ICT-ENABLED BOTTOM-UP ARCHITECTURAL DESIGN

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Abstract
This paper aims at discussing the potentials of bottom-up design practices in relation to the latest developments in Information and Communication Technologies (ICT) by making an in-depth review of inaugural cases. The first part of the study involves a literature study and the elaboration of basic strategies from the case study. The second part reframes the existing ICT tools and strategies and elaborates on their potentials to support the modes of participation performed in these cases. As a result, by distilling the created knowledge, the study reveals the potentials of novel modes of ICT-enabled design participation which exploit a set of collective action tools to support sustainable ways of self-organization and bottom-up design. The final part explains the relevance of these with solid examples and presents a hypothetical case for future implementation. The paper concludes with a brief reflection on the implications of the findings for the future of architectural design education.

Keywords: Bottom-up; Participation; Architectural Design; Crowdsourcing; Crowdfunding; Self-organization.

INTRODUCTION
In his seminal book "The City Shaped", Kostof (1991, p.43) identifies two different kinds of cities in history: planned and unplanned. The first one, ville créée refers to an urban pattern designed by an authority in a top-down manner. A clear example from the middle ages is the nieuwestad (new city) Naarden in the Netherlands with a grid plan dating from 1350.

The second kind is a city which grows dominantly from the bottom-up in a spontaneous manner: ville spontanée. It emerges as a result of unplanned evolution without a master plan, as a result of centuries of daily struggles and bottom-up spatial interventions of the citizens. Numerous cities fit in this description such as Cappadocia in the Göreme Valley, Turkey, dating from 1800 B.C. and Thera, Santorini in Greece, 3000 B.C (Rudofsky, 1964, p.58). In this context, bottom-up participatory architectural practices can hardly be considered as novel.

For thousands of years, architecture was an evolving and emergent communal work, in other words, a spontaneous and continuous activity of people with a common heritage, acting under a community of experience (Belluschi, 2012). Vernacular architecture was produced through the collective work of ordinary inhabitants through the use of local materials. Their simplicity and harmony with the environment made them sustainable.

Indeed, some examples with antecedents dating from 6000 B.C. are still occupied and functional today (Figure 1). Instead of trying to challenge the nature, these practices welcomed and made use of the climate. However, the most powerful affordance of the vernacular architecture was the direct and unself-conscious translation into the physical form of a culture, its needs and values, as well as the desires, dreams, and passions of a people (Rapoport, 1969, p.2).
Overall it is clear that vernacular architecture examples around the world have close associations with durability, versatility, flexibility, adaptability accompanied with a strong sense of community, identity, and place (Rudofsky, 1964, p.13).

However, as a result of the professionalization of architectural design beginning with the Renaissance as well as the industrialization in the following centuries, these essential priorities started to be replaced by cost-cutting mass-production approaches. Besides the loss of essential characteristics of spaces, modernity caused a significant shift in the understanding of the relationship between time and space. This transformation was in the form of the rejection of contingency through the assumption of a state of perfection to be reached tomorrow (Bauman, 2000, p.25, p.29). It was this moment when space and time became separated in the minds of the producers. The communal building aspects of architecture and collective endowment were deteriorated in favor of massive individualization and privatization of nearly all aspects of life. The architecture serving to its users' needs and values was no more.

As a reaction to the developments above, participatory bottom-up architectural practices were brought onto the agenda of architectural design prominently after the Second World War and gained traction with the movements of 1968 (Jencks, 2011). The following decades witnessed the emergence of alternative approaches to architectural design. A bottom-up pluralist strand became popular in Western Europe, the Americas and many other regions around the world as an alternative to state-centered and top-down models (Bowns and da Silva, 2011).

In this paper, I will make a brief review of these approaches with examples from specific cases which can be claimed to be the frontiers of bottom-up participatory design. This review will be followed by two antecedent projects: Medical Faculty Housing by Lucien Kroll (1976) and Cedric Price’s unrealized Fun Place (1965) through which a wide range of participation forms were conceived. In both of these projects, the designers attempted to use various industrial and computational methods for augmenting participatory design processes. However, the capacity and potentials of these were limited at the time.

