Chapter 14
Facing Vulnerability: Sustainable Healthcare Design in the Global South

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14.1 Introduction and Scenario

Vulnerability gained a central role in understanding the condition of a system (both social and technological) or its predisposition to be damaged by different types of hazards, although "situations of vulnerability are not fixed and will change over time with changing circumstances" (UNHCR, 2016). Social vulnerability represents the inherent state of a community and comprises social, economic, political, and institutional factors (Lee, 2014).

The definition of contexts and situations of vulnerability is therefore itself dependent on many economic, social, and context-related variables. One of the aspects that is particularly relevant in several models in the assessment of the level of vulnerability of a community is the type of healthcare available. The Human Development Index (HDI), promoted by the UN Development Program in 1990, used life expectancy, education, and income as the main tools to rank countries in terms of performance. The HDI has been shown to be workable in highlighting the social progress achieved or expected in each country, particularly in relation to education and healthcare (Angeon & Bates, 2015). Furthermore, a negative relationship may be recognized between infant mortality rates and social vulnerability (Cutter et al., 2003) or in relation to limited access to healthcare (United Nations, 2015a).

A strong connection is also determined between vulnerability and sustainable development, as far as the Agenda for Sustainable Development and the related 17 Sustainable Development Goals are focused "particularly on the needs of the poorest and most vulnerable" (United Nations, 2015b).

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E. Giorgi et al. (eds.), *Design for Vulnerable Communities*, The Urban Book Series,
https://doi.org/10.1007/978-3-030-96866-3_14

This is a priority that is reaffirmed in a cross-cutting way throughout the Agenda, demonstrating not only a programmatic focus on the needs of the most vulnerable individuals and communities, but also the multiplicity of approaches that can be implemented in this perspective.

In such a context, it is possible to assume that healthcare design strategies may have a positive impact on local communities from the perspective of reducing social vulnerability.

14.2 Methodology

For more than 20 years, the University of Pavia, through the CICOPS (Committee for International Cooperation and Development), has been promoting and supporting international collaboration with foreign universities. The Committee aims to promote cooperation activities between the University of Pavia and foreign universities. Final aim is to expand cultural, scientific and technical cooperation in order to extend the study of the social and economic problems of these countries and to contribute to the advancement of collective development. Experience in the field has shown that the development of joint research projects between scholars from different areas of the world can concretely contribute to the achievement of results of common interest, with a view to scientific and cultural collaboration and exchange.

The method applied in this specific study follows a systemic approach developed at the Laboratory of Science and Technology for Construction and Design (STEP) of the Department of Civil Engineering and Architecture (DICAr) at the University of Pavia since 2006, within didactic and research experiences. The approach relies on three main pillars: knowledge, feasibility, and sustainability (Morandotti & Besana, 2012) (see Fig. 14.1).

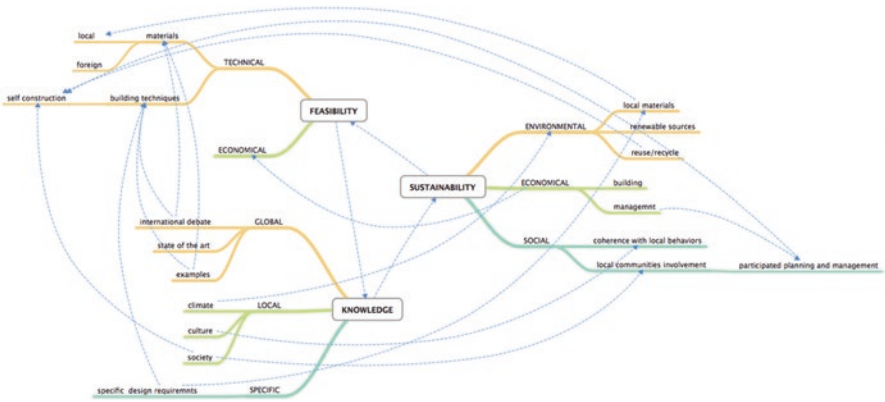

Fig. 14.1 Methodology diagram

The knowledge necessary in these cases relates to two different scales: global and local. The first obviously refers, as accurately as possible, to the knowledge from the design experiments carried out and the specific debate on the subject, as well as its evolution over the years. It constitutes an essential background to solutions, proposals, and attempts, whose mastery guarantees the possibility of comparing strategies, solutions, and contexts in order to stimulate specific solutions.

Inextricably linked to this second categorization are all aspects related to the context of specific intervention, which relate to a wide interaction of cognitive fields and necessary information. In fact, this "local" knowledge covers the socio-anthropological data of the context, such as the characteristics of traditional culture and the main economic reference data, in addition to the physical aspects related to the site.

The latter primarily concerns the climatic characterization of the context, including temperature, relative humidity and average diurnal rainfall (monthly, seasonally, and annually), the possible presence of prevailing winds and their average and maximum speeds, the local sun curve, the geomorphological characteristics of the site and the geological behavior of the soil. Aspects related to the technological scenarios available complete the analysis of the context, taking into account both the intrinsic characteristics of local materials and construction techniques, as well as specific building materials.

