

Low-cost as a Design Tool

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Abstract

Amartya Sen demonstrated that the best results in fighting poverty could be obtained by operating directly into the culture of common people instead of waiting for the development of a productive structure; and that culture is intellectual as well as material. In the field of the material culture, designers and builders can aim to experiment with new tools suitable for humanitarian activities. Specifically, self-construction is an argument without interest for industries, craftsmen, and research centres; but the cost cutting has a direct relationship to poverty and social out-casting, which concerns most people in the world. What is the difference between *learning* by doing and *knowing* by doing? While learning is referred to something already known which has to be reproduced, knowing is a direction, an aim towards which to proceed. So doing assumes the role of experimentation aimed to improve life and quality of the environment. If 'doing' refers to the construction, is it possible to consider building as an opportunity; as a way towards knowledge, a research field, a door opened on the future? In operational terms, a department group (students and teachers) in association with a humanitarian association is developing a construction system suitable for the African context. To build the architectural envelope with its own hands, the workgroup designed a shell made of metal net, covered with a jute fabric soaked in a liquid mortar. The metal net can be easily folded into a shell with a double curvature. The satisfaction of human needs motivates the renovation of practice through invention and experimentation. The invention proceeds in a chaotic way, while the experimentation can fail. The duty of design is to provide an answer to the evolution of environment, economy, culture and society through experimentation.

1 Introduction

Visiting the cities and villages of Africa as well as of Asia or South-America, the contradictions between the original and imported pattern of housing is evident - often dramatic, and most of the time pollutant. The problem can be faced in a lot of ways (urban planning, typology or morphology, etc.); one of the crucial points being the technological colonization that imposes a constructive system indifferent to people, environment or economic disposability. This involves not only the offer of houses, but also the consumer expectations. Even if the phenomenon is diffused all over the world, the theoretical justifications seem insufficient. For instance, the economic reasons are not clear if compared with the local opportunities; the performances of the buildings do not consider the climate specificity; all the contexts receive the same solution, etc.

The following considerations about causes and effects of technological patterns can free research and design from some diffuse dangerous habits, even though the analysis is kept at a theoretical level for the moment.

1.1 The Trend

The productive system is based on technology on the one hand, and influences consumer behaviour on the other. Therefore, if technology changes due to a specific interest of the consumer, the productive system is forced to modify or adapt itself. However, this process guarantees (or should guarantee) the profit or convenience of both producers and consumers.

The innovation can be a motor of economic development and when peoples revenues increase, the buying capability increases proportionally: the desired dimensions of the house practically depend on the family revenues. At the same time, the cost of the house is the consequence of many factors such as productivity, external or internal economy, consumer target, product quality, etc. Intuitively all these factors are a function of the technological level of the single firm as well as the industrial system in its complexity.

In western countries wealth (or, in economical terms, the national revenue) is generally considered as the first parameter, and all the evolutions of technology, productive system or consumer behaviour are referred to or begin from it. Are the relationships between cause and effect the same in the rest of the world, specifically in the poor areas? The cited Amartia Sen thinks that national revenue is a wrong parameter to evaluate quality and quantity of the development [1]. He suggests that the strategy to help the disadvantaged people or areas has to be based on a cultural change.

1.2 The Scenario

In the so-called third sector production and sale cannot be finalised to obtain a profit. Moreover, in the humanitarian sector goods are exchanged or offered without a correspondent money transfer [2]. So, in the first superficial analysis it seems that no technological evolution can be stimulated by the third sector or humanitarian activity. Fortunately there are many other drives to improve the satisfaction of social needs in the weak or backward areas. The actual scenario presents initiatives and projects that continue increasing and now the NGO should be considered the first interlocutor in the disadvantaged areas.

In the world of humanitarian activities a lot of experiments are developing. The recent evolutions need a new starting point of research to promote technological innovation, aimed specifically at the third sector. The majority of humanitarian projects are demonstrating that a generic better satisfaction of users is not enough to justify or motivate the evolution of designing and building. Often construction (or architecture) for the poor are a synonym for traditional techniques, while innovations are considered to be exclusive expensive products. This is a vision too banal to be significant.

1.3 The Criteria

Another particular coincidence is surprising: environmental quality as well as the survival of the poor have many common elements in terms of technological tools, benefit evaluation criteria and competition with market dynamics. In fact the concentration of industrial processes results in maximum impact on the environment on the one hand, and requires too many financial resources to be useful in the disadvantage areas on the other. Symmetrically a technology can produce a low impact and require a low cost at the same time.