Acknowledging this gap, this paper aims to discuss the potentials of modes of participatory design in relation to the latest developments in Information and Communication Technologies (ICT). Regarding this aim, the research questions to be explored in this paper are:
1. What are the participatory design strategies used in the prominent bottom-up cases?
2. Which forms of ICT use were conceived in these?
3. Can these serve as a basis for a novel approach that incorporates state-of-the-art ICT?

In this context, the first part of the study (Section 2) involves the extraction of basic strategies and principles from the antecedents of bottom-up participation. Building on the findings of this case study, the second part (Section 3), reframes the existing ICT tools and strategies in terms of space and time and elaborates on their potentials for supporting the revealed modes of participation. The following section introduces a framework for ICT-enabled design participation which exploits a set of digital and non-digital collective action tools to support sustainable ways of self-organization and bottom-up design. As a result (Section 4), by distilling these findings, the last part of the study reveals the future potentials of ICT-enabled bottom-up participation including novel methods such as crowdsourcing, crowdfunding and emergent technologies such as smart structures and fabrication.

BACKGROUND: LEARNING FROM THE PAST

As briefly introduced above, it is possible to identify two main strands of city-making from the perspective of governance. Top-down approaches are based on the conception of citizen participation as a state-centered practice. In contrast, bottom-up approaches are characterized by social activism and civic engagement in the absence of higher level direction (Bowns and da Silva, 2011). Although these models seem to be conflicting with each other, bottom-up and top-down practices are often used in combination during the production processes of the cities. It is impossible to find a practice which purely fits in one category (Salingaros, 2005, p. 223).

After the beginning of the twentieth century, with the introduction of the modernist approaches, authorities in the Western World increasingly adopted strict predefined territorial boundaries and zones, and predominantly top-down planning methods which increasingly disabled the community participation (Nour, 2015, p.21). At the beginning of the 1960s, architecture was in a severe crisis. The problems of modernist functionalism and bland architecture emerged as a consequence of economically-driven utilitarianism and these became more and more evident in the media (Blundell-Jones, 2005). A monumental example was the Pruitt-Igoe Housing located in St. Louis, Missouri, USA, in which the living standards started to decline only after two years and eventually, in less than eighteen years, it had to be demolished due to its social and physical unsustainability (Larsen and Kirkendal, 2004).

The decades that followed these developments gave birth to new approaches criticizing modernist top-down practices. Through specific design cases, the architects aimed at the bottom-up involvement of users in alternative ways and made extraordinary experiments which served as a model or stimulus for later developments. In this section, I will make an attempt to relate these cases to each other and extract the common strategies behind these.

Frontiers of Bottom-up: Experimental Practices after the 1960s

Habraken (1961) was one of the first to introduce the idea of spatial self-determination as a citizen right. In his book “Supports: an alternative to mass housing” he suggested a participatory design method based on the decoupling of the support infrastructure and the “infill”. In this method, while the infrastructure is framed as a static and long-term investment, individual habitation units were envisioned to be customized by the users with the help of an architect.

Habraken’s concept of a supporting/enabling megastructure was not novel at that time (Figure 2); it can be traced back to Nieuwenhuys’ New Babylon experiments between 1956 and 1978, Friedman's Mobile Architecture in 1958 and Fuller’s structural designs in 1955 (Lobsinger,
His ideas also resonated with Jane Jacob’s (1961) coeval critique of planning practices in the USA and the Situationists (Mathews, 2006).

The real contribution of Habraken was his ability to combine the criticism of modern architecture and bottom-up participatory practices with an alternative industrial vision. The methodological studies of Habraken’s office SAR (Stichting Architecten Research) that followed the lines set in his book increased his impact on the world of architecture and inspired several architects including Lucien Kroll. Even today, this school of thought is still active under the name of “open building network” in close collaboration with the building industry (Kendall, 2015).