Climate-related topics should also be considered in the perspective of building's behavior related to its morphology and the adopted construction techniques.

Having acquired an adequate knowledge of the local context, an integrated system of constraints and suggestions can be obtained, which will be rooted in the specific response that the project provided. These responses should not only be consistent with the framework of specific contextual and economic constraints, but also with the set of specific needs related to the function to be set up.

Technical feasibility, or operational translatability of an architectural idea in a building organism, is crucial for any architecture in a wide range of intervention contexts. Design in the global south, however, raises specific issues that are particularly challenging in this regard. It is in fact a question of verifying the actual construction of the project, starting from the skills of local workers, which normally requires a significant realignment of the package of eligible techniques. Moreover, this is to be put in relation to the attempt to use, at the widest grade, materials available in the local context in order to avoid, or at least reduce, the behavior of materials and techniques coming from abroad and, as such, difficult to manage once the work is completed. The approach developed by the laboratory is precisely to limit the phenomenon of technological dependence regarding materials and construction techniques from local markets. The issue of durability and maintainability of the proposed design solutions is crucial from the perspective of not only the technical but also the economic sustainability of the project, hence the preferred choice of durable and yet easy to maintain construction technologies with limited costs and using local expertise.

The economic feasibility of the work is in fact an essential condition in determining the design options, as well as the technical-constructive aspects. This has not only to do with the requirement to respect the initial budget forecasts, but also to introduce the economic evaluation of technological choices as a real project discriminator. One line of active engagement is, for example, the search for constructive solutions at a lower cost than those traditionally used on the individual reference markets, allowing the possibility to reuse the amounts saved on the initial budget in technological upgrades to the system, such as by forecasting auto power plants (thermal and/or electric) through renewable supplies, or by forecasting meteoric water recovery systems with filtration and purification.

The control of the economic feasibility of the project is, on the other hand, one of the three possible and complementary constituents of the sustainability of intervention; the other two are the social and environmental dimensions.

At the same time, economic sustainability should consider both the effective eligibility of the building and the control of management costs. This second relevant topic refers both to the reduction of costs due to the maintenance of the asset, which should be minimized as far as possible, and any lower costs related to the production of energy (heat and electricity) gained from renewable sources.

Social sustainability means the ability to trigger, through the implementation of the project, some degree of collective participation in the phases of design and implementation, both in terms of participatory design and incentive to self-construction. When happening, the positive results are of two different orders. On the one hand there is a possible redistribution of resources at a local level, which in the case of a project managed by companies from other regions or countries would not occur. Moreover, and perhaps even more importantly, this determines the feeling the building really belongs to local community. This perception can spontaneously trigger more attention being given to the proper maintenance and management of the building. At the same time, in cases where a building can be self-built, it also determines a natural learning of techniques and methods of realization that can take root in the community, triggering emulative processes that multiply the positive effects of the original realization.

Finally, environmental sustainability means verify climatic adequacy of the building so that this can ensure the best levels of comfort expected, given the environmental conditions of the surrounding area, minimizing the necessity of air conditioning in order to achieve adequate indoor comfort results. The close relationship between the climatic investigations conducted in the analytical phase, the technological-constructive choices defined in the perspective of the technical feasibility of the intervention, and the degree of efficiency in the system's behavior determines its overall environmental sustainability.

In addition to indoor comfort at least two other elements may be considered within the topic of sustainable design. On the one hand, there is the self-sufficiency of the energy of the organism (complete or partial) through the generation of energy from non-renewable sources, and the recovery of rainwater. On the other hand, the use of recycled materials in the construction, which can have a positive impact on the allocation of the total resources available for the project, partly reducing construction costs.

Within the framework of this specific study, a critical analysis of the possible implementation of UN SDGs played a relevant role in terms of the general assessment of the effectiveness of the approach of local developing strategies.

In general terms, the study takes as its main benchmark the objectives and indicators of SDG11: "Make cities and human settlements inclusive, safe, resilient and sustainable." As the issues of global sustainability seem impossible to address without focusing on sustainability on an urban scale, SDG11 deals with both the city and the community scale. This is relevant not only from the perspective of achieving long-term developmental objectives, but also of directly impacting the quality of life among the rapidly increasing population of those living in urban contexts.

As known, the targets of SDG11 are ten and more precisely:

1. Ensure access for all to adequate, safe and affordable housing and basic services, and upgrade slums.
2. Provide access to safe, affordable, accessible and sustainable transport systems for all.
3. Enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management.
4. Strengthen efforts to protect and safeguard the world's cultural and natural heritage.
5. Significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters.
6. Reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.
7. Provide universal access to safe, inclusive and accessible, green and public spaces.

    (a) Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning.
    (b) Increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement holistic disaster risk management at all levels.
    (c) Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials.