How can this coincidence be translated in a design criterion? How can the desired characteristics be synthesized to guarantee the best results in environmental and social terms? Obviously there are many implications and contradictions too. However, some attributes appear more frequently than others in

the positive experiences. Specifically, attention has been progressively focussed on two kinds of architectural performances: 'suitable' and 'light'. The term 'suitable' expresses the aims or the priorities that inspire the projectual research, while the term 'light' resumes the disposable tools to pursue the same priorities. In analysing these two terms, the research steps and the proposal contents should become clearer.

2 'Suitable'

The term suitable is relative in itself. It represents a parameter that needs a second term: suitable for whom or for what? When the second term changes, the first term can be judged in a different way. It is not the subject (who qualifies the result) but the object that offers the criterion that determines the evaluation. A solution suitable for a clan is often unsuitable for a community and so on. Changing the context as design object/objective, the technology has to change or be adapted. Thus the proposals for a metropolitan area should be based on specific tools, different to those serving a rural area, etc.

In the design field the adjective sustainable is often preferred in the evaluation of a technology or a building. However, in this way, the evaluation tends to compare two different solutions for the same problem, without reflecting on the approach to the problem itself. Moreover, while sustainability assumes the role of final judgement, suitability can help the architectural research to progressively obtain the desired performances.

2.1 Suitable for Poverty

The innovative technology can be referred to knowledge, freeing it from productivity, profits, investment and so on. The cost of productive factors changes a lot in different economic contexts, beginning with the handwork. In poor areas work times and costs can radically modify the appreciation of the technical solutions. Specifically the work required for the assembly can cost less than the investments for automation. The productivity level depends on the industrialization that needs a big market, a perspective to sell a relevant number of the same product. If the users are few and poor, this perspective does not work and the economic motivation of the technical choices have to be modified. Moreover, the competitiveness among the producers radically influences the satisfaction level towards the offered goods. In a free wealthy market, the producers try to totally satisfy each consumer.

When financial disposability is so limited that the market can be considered absent, satisfaction can be a wrong parameter. It will be better compare the urgency of a few people needs with the dimension or seriousness of collective requirements. Time and again a limited answer to a large number of people can be preferable to a better solution for few people, and vice versa. So, the question becomes: what is the suitable technology in the contemporary scenario in Africa, Asia and South America?

Surely the design has to consider a range of technologies and not insist on or hope that a single pattern can be right in all seasons. If in the western productive context the designer must consider the efficiency of constructive solutions, many human needs are asking for diversified answers that would be effective in terms of operational and technical tools. This is true not only for extreme, far or particular situations. Within our advanced and organized western world, the contradictions between environmental quality and economic efficiency are becoming more evident and urgent each day.

2.2 Suitable for Environment

Many authors, designers and technicians talk about renewable sources to the point that it can appear superfluous introducing the question. Generally the analysis concerns the comparison between effects and results obtained using renewable and non-renewable energy sources, materials and so on. On the contrary, to what extent can the productive process change if almost only renewable resources are used? [3, 4, 5, 6] As said, the first renewable resource in most parts of the world is work (handwork).

It is largely offered at a low price and does not require any investments or equipment to concentrate the production. A design approach prefers renewing the traditional techniques (besides the resources); and is based on the constructive system of local materials that can offer a useful prime matter. Bamboo cane is largely found in many poor regions, and can be considered a material without environmental or economic costs. The same can be said for the clayey mud.

However, there are other two kinds of matter that can offer important results. Even if in this paper they have a marginal role, the perspectives offered by recycled materials are becoming a productive reality. In particular, attention is given to some semi-manufactured industrial products, marginally used in our advanced systems. The jute or TNT fabrics and the metal wire mesh are two central starting points in the present research strategy, because they are cheap, light (as explained later), thin and their production has no significant impact on the environment. The required quantity is limited; the availability of prime matter is plentiful; and the energy for the processing is limited.

2.3 Suitable for Producers

Another cliché to discuss is the ability to adjust the workers skills to the requests of the design or to technological choices, as if the human and environmental context should be a consequence of the design objectives. What does it change in the design process if the designer decides to start from the actual ability of the people involved in the construction? First of all the designer should understand what the workers could learn during the construction as discovery, transfer of knowledge. In this way the technological innovations are not finalized to the industrial productive system (the main defendant of the world pollution) and can show to what extent the control of the chemical and physical laws improves life and environment quality.

Dimensions, weight, materials, tools serve to give back autonomy to non-experts, volunteers, students or the disabled. For instance, brick and concrete require a building site generally not accessible to paraplegics, while tensile structures can be assembled and raised from the ground by anyone without framework. In the same way, a temporary shelter (as can be seen from the gypsy people) is an opportunity to qualify their settlement without changing habits or culture.