The most classic example following a similar design approach as Habraken’s supporting/enabling structure was Le Corbusier’s Unité d’habitation, in Firminy France (1962). This design employed a “bottle rack” principle: an open structural frame infilled with different housing types (Schneider and Till, 2007, p.168). However, the central focus of this project was not necessarily on bottom-up design but rather on creating variety and opening up possibilities for choice.

In Poland, Oskar Hansen, a member of the group of architects Team X, was one of the first critical voices regarding the orthodoxy of modern Athens Charter and the followers of Le Corbusier. He presented his “open theory” to the founding meeting of the group Otterlo in 1959 (MACBA, 2015). This "attitude" (rather than a theory) was conceived initially as a tool for the design of architectural projects, although evolution and its application in the fields of education, editing films, the games and visual performance practice led to broad set experiments that were interacting with each other, sharing and socializing through art objects. Hansen experimented with strategies open to uncertainty, flexibility and collective participation. He coined the term "open form" to describe architecture open to the possibility of continuous transformation, open to the influence of nearby practices as well as to the approval of the users (MACBA, 2015). One of
the most memorable products of Hansen was the design of adaptable furniture which allows almost infinite uses of a rectangular living room.

In parallel with these contributions, in 1962, Walter Segal developed a low-cost housing solution suitable for self-build, while trying to address his own problem of providing a temporary home for his family. This practice evolved into the development of “The Segal Method” and several participatory design projects in which 27 families worked with architects to design and build their own homes (Broome, 1995).

One of the most interesting bottom-up cases in the same era was the building of the Gladsaxe playground in 1969 (Gehl and Svarre, 2013). Led by Jan Gehl’s team, residents from Høje Gladsaxe, a newly built public housing complex in a suburb of Copenhagen, Denmark and the students from Copenhagen universities ventured into an unauthorized construction of a large playground on an empty stretch of gravel in front of the multi-story complex (Figure 3). According to Gehl and Svarre (2013) the playground was perceived as quite successful while it was being built and for many years later. This case was recorded as one of the earliest examples of truly bottom-up design and construction of a public space in the Western world, triggered by an architect/urban designer.

Around the same time period (1969-1978), Lucien Kroll orchestrated the design of the Medical Faculty of the Catholic University of Louvain (UCL) with the student organization “La Maison Medicale-La Mémé”. In the following text, I will make an in-depth review of this case.

LA MÉMÉ (IN-DEPTH CASE 1)

The project was initiated when the Catholic University of Louvain (UCL) decided to move its Medical Faculty to Brussels, Saint-Lambrechts-Woluwe. The university authorities made an exceptional decision and presented the preliminary design of the Medical Faculty Housing to the student committee. The students rejected the project and contacted Kroll for his services (Kroll, 1987). As a close follower of Pierre Bourdieu, Kroll took the task and questioned every aspect of the institutionalized practices with the contributions of the spirited students of UCL. He intended to create an open design process, “an action open to new necessities and to decisions that are always provisional and incomplete” (Kroll, 1987). He aimed at establishing an intellectual climate through which a kind of friendly organization would emerge to result in a homeopathic kind of architecture (Kroll, 2005).

Kroll organized meetings with the committees and discussion groups. In these meetings, he received conflicting ideas. Instead of flattening out all the differences of approach and attitudes he tried to incorporate them into the design process (Kroll, 1997). This was a creative refutation
of the idea of “consensus”. Throughout the project, the students were empowered to participate in two forms: through getting involved in the design process and through the participation opportunities provided by the architectural design *per se* (Figure 4).

Figure 4. Medical Faculty Student Housing by Lucien Kroll. The users participated in the decision process, and the architectural product enabled them to shape and reshape their surroundings (Source: Author).