Many of these targets are thought to be applied at regional or national level, but they do in any case indicate a set of parameters that can support the definition of local action strategies, at least in terms of more or less consistency with global scenarios.

A particular case, however, is represented by the target 7(c) referring to the study of materials and techniques aimed at sustainability at building scale, within the global south scenario. The indicator defined to evaluate the target compliance is defined as the proportion of financial support to the least developed countries that is allocated to the construction and retrofitting of sustainable, resilient, and resource-efficient buildings utilizing local materials.

With regard to sustainable strategies to be adopted in such a context, the proposed methodology could suggest the use of the following:

1. Reuse/recycling of building materials.
2. Use of technological/constructive solutions aimed at achieving indoor environmental comfort conditions without the use (or with the minimum use) of climactic solutions such as roofing and ventilated façades; use of shielding and shading elements.
3. Use of solutions aimed at the recovery of rainwater for service functions/support to the activities planned in the building.
4. Integration of technological elements aimed at the production of electricity functional to the activities carried out in the building, or otherwise available to the local community.

14.3 Case Studies

Three different case studies, developed at different times within the research activity of the laboratory, are summarized below. Each example differs from each of the others regarding dimension, budget, and location, although they all follow the method previously described, as a common design approach.

The first example refers to the design of a medical dispensary in Kenya, about 70 km west of Malindi, near Tzavo Park.

The project started due to a proposal from the Policlinico San Matteo of Pavia, which was supported by the Diocese of Pavia answering a specific request by the local Diocese. The University of Pavia, with the Laboratory STEP project team (Marco Morandotti, Daniela Besana, and Francesco Maccarone), provided the technical support for the design and construction of the dispensary (Morandotti & Besana, 2014).

The project aims to fulfill the needs of the Chakama village community, consisting of about 2500 people. The isolation of this village from other settlements made the construction of a small residential care home, also to be used as a first aid and healthcare medical unit, a priority.

The main aim of the intervention was, therefore, to provide a small rural dispensary for local medical assistance and to direct the more serious cases to the larger neighboring hospitals, such as the Malindi General Hospital in Malindi.

The village of Chakama is located in a rural area about 70 km west from Malindi and has no transportation infrastructure, with the obvious difficulty of moving during the rainy season when unpaved paths become impassable. Due to the geographical and climatic conditions mentioned above, the nearest health service is often impossible to reach, especially by sick people, because of the almost total absence of public or private transport and adequate infrastructure.

Health and welfare are certainly major gaps in the Kenyan socio-cultural context, partly due to the fact that in recent years urbanization has been increasing in Kenya at a rapid pace. According to last data available, 46.5% of urban population live in slums (Begashaw et al., 2020).

This aspect is even more dangerous when the climatic situation of the Kenyan context is taken into account, especially that of neighboring Malindi. There is a general decline in rainfall during the main rainfall season of March-May. Drought is becoming more frequent and prolonged during the so-called "long rainy season." On the other hand, there is the generally positive trend of more rain from September to February. This suggests that the "short rain" (October-December) season is extending into what is normally a hot and dry period in January and February. This aspect has caused another phenomenon: the problem of desertification. Due to climate change and other human factors, desertification, the extent of arid and semi-arid land, is increasing, with severe consequences as social vulnerability due to agricultural crisis.

The water resources are unevenly distributed in both time and space. Climate change will worsen this already precarious situation as it affects the main hydrological components. Serious droughts have occurred in the last years. Major rivers show severely reduced volumes during droughts and many seasonal ones completely dry up. Malaria, cholera, Ebola, Lyme disease, plague, tuberculosis, sleeping sickness, yellow fever, and rift valley fever are some of the diseases that are expected to spread as temperatures rise and precipitation patterns change.

The starting point for the project was therefore a structure that primarily responds to the functional needs of the community, but at the same time could be easily recognized by other local communities and, from the perspective of a future network of healthcare units in the area, replicated. Therefore, the sustainable approach was attempted and emphasized, considering its environmental, economic and social dimensions, and actual technical and economic feasibility.

A vertical wall that becomes functionally the plants and technological plug of the whole structure characterizes the morphological layout of the dispensary. It allows for the division of the space into two areas: one, more public, just covered by a roof, and the other, more private, reserved for health services (see Fig. 14.2). This functional distribution is simple and clear and easily recognizable.

The open public space is paved and covered by a roof with a sunscreen function. Functionally, this space allows the family members of patients to rest in a separate space from the health area and which also acts as a waiting area for any patients who require treatment. Through a single entrance in the wall, patients can enter into the strictly medical area.

The dispensary's medical wing consists of modular spaces dedicated to care and is compatible with different building technologies according to the final budget.

The first space is a clinic for early medical evaluation and triage. Adjacent to it is located a medication room with first responders. The triage room also leads to a doctor's office and a room for the conservation and storage of medicines. The

Fig. 14.2 views of the dispensary of Chakama. Note the central red volume, which houses the power plants

dispensary is equipped with a room with toilets for both doctors and patients. Typologically, the areas containing the medