter require, we focus on additive manufacturing techniques to develop different joint systems to combine the easily found and often recycled material such as textile, wood, and metal, according to specific needs. Waste management and circular economy are hot topics in Algeria inspiring many young entrepreneurs to invest in, such as Plasticycle Algeria [5]. We envisage a self sufficient network that involves the production of local plastic filaments for the use of additive manufacturing.

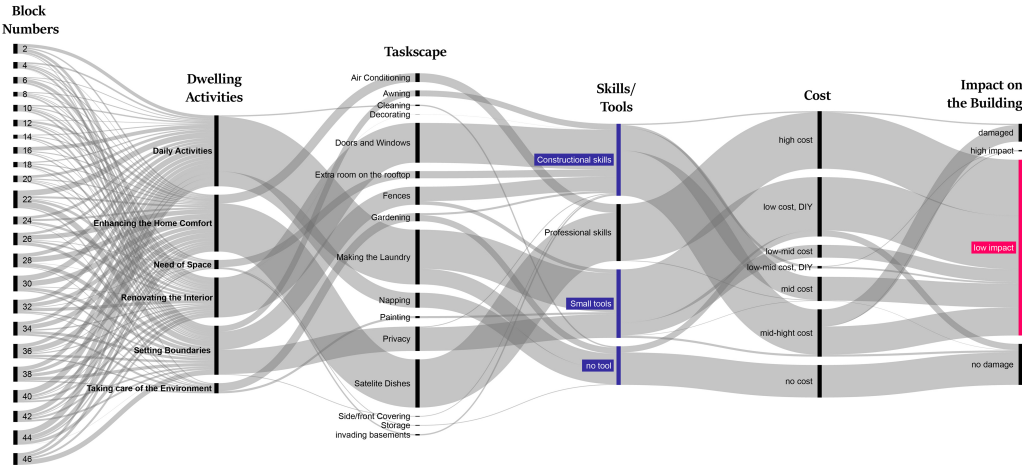
A SELF-SUFFICIENT COMPUTATIONAL COMMUNITY NETWORK

In order to develop an approach to the residents' needs with additive manufacturing, we analyzed all the modifications and the material used to make them. We identified repetitive patterns in modification types and set an example of possible solutions to these types. We mainly focus on offering model solutions for typical awning supports, laundry rack attachments and outdoor curtain holders. The goal is to open a platform and to create an array of solutions that could be further developed and adapted by the residents themselves. This kind of activity may positively transform the community and provide a platform for sharing, making and maintaining their houses up to an adequate standard. Similar cases such as the smart city approach projected for Barcelona attest to potential success. In Barcelona, the aim has been to deploy fab labs in every district to create a city that is globally connected but locally self-sufficient locally (March & Fumaz 2016). Fab labs have been set up to offer programs for at-risk youth for social service and kids for educational purposes in the United States (Gershenfeld 2012). Birtchnell and Urry (2016) discuss the positive impact of 3d printing at the local community level on economic and envi-

ronmental sustainability "without burdensome top-down governance and administration". Gershenfeld (2012) emphasizes that "the real strength of a fab lab is not technical, it is social".

Modifications are a great part of the dwelling activities of the residents of Climat de France and additive manufacturing in response to many levels of daily activities and visions of future rehabilitation is a support system for the open building. We propose a framework and a set of prototypes to create an open and accessible computational platform to support the potential for user empowerment in housing rehabilitation. A decentralized organization of fab lab practices, rather than a physical center that would serve as a fab lab in Climat de France, would encourage the presence of women in the network of making. Women and minorities are already underrepresented in the fields of digital fabrication (Gershenfeld 2012), and labeling a central public space of fab lab open to public in Climat de France may bolster their exclusion from the making process. Gender segregation is still an important issue in popular settlements where the unspoken rule of "public spaces, hence streets, belonged to men, and domestic spaces to women" (Çelik 1997) is still valid. Women are "quiet activist"s of everyday making (Hackney 2015). They are the leading actors in the domestic taskscape of

Figure 1  
How resident modifications are distributed across the ranges of activities and criteria considered in the study.



the daily activities of dwelling.

In low income communities it is crucial to be self-sufficient, and sustainable. Additive manufacturing technologies are versatile in terms of material use and are favorable for the low-income context. New recycled materials such as paper pulp, coffee, sand-stone and biodegradable composites are persistently investigated for 3d filament production alternative to plastic along with other PLA based hybrid materials [6,7]. On the other hand, there are expanding studies on extruding 3d filament from recycled plastic with DIY extruders (Baechler et al. 2013). According to an Our World in Data report [8], the plastic waste generation in 2010 was 0,14 kg per person per day in Algeria and is considered a major problem. Recycling plastic into 3d filament to create value from it has been catching locals' interests. Precious Plastic [9] is an open source project of plastic recycling, that has a machine builder, a workspace and dozens of volunteers from Algeria. It does not only provide documents and drawings for a shredder, extrusion machine, injection machine and compression machine, but also a community network that connects volunteers to work together in this domain. There are other open source DIY 3d filament extruder initiatives such as Recyclebot [10] who shares the know-how for a waste plastic filament extruder under 1000 US dollars. Precious Plastic is among the most accessible initiatives and its social platform draws and supports many volunteering communities from all over the world. That many locals in Climat de France have Facebook and Twitter accounts and are familiar with the context of social media, facilitates the introduction of platforms such as Precious Plastic and sets the required infrastructure for digital fabrication.