Kroll developed a flexible structure system which he called “wandering columns” based on a loosely defined grid. He collaborated with a professor of computer engineering to manipulate the grid to support the irregular and heterogeneous shell of the building. He designed the artificial ground around the project to provide raw space for further development (the aspects of wandering columns and his long-term vision for expansion are more evident in the Alma Metro Station, which was built as an extension of the project).

The “infill” –inherited from Habraken– is hypothetically removable: demountable window frames, moveable partitions, and prefabricated sanitary units. The architect used his own interpretation of the Habraken’s SAR module but refuted the idea of functional zones (Kroll, 1987). According to the principles of co-habitation, the infill can be torn down by the users, which encourages them to take initiative in planning and re-planning their environments. The plan would always be incomplete.

In La MéMé, Kroll did not see aesthetics as the central point of design. Through this project, he strongly criticized what he called the “easel architecture”: aesthetically pleasing but isolated from the people, culture, and community. In his book “Architecture of Complexity”, Kroll (1987) reserved a whole chapter to the computers. Instead of computer-aided design (CAD), he suggested computer use in design (CUD) as a more appropriate term for describing his vision. He stressed the importance of open-endedness and heavily criticized the inflexible artificial intelligence practices of the time that led to self-contained, closed and repetitive results.

In contrast, Kroll envisioned the drafting software as a potential tool that allows open-endedness through which the architectural product and the social relationships can be involved in the design and manufacturing process. However, the communication technologies were not developed enough to realize fully the social part of the potential.

The computer-based social interactions he foresaw were limited to three-dimensional drawings which he found useful for the communication of early ideas to the inhabitants. He
suggested that infinite interactions were required to deal with the infinite diversity of the real world.

In close contact with the users, he employed various algorithms to create diversity and differentiation and presented a library of components that can be combined according to user needs (Kroll, 1987). He tested a computational method –anthropomorphism– to allow a type of architecture with variant building programs and devised the role of the architect as a developer of “types” which can be varied by the inhabitant. The diversity of the outcomes was unmanageable due to the technological limits of the time. As a result, he worried that the process would lead to the Taylorist practices that he criticized (Kroll, 2013).

In the same chapter relating to the ICT use, Kroll (1987) described another possible role for the computer: evaluation and modification. During the design process, a custom program provided comparisons between the choices of components designed by the architect and enabled rapid updates of these particular components throughout the process. Furthermore, by creating associated representations of the components, Kroll used a computer to generate façade drawings to be revised and detailed by the designer. However, he stressed that this process can never be reliant on automation, which Kroll found “an absurd and unhealthy claim”.

In conclusion, Kroll created an ambitious piece of “anarchitecture”, challenging every possible aspect of the architectural practices of the time. It became an “icon of democratic architecture” (Poletti, 2010) for Kroll’s alteration of the usual hierarchical relationship between the architect and the user during the process –and most importantly– the development of novel design interventions to enable bottom-up participation. As Jencks (2011) suggests, although his ideas were not realized to the anticipated extent (both in terms of the process and the product) Kroll’s importance in participatory design history can never be exaggerated. For some critics, La MéMé was the absolute denial of architecture (Kroll, 1997). However, Kroll was not the only architect who made a significant effect on the future bottom-up practices.

THE FUN PALACE (IN-DEPTH CASE 2)

In the intellectual climate of the 1960s described above, director Joan Littlewood commissioned Cedric Price to design an informal and dynamic entertainment center: the Fun Palace. It was conceived to be permanently under construction meant to empower the ordinary citizens to be active participants in a never-ending and reflexive play (Banham et. al. 1969). The extraordinary nature of the project came from the wide range of interdisciplinary contributions of Gordon Pask (cybernetics), Buckminster Fuller (structural design), Yehudi Menuhin (symphonic music) and Reyner Banham (architectural theory) (Lobsinger, 2000).

The project aimed at fusing information and communication technologies and industrial building principles “to produce a machine capable of adapting to the needs of users” (Price, 1965). In contrast with Kroll’s refutation of Le Corbusier’s metaphor of architecture as a “machine-to-live-in”, Cedric Price adopted and developed it further. The project was an attempt at exploring improvisational architecture with the means of cybernetics and information technologies (Mathews, 2005).