Decomposing the design and the building process in single phases is in accordance to the segmentation of industrial and economical processes of our contemporary world. On the other hand, if well managed, this segmentation can be the opportunity to host at each step all those virtuous inputs, which can arrive from a diffuse knowledge, even if not structured and specialized in any way.

The amateur's eyes can be a different starting point, instead of experts, specialists, etc. Even students (at first year university level) look at design and construction with amateur's eyes. If the students take a material like paper, cardboard, rush, cans, bottles, nets and mesh, what kind of construction will they build? Obviously a building system does not arise without a patient elaboration able to solve all the potential conflicts among materials, tools, functions, etc. However, a spontaneous relationship between the student and a sheet or a cable makes him/her imagine a simple envelope, a built space. It's less probable for an architect or a researcher to come back to the sheet as the starting point of his design process. Students are ready to discover how the sheet can be the result of a recycled juice container as well as of some glued newspapers: the first one can be folded and jointed; the second one can be moulded. Spontaneous or intuitive approaches to design and construction produce a lot of research hypothesis free from commercial and economic ties. Only few of these hypotheses deserve to be studied, verified and applied. The selection depends on the context or scenario in which the design idea can be used.

2.4 Suitable for Users

The improvement of residential quality in a slum can be better obtained by promoting a self-construction approach; while the export of western housing patterns has produced and is still producing the discussed suburbs of Cairo, Mumbai, Mexico City, etc. Most of the time the

cooperation uses local enterprises that use some technologies with a hard impact on environment. It can be useful to experiment together with users, local schools and universities in a different way to exploit the poverty resources in order to change or adjust the direction of a polluted environment. Even if European and North American reviews have not offered a visible space for innovative approaches in the field of architecture for the poor, on the web it is possible to find many sites about diversified and important developments in South America, Africa and Asia. It is not easy to document and compare the different experiences and results: the hope is that this IAHS congress will be an important opportunity to make these experiences visible.

3. 'Light'

As 'suitable' modifies the meaning of economic and environmental variables, 'light' tends to introduce a new order among the architecture rules. *More with less* is not only a famous slogan by Mies van der Rohe; it is also one of the central and constant fixed points of 20th century research in architectural innovation. So weight, or improved lightness, can actually measure the environmental suitability/sustainability of different solutions. In fact, lightness coincides with the main aim of minimising building and construction process impacts [7, 8, 9, 10]. Physically weighing and comparing two models collocate the design research in a correct frame of environmental compatibility, socio-economic efficiency and constructive rationality even without entering into punctual explanations about each proposal's compatibility, efficiency or rationality.

The design process is influenced by lightness in different ways that require much experimentation to be clearly understood. Specifically the transition (or progressive definition) from material to shape can be seen inverting the traditional sequence from shape to material. The same can be said about what concerns the transition from shape to structural behaviour. The method that most designers view as normal or rational proceeds from the general to the detail, from the big to the little. The whole building is the first step, even if in an approximate way. The structure appears in an intermediate point; the materials with their details follow. What happens if the material becomes the starting point?

3.1 A Light Draw

Assuming this new starting point, our research proceeded by elaborating or transforming a flexible material to obtain a rigid shell or a tense membrane: these structures are not so different from trusses and nodes of stiff material or fabrics and cables, even if some problems appear in a different order. It's impossible to shape the structure by modelling it like one would do with mud, bricks, concrete, stone or other heavy materials. The builder has to stretch the membrane in the space in order to see what kind of configuration it assumes. Before doing this, the designer can only presume that the conjunction between two cusps will be similar to a catenary. The bends will be more or less stressed in relationship with the elasticity of the material or the modality of tensioning and anchoring.

This is probably the obstacle lightweight structures have had in a huge part of modern and contemporary architecture; the difficulties in punctually defining the form or geometry of shells and membranes requires a specific design approach. With lightweight structures the morphology belongs to the material and to the structural typology; it can be adapted, made congruent with a specific task, but it will always be more revealed than drawn. This could be a translation of Rem Koolhaas's hyperbole when he said: "architecture is a hazardous mixture of omnipotence and impotence". While 'omnipotence' is to insufflate life in a material through the form, 'impotence' is to measure oneself humbly with the laws of nature.

3.2 A Light Shape

If a self-builder or a young student intends to use a jute fabric to create a public shadow space, the first problem to solve is how to assign a resistant form to a flexible material. One possibility is to set it in tension using struts and cables; another one is to use a polymer to make it rigid. In both cases the

geometric and formal results will be the materialisation of the transformations the builder has induced through manufacturing. The resin makes the form momentarily assigned to the tissue stable and resistant. How can the designer/builder determine the form if it does not depend only on the kind of fabric or resin? A negative mould is unadvisable to be coherent with environmental suitability, especially if it leads to techniques, which are not directly practical for the builder himself. Most of our recent experimentation has involved the use of gravity to assign a shell form to their tissues. Cables, cuts and folds helped the research of the best solution to control the modulation of the doubly curved surfaces.

It is not always easy to overturn the relationship between material properties and model. It's a habit to elaborate an abstract idea, from which practical decisions and actions will be derived. Even first year students who have not yet consolidated code or theory related to working method, tend to look at the project as something born from a process of abstraction. The idea of the project as a drawing is strongly anchored in our culture. It seems to be a prerequisite that a drawing precedes the transformation of material; while the genesis of a form through a gesture, a physical action or manual dexterity is regarded with suspicion, diffidence or aversion.

3.3 A Light Geometry

Since the first approach, lightweight structures present less limits or ties, and less professional conventions if compared to heavy structures. It is not possible to design them without relating to the nature of materials, to the natural laws and especially to the forces. Abstract interpretations or formulations become subordinate to personal experience.

Theory sometimes seems to present itself as an obstacle instead of helping and facilitating practice. The project of a semi-enclosed building skin used to create a zone of shadow can be an example. The brief is to make a comfortable and welcoming weekly market in a Mediterranean urban place during the summer period. Cardboard sheets, cut and folded in order to form a ribbed curved surface (composed of plane polygons), are the chosen materials. The structural behaviour of this surface is close to the one of a shell. There are no difficulties in building it and in practically ensuring its resistance and stability. A group of students with a bit of curiosity for building processes are able to prepare the market in a few days just using pencils, rules, compasses, strings, glue, scissors and clippers. The same students would employ much more time to digitally optimize or model their forms than actually building them. The same paradoxical conclusion derives from the careful examination of the instruments a designer can use for the geometrical and structural control.

Many examples of easy software for professional use exist in the field of brickwork buildings. The management of the building process with concrete structures demands a minimal level of knowledge and an ability to face slight difficulties. These difficulties increase if we move to iron constructions, especially if we consider framework structures. More obstacles have to be overcome in order to represent, manage or verify plywood-laminated structures and similar.

The lighter the construction becomes, the greater the conceptual and methodological obstacles to be faced. The building market still pushes obsessively towards heavy systems, which are completely indifferent to the environmental costs they impose on the community. Lightweight structures are relegated to academic circles. For most designers and constructors, shells and membranes seem to be acceptable only in a limited number of cases; they do not consider them as usable instruments capable of providing daily answers to the demands of contemporary habitat.

3.4 A Light Equilibrium

The highest point of lightness is achieved/achievable in the field of tensile structures. Here the designer directly shapes the space and not the material; lightness becomes an instrument rather than an aim. Inclinations and distances are the discovery of the equilibrium among stiff, flexible or elastic elements. The relationship between the parts is a matter of harmony and integration of the opposites

(internal external; full void; etc.). One has to pull the extremity of a membrane or a cable in order to allow the tensions to run uniformly along its surface or its length. The aim is to discover the best condition of collaboration among the elements or the minimal effort of the material. The material features (weight, resistance, elasticity) show the way to the solution: the folds in the membrane reveal the mistakes. The latter can be corrected by intervening on the anchor points or on the profile of the surface itself. Manipulating the material, the design becomes a sort of direction of an orchestra. Besides the elements physical characteristics; interdependencies, collocations and dimensions should also be considered.

Lifting one point of the membrane using an aerial strut suspended between two struts, which touch the earth, is a purely spatial operation. The first time the designer meets a tensegrity structure, he cannot really understand how it manages to stand upright and he is fascinated by the apparent possibility of suspending solid elements in the void. Construction experience goes beyond the sense of surprise and allows us to leave behind the original sin of the cave dweller.

Even if human beings cannot live gliding in the air, they are not obliged to live merely hidden behind a (hollowed or an artificially built) rock. Man is not doomed to a relationship of estrangement or antagonism with the natural elements. A thin screen, tended in space, can be enough to prevent people getting wet or being exposed to too much wind, exactly like a spider with its silk threads and tissues. Vegetation offers an unlimited choice of anchor, lifting or tension points to the spider. A designer can also continuously discover new opportunities to unfold transparent but waterproof surfaces, light filtering fabrics, and much more just by following the tensions in a cable.