Open source platforms impact communities as in the example of RepRap, an early low cost 3d printer buildable from an open kit of parts [11]. Resident empowerment can be achieved by design technology expert initiatives creating a maker ecosystem that sustains itself at different levels in which residents are encouraged to recycle material, built their own 3d printer and extrude their own filament and start mak-

ing.

## RESIDENTS AS MAKERS

Residents of Climat de France create solutions to their daily problems "using whatever materials are available" [12]. They are "bricoleur"s who seek for rapid and practical solutions with whatever is at hand but can evolve into "do-it-yourselfers" if they are more involved in the creation and the conception of the making. DIY is a domain that is much dependent on consumption as production (Shove et al. 2007). In Algeria, home improvement retailers either do not exist or are not accessible to low income communities. Big home improvement retail chains and ready to assemble flat pack furniture groups are not relevant in this context. Therefore, consumption in resident modifications is almost nonexistent. Modifications are mostly based on the reuse of existing material and recycling. As novice makers, residents need support to understand and experience what can be done with the provided tools and existing material. Basic libraries, i.e. of joints, for most common modifications, can initially be instrumental in the transition.

Revisiting analysis of site data, we focus on resident modifications that have low impact on the building, that requires basic construction skills and the use of small tools. The modifications that require basic constructional skills are related to the following dwelling activities: awning, decoration, security fences and gardening. The modifications that require small tools are laundry racks, mosquito nets and curtains. Existing solutions in 3d printing libraries, such as that of Thingivers [13] a popular 3D design community, yield to 27 results on laundry rack, 6 results on mosquito nets, 975 results for curtain rod, 94 results for awning and 665 results for gardening. It was possible to adapt existing joint designs to the context of Climat de France in the spirit of a universal maker culture. Nevertheless, belonging to different contexts, not all existing solutions that communities share are applicable in the case of Climat de France, and there is a need to develop a set of 3d printed joints that can be adapted and used by the

residents of Climat de France with minimal damage to the building. Within the repetitive modifications made by the residents, we identified patterns of appropriating any material on hand over and over again for different purposes. Adaptability of the joint system is crucial for this line of use. For instance, bolted joints consisting of a minimum of two interlocking pieces allows the first bolt joint that is fixed to the wall to be adapted with different screw joint ends. These ends differ according to their functions such as curtain rod holder, laundry rack attachments and support elements for awning.

### **3D Printed Joints**

**Curtain Rod.** The issue of visual privacy is an indispensable aspect for the locals and a key motivation for modifications. Resident modifications related to visual privacy narrow down to three different solutions: outdoor curtains, wooden shutters and roller shutters. Wooden and roller shutters are constructional modifications and outside the scope of this paper. Outdoor curtains, however, are applied using small tools and low level of skills. We prototyped a merely functional and economic joint system aside from aesthetic or culturally symbolic concerns. This joint system consists of two pieces, one can be easily fixed by the resident to the wall and a second end screwed to the fixed end that can be adapted to different rod profiles and size (figure 2). The fixed end of the joint system can be combined with different ends that can be interpreted to different functions such as the laundry hanger or the awning support.

**Laundry rack.** Within the solutions developed by the residents for laundry drying, we identify five different types. Three of these solutions are achieved by wiring robe to existing metal frames or nailing it to the wall. We focused on the other two solutions that make modifications with higher impact, the first solution is based on the implementation of metal linear elements to the wall and the other one is attachment of industrial laundry racks to the wall with different methods. We propose the use of the universal tube fitting to fix on the wall and attached different ends to

it according to the material in use. In the case of linear elements, the screw tube is designed according to the profile of the linear element. For the second type, we propose a different end to the same fixed tube fitting to hold the readily bought drying rack (figure 2).

**Awning.** In existing awning solutions improvised by the residents, fixing the awning with a supporting element, mostly metal profiles, and forming it out of cement are the two main approaches. The latter results in irreversible impact on the façade. Therefore, we explored the first option of creating 3d printed support elements in two ways: first is a ready 3d printed support element that could be fixed to the wall directly and a second set of joints consisting of bolt joints used for the previous purposes (figure 2).

### **Time and Resources**

While experimenting with the joint systems we envisaged two essential aspects that would have a considerable impact on proposed maker community, these are the printing time and the amount of filament used. We set the following arguments based on the data we gathered using 1.75 mm diameter industrial filament to print with Prusa i3 MK3. The printing time of each joint is an important input that should be taken into consideration in order to set achievable goals in a possible implementation of digital fabrication on site. The printing time of the six parts that constitute the laundry rack joints for one window is 5h:55min:46sc, the four parts of curtain rods is 04h:38min:48sc, the two parts of the awning is 03h:40min:56sc (table 01). There are a total of 774 registered apartments in CF 200 Colonnes building, with an average of three windows for each apartment which makes an average total of 2322 windows for the whole building. If each apartment would print one laundry rack, three curtain rods and three awnings and we would have one printer for each joint system working 12 hours a day. It would take 3 years, 2 months and 6 days to print laundry rack joints, 2 years, 6 months and 19 days to print curtains rods and 2 years, 1 month and 14 days to print awnings

### Visual Privacy



### Laundry

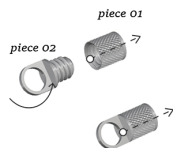


### Sun Protection

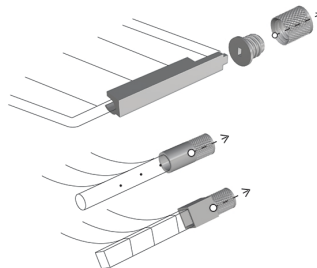


Figure 2  
Resident  
modifications  
related to visual  
privacy, laundry  
and sun protection  
and the prototyped  
curtain rod, laundry  
rack and awning  
joint details.

### Curtain Rod



### Laundry Rack



### Awning

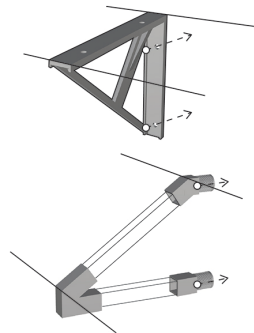


Table 1  
Time and material resources required to 3D print the proposed joints for Climat de France '200 Colonnnes' Building. The amount of Plastic required for 3D printed joints constitutes 4% of the daily plastic consumption of the buildings' residents.

Taskscape	Printed Pieces	Filament Used (m)	Print Time (h)	Total Print Time (h)	Number of Joints for '200 Colonnnes'	Print Time for '200 Colonnnes' (printing 12 h/d)	Filament Used for '200 Colonnnes' (m)	Recycled Plastic Required for '200 Colonnnes' (kg)
Laundry rack	part 1/ tube fitting	3,9	00:59:52	05:55:46	774	1161	20084	167
	part 2/ screw tube	2,4	00:52:15					
	part 3/ hanger	6,7	01:05:46					
Curtain rod	part 1/ tube fitting	3,9	00:59:52	04:38:48	2322	928	31313	261
	Part 2/hook bolt	2,9	01:19:32					
Awning	Part 1	10,5	01:50:28	03:40:56	2322	774	48985	408
TOTAL								836

for all registered 774 apartments. This is an important amount of time that needs to be planned meticulously before implementation. The advantage of open source design is its easy distribution and efficient individual fabrication, however, the presumption of individual 3d printers is not realistic in the case of overpopulated mass housing. Therefore, time is an essential issue to be planned and organized beforehand.

The other issue on 3d printing is the amount of material required for such a large settlement and its affordance. Considering plastic recycling, we calculated the average amount of filaments used in each joint and compared it to the plastic consumption of residents of Climat de France. There are companies that are producing recycled PET filament (Holweg et al. 2015) using mechanical and chemical recycling. They used 10 gr of PET water bottle to produce roughly 1.2 m of filament with 1.75mm diameter. We make a rough calculation on the amount of recycled plastic required to print these joints. For 1m of filament, an average of 8.33 gr of recycled PET is required, therefore the amount of filament needed to print one laundry rack, three curtain rod joint and three awning joint for each apartment in the whole building of 200 Colonnnes is estimated to be 836 kg (table 01).

If a person's plastic waste is 0,14 kg per day in Algeria [8], an average 4 people in each of the 774 apartments of 200 Colonnnes consumes daily a total of 433 kg of plastic daily. The 836 kg of plastic needed to create all the joints mentioned earlier is almost the

amount of plastic consumed by the residents in two days. Certainly, not all the plastic consumed by the resident is PET and is recyclable for 3d filament yet this calculation indicates the potential reuse of plastic waste on site. Plastic recycling also can have a broader impact on the community than sustaining filaments for their own 3d printing.

### CONCLUSION:

Architecture in the age of the 4th industrial revolution is more and more defined by networking resources, technologies and people to build better, smarter and sustainable futures. Making use of the existing building stock and rehabilitating it towards better use is an essential issue. In case of rehabilitation, given that construction safety is sustained, it is compelling to include the residents not only in design processes but also the making of space. To do so, we explored a framework for producing building components by additive manufacturing to support open-ended solutions that can be elaborated and transformed by the residents. In current practice, most of the modifications made by the residents of Climat de France are provisional. They use the material available in their local market or recycle the discarded materials they find in their surroundings. Developing alternative joint systems as a case, we prototype easily mountable joints that would not damage the existing structure. Our detailed analysis sets the context and introduces the capacities of the site and the competencies of residents as agents in reha-

bilitating a lived-in architectural heritage. The assessment with regards to the additive onsite manufacturing of the joint system indicate the potentials and the limitations for the DIY framework as part of rehabilitation. The long-term objective of the framework is an open source platform and a computational community network where user modifications are informed through design technology, and in return, inform the sharing community to improve the architectural solutions in a given social housing rehabilitation.

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