Fun Palace did not have a fixed floor plan and intended to “encourage random movement and variable activities” (Lobsinger, 2000). Mobile components such as flying escalators, walkways, and activity enclosures were carried by a megastructure and transported by a crane when necessary (CCA, 2015). The suggested time and place specific facilities covered jam sessions, dance and science playgrounds, teaching film, drama therapy, modeling and making areas and music stations with instruments on loan (Landau, 1984). Similar to La MéMé, Fun Palace was not primarily an aesthetical exploration. The building was conceived to be super-functional and adapt to the people’s needs in a sustainable manner (Figure 5).
As introduced in the previous section, the interdisciplinary design team which Price collaborated with included an English cybernetician and psychologist, Gordon Pask. During the project, several practices were proposed by Pask for the cybernetic regulation of day-to-day activities (Mathews, 2006). In this sense, Fun Palace would be an ongoing conversation between the building and its users – “an assemblage of interactive systems of interaction” (Harding, 2008).

Pask (1969) defined a number of domains of interest for cybernetic interventions. Among those were the Fun Palace and environment, visiting patterns, mechanical and architectural considerations, provision of specific participant activities, interactive activities, individual participant situations (teaching machines), controlled group activities, conditioning systems and cybernetic art forms (Mathews, 2005). As a proof of concept, Pask created an apparatus to collect feedback from the users after the realization of the project. The proposed tool was a physical communication system which he planned to be used informally in one of the theaters to “accommodate an invited audience” (Pask, 1969). The audience would be responding to a variety of activities using this tool and would be able to transform the theater based on their preferences. Through this exercise, Pask questioned the role of the users and explored novel ways of participation in an open-ended and performative manner.

The Fun Palace was never realized, but it is still known as one of the most prominent participatory design cases to inspire numerous architects including Richard Rogers’ and Renzo Piano’s Pompidou Center (1976) which closely resembles the initial sketches of Price.

Figure 5. The Fun Palace project by Cedric Price and Joan Littlewood proposed a dynamic program that joins ICT and industrial building principles to produce architecture capable of adapting to the needs of the users. Illustrations: CCA Library Database (2015).
In conclusion, Kroll’s and Price’s works can be considered as prototypes of participatory, bottom-up architectural design. However, it is necessary to differentiate between these two projects. First of all, Price and his team failed to realize the Fun Palace. Although it was designed to be built, it can be seen as a proof of concept for a utopic project. On the other hand, La MéMé was partially realized and served as a semi-functional prototype through which many inspiring ideas were experimented. It still stands in Brussels as a heterotopia between the ideal and the real, frozen in time.

DISCUSSION: MODES AND STRATEGIES FOR BOTTOM-UP PARTICIPATORY DESIGN

Reflecting on the typical characteristics of vernacular architecture reviewed in Section 1, it is possible to claim that there are significant similarities between the basic principles employed in vernacular architecture and bottom-up participatory design practices after the 1960s. Among these, the most recurrent ones are flexibility, adaptability, and self-organization. However, the nature of these practices is quite different.

The vernacular cases illustrate ventures of collective bottom-up activity leading to an anonymous construction. On the other hand, in the latter cases architects play a central role as a “co-designer-enabler”. From this perspective, in these cases architects aimed to combine top-down and bottom-up activities and facilitate a bottom-up participatory design process. In parallel, they intended to empower users through the design itself through some form of consultancy. In this sense, it is possible to derive two interconnected modes of participation from the reviewed cases:

1. Participation {in} the design process
2. Participation {through} the design product

These two modes were significant in the ways they enable the users and architects to co-produce architectural designs in a sustainable and participatory manner. To start with, Participation {in} the design process is similar to today’s widely recognized interpretation. It involves practices that “allow various actors to contribute to the overlapping phases of the planning and decision-making” (Horelli & Wallin, 2010).