4 The Experiment

In the cooperation activities, architecture does not represent the central aim of the project. The humanitarian and economic objectives are the heart and the soul of the activities. Architecture plays a secondary role, since it can be useful to facilitate the objectives. The role of technology can be different: introducing a new criterion in the use of a prime matter and promoting conditions for the self-knowing are qualified objectives in the cooperation activities [11, 12].

4.1 The Proposal

With the design theme of the Technological Innovation course (Faculty of Architecture, Roma Tre University), based on poverty and cooperation, students' work spontaneously left the traditional approach, proceeding from typologies to organism, structure and so on. They preferred to reason directly regarding surfaces that separate an interior from an exterior to control climatic conditions, and thus improve the habitability of a site. In this kind of approach, the envelope substitutes the functional distribution. The point of reference is not a commercial target, with its consolidated preferences, habitudes or behaviours. Facing poverty, the solution should be searched simplifying the problems, accepting partial satisfaction for more people rather than a better answer for few people.

The most interesting students' proposals are based on three kinds of constructive systems. Some prefer working with bamboo cane that is cheap and diffused in many poor countries. Others prefer using mud following the traditions of the local contexts. A third kind of proposal showed more potential to introduce a new vision of technology based on manual or primitive operational tools. This proposal is based on a new mix of materials and seems to be in conformity with two priority aims: working in the field of lightweight structures has a better response to the environment (not only in the poor countries, but even in the rich and developed ones) and it could be an important opportunity for the local productive structure.

In fact, a recurrent objective of the cooperation projects is the technological transfer towards the local enterprises. In this case the transfer is not limited to a specific technique that needs high investment,

but shows the numerous ways in which it is possible to exploit natural and anthropic resources, beginning from the human work.

4.2 The self-construction

If the problem is organizing the work of about twenty university students to build a family-house for sick children in an African village, what can this workgroup make in two or three weeks? What kind of materials can they manipulate? How are they integrating with the local productive structure?

The definitive design has been based on the precise following features:

- a) the metal wire mesh can be easily folded (by cutting and superposing the borders) to obtain a shell with a double curvature. Since the wire mesh is sold in rolls 1 meter high and 25/30 meters long, the envelope has been divided in strips or arches, jointed together to form a sort of tunnel;
- b) each arch is made by two layers: the interior flat, the exterior curved. They are jointed along the edges with some metal rings pressed through the mesh stitch, forming a resistant section (orthogonal to the arch and parallel to the tunnel development, horizontally as well as vertically or inclined) like a half wide parabolic cylinder. The designer can increase or decrease the curvature and, at the same time, the resistance of the structure by modifying the dimensional relationship between the interior and exterior layer;
- c) the curved section of the tunnel (or the form of the arch) is obtained by connecting a series of linear pieces in order to form a curve made by segments. Spirals, ellipsis and parabolas are derived from the variation of the segments and angles dimension according to a geometrical or mathematical progression;
- d) the construction (just made of metal wire mesh, a deformable material) becomes rigid, solid and resistant with a jute fabric soaking with cement. The layers become continuous, maintaining a large air thickness between them;
- e) in hot and humid climates the comfort depends on ventilation more than on isolation. So the aired envelope (with the discontinuity of the tunnel changing the dimensions of the section) guarantees the ventilation and there are enough local poor materials, like leaves, barks or straw, mixed with cement and sand, to insulate the envelope;
- f) the energetic autonomy can be helped by photovoltaic cells distributed on the surface of the envelope.

5 Conclusions

The last question is: what kind of technological transfer can be derived from this constructive system? Coherently with the preliminary remarks, exporting patterns of architecture is a cause of pollution in cultural, economic and environmental terms. The most ambitious objective is to promote a new way to knowledge through the self-construction workshops, by exploiting the intuition of physical and chemical laws on the one hand, and the collaboration between aware (university students) and conventional (local craftsmen) subjects on the other.

For instance, the metal mesh elasticity permits the exterior arch layer to fold, using the interior as dimensional reference. The elasticity interacts with the two dimensions generating the geometry. The soaked fabric allows the very thin continuous surface to take advantage of jute absorption. The rigidity is given to the structure by combining three different materials, each one used as little as possible.

Perhaps the suggestions to ventilate walls and roofs can be applied to different constructions or constructive techniques, even if other aspects of the experimental technology will be abandoned. The beginning of technological transfer cannot be different from the sowing of unexpected information in an introvert technological context: a new design approach should test different seeds in the same context to obtain the best result, hoping that each seed can offer a positive contribution.

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