In the case of La MéMé, Kroll has arranged numerous meetings with committees and discussion groups to empower the student groups (although the level of participation and openness were challenged in the following years). Price, on the other hand, did not believe that the user needs can be precisely forecasted. The user participation model he conceived would take place post-occupancy. However, he shared his authority with several intellectuals such as Littlewood, who acted as an essential part of the design team. Instead of pursuing traditional consultation meetings, he asked for the participation of an interdisciplinary committee to collaboratively design an enabling type of architecture that facilitates participation to the greatest known extent.

In this context, action research orchestrated by Jan Gehl in the Høje Gladsaxe Playground was one of the extreme cases. The design emerged directly from the user needs and built by the residents in the area. It was a constructive revolt on top-down planning approaches which created a long-term impact on public space. The second and the most interesting mode observed in the presented cases is participation {through} the design product. This kind of empowerment takes place when various spatial qualities of the architecture enable the inhabitants to shape and reshape their own living environments. As reviewed in the previous section, several terms were used to describe this kind of participatory approaches, among those were: “open form”, “open design process” or “open building”.

In both of the in-depth cases presented above, Kroll and Price aimed at the participatory creation of infinitely flexible interactive spaces which represent the diversity of the needs of the inhabitants. The forms of their designs were intended to be altered to accommodate the changing needs of the users. In the La MéMé case, the dynamic elements were the “infill”: demountable
window frames, moveable partitions, and prefabricated sanitary units. The Fun Palace project envisioned mobile components such as flying stairs, walkways, and modular activity enclosures.

Furthermore, in both of the cases, a structure independent from the infill was used for facilitating the dynamism of the architectural program. Besides the participatory modes discussed above, it is possible to identify several strategies for recurrent in the bottom-up practices. Among those the most prominent ones are:

- Orchestrated self-organization
- Intense focus on the impact which architecture can make on the users
- Incorporation of user variety and differences into the architectural design process and the product
- Incomplete, dynamic program as an enabler for the continuous representation of the user needs
- Embracing spontaneity and improvisation in the design process
- Development of design rules or systems that “regulate” the building in an open-ended way
- Long-term vision: flexibility, adaptability, and polyvalence
- Reflexivity in terms of viewing the everyday life as a site for transformative spatial practice

In the next section, I will discuss how these can be strategies which can be employed in an effective manner using cutting-edge ICT tools and methods.

FUTURE POTENTIALS OF ICT-ENABLED BOTTOM-UP PARTICIPATION

Building on the strategies and the participation modes introduced above, participation can be understood as a reflective self-organization practice which includes interactions (in) the design process as well as (through) the design product. In this approach, ICT tools fuse two cycles of cooperation in which the output of one process is transformed by a second process and transferred to the other one as input. In contrast with completely digitalized mode of operation this suggests the augmentation and enhancement of traditional participatory practices through the use of ICT tools and strategies.

The first cycle involves a type of social knowledge construction, building social capital. This capital is transferred to the second cycle through which the users gather resources, take action, accumulate experience and give feedback to the first cycle. This open-ended process involves several techniques which can be supported by different types of novel ICT-enabled participation accessible today:

- Crowdsourcing
- Crowdfunding
- Responsive structures
- Fabrication and low-cost manufacturing
- Each participation technique is appropriate for specific levels of civic engagement (Megahed, 2014, p.104). In the following part of this paper, I will try to explain the relevance of the above with solid examples.

Crowdsourcing: Collecting Feedback, Ideas, and Information from the Users

The last decade has witnessed the proliferation of new web-based social software and information aggregation services which facilitate social knowledge construction. These are commonly put under the umbrella of the term "Web 2.0" which has been described in the manifesto of O'Reilly issued in 2005 as “practices in which web is used as a platform for harnessing collective intelligence, delivered as a service, not a product, based on lightweight programming models, backed by a specialized database, supporting PC and non-PC devices and providing a rich user experience” (O'Reilly, 2005). Relying on a combination of web 2.0-based social software and information aggregation services, Geoweb 2.0 technologies stand as a strong
alternative to the traditional linear and hierarchical knowledge production methods. They are loaded with constructivist learning, and production principles applied both in the making of the facilitating open-source environments, and the ways they enable social knowledge construction. In this sense, they are well positioned to act as a medium for facilitating dialogue and learning as well as bottom-up communicative action. The real power of Geoweb 2.0 comes from the way it is utilized for the inclusion of knowledge acquired through lived experience or experiential knowledge; which had been granted less legitimacy in the past (Elwood, 2006).

Figure 6. An example of a crowdsourcing interface for collecting user ideas, preferences, and socio-spatial problems from the perspective of the users (Pak and Verbeke, 2014).

The democratic promise of crowdsourcing practices is that complex problems can be adequately addressed by harnessing the wisdom of the crowds, such as by allowing the general public to formulate their needs, problems, opinions (Figure 6), and even solutions themselves (Surowiecki, 2004).

**Crowdfunding: Gathering Resources and Endorsement**

Crowdfunding is an emerging method which provides novel ways to empower users and designers over the internet to obtain funding for the projects they want to endorse. During the recent years several community-based web applications have successfully managed to accomplish this goal. For instance, according to the Architizer website (2015), since 2009, Kickstarter Crowdfunding platform has collected more than $660 million to support various types of projects, ranging from film productions to food industry to the design and development of...
technology and devices. In this sense crowdfunding had significant potentials for activating bottom-up change, specifically the resources and intervention steps referenced in Figure 6.

In order to gather resources in a bottom-up manner, at least four types of crowdfunding are identified (UK Crowdfunding Association, 2015):

- Donation crowdfunding: The users invest because they believe in the cause and donate without the expectance of anything of tangible value in return.
- Reward crowdfunding: In this model simple rewards are offered such as early access to the endorsed products.
- Debt Crowdfunding: Investors receive their money back with interest. Also called peer-to-peer (p2p) lending.
- Equity crowdfunding: People invest in an opportunity in exchange for equity.

These provide a wide space for action for the bottom-up practices, ranging from communal living and joint ownership ventures to the use of endorsements as an indication commitment to the suggested ideas.

**Responsive Structures: Dynamic Interventions adapting to user needs**

Reflecting on the latest developments in ICT, it is possible to claim that sensor networks and smart structures can play an important role in the gathering of feedback as well as the support of user interventions. Responsive structures is an emerging field which involves measuring actual environmental conditions via sensors and adapting their form, shape, color or character responsively via actuators (d’Estrée Sterk, 2009).

The biggest potential of these technologies is the establishment of an ongoing conversation between the building and its users as described by Pask (1969) as “an assemblage of interactive systems of interaction”. In this sense such structures can afford to encourage random movement and variable activities as well as time and place specific facilities foreseen by Cedric Price in the Fun Palace Project reviewed in the previous section.

**Fabrication and low-cost robotic manufacturing: enabling user interventions**

Low-cost robotic manufacturing methods have a potential to unlock self-production practices, which can also be integrated into the proposed model after the crowdfunding step. In this sense, 3D printing can change the way we produce buildings and building components. These methods involve the assemblage of units by depositing thin layers of material such as plastic, metal, concrete and even ceramics, therefore making it possible to build product structures that are strong yet lightweight which can be carried around by the users.

In this context, the ability to produce and reproduce the “infill” can empower the users to shape and reshape their living environments. The dream of a dynamic plan would be possible as a result of this evolution.

However, at the moment, these technologies are far from being affordable. Different low-cost techniques are still under development. Moreover, existing regulations also poses a challenge to these practices since they are based on a static understanding of space. Technologies such as radio-frequency identification (RFID) can help to keep a dynamic representation of building elements. This will be possible through the wireless use of electromagnetic fields to transfer data and automatic location and identification of tags attached to objects. These can be components such as walls and windows, as well as furniture. These will enable a new way of designing through “a plan that draws itself” as the users continuously reshape their living environments.

**A Hypothetical Use Case in Practice**

This part of the paper takes a large-scale housing project as a hypothetical case for demonstrating the potential of the ICT-enabled participation techniques presented above.
Following the cooperation cycles introduced in the previous section, the participatory design process starts with **crowdsourcing** through which the needs and requirements are collected in a structured manner. Then, these are converted into several alternative design **ideas** and **integrated** into the context by the architect, with the continuous ICT-enabled feedback of the users.

Afterwards the users are asked to fund the project through **crowdfunding**. If the process succeeds, the project gets transferred to the second cycle and constructed with the contribution of the users. If the funding process fails, the design process cycle is repeated: through a new crowdsourcing practice, the user feedback is collected to identify the problems of the design, and to develop new alternative projects, which will then be asked to be **crowdfunded** by the users.

The contribution of the model becomes more evident **after** the construction of the architectural project. Following the experiences of the residents, **post-occupancy feedback** is collected through crowdsourcing.

When necessary, novel ideations on how to improve the architectural design are created with the continuous ICT-enabled feedback of the users and integrated into the existing context. Examples of these ideas can be making interventions regarding the communal or personal spaces, removing/adding partitions or reconfiguring the rules for co-habitation.

Afterwards, the users are again asked to fund the changes through crowdfunding. If there is enough support, the process moves to the second cycle and suggested interventions are made. Following the intervention, the user feedback is collected, and the participation continues to take place when necessary. In this context, it becomes possible to develop habitats which can adapt to the users' needs in a sustainable manner.

**Reflections on the Future of Architectural Design Education**

While the strategies and tools presented above have the potential to empower the citizens in design practices, they can also serve to facilitate and augment novel educational approaches in design education. For instance, a **crowdsourcing** platform can be utilized as an infrastructure to implement the “community-based design learning model” introduced by Salama (2015, p.116). The first possibility to accomplish this goal is to position the referenced platform as an interface enabling learning from the inhabitants, non-governmental organizations and local experts (Pak and Verbeke, 2012). Such practices can enable learning through various research tracks:

- Understanding the socio-spatial complexity through online participatory mapping
- Learning about the spatial issues relevant to a specific area by a geo-located analysis on how people manifest their identities and appropriate spaces
- Creating simple challenges to motivate users to respond and act; and identification of their needs through this practice (Salama, 2015, p. 171)
- Stimulation of rigorous research strategies combining personal observations with participatory data and interviews (triangulation) (Loopmans et al., 2011)

Specifically, in urban contexts such as Brussels, London and Istanbul super-diversity brings many challenges to spatial design and creates conflicts due to the overlapping needs (Vertovec, 2007). In this sense, crowdsourcing can specifically be fruitful for students to address this complexity and help them in the design process.

A second possibility is to position crowdsourcing platforms as an interface for the mediation of the dialogue between the design students and studio teachers. Particularly in design studios with a large number (50+) of students, the platform can be configured to support, augment and enrich the reflective learning processes (Pak and Verbeke, 2014) by enabling students and teachers to provide feedback to each other to improve their performance (Salama and El-Attar, 2010).

Furthermore, following crowdsourcing, through **crowdfunding**, design ideas produced by the students can be opened up to public for endorsement and developed further through the cycles
introduced in the previous sections. In the case of relatively small scale interventions (e.g. urban furniture, simple artistic interventions, parklets) raised funds can be sufficient enough to realize these ideas. For larger scale projects (e.g. public squares and community centers), public endorsement can be interpreted as support from the public and used as leverage to promote further the projects to the authorities.

Finally, low-cost fabrication tools such as laser cutters can enable the students to make prototypes and test in a real-world context, gather feedback from the users and improve their designs (Nys, 2015). Specifically, in disadvantaged urban areas and the developing world these kinds of practices can provide the students and local citizens various opportunities to participate in the shaping of the urban environment with the contributions of the civil society as well as other relevant actors.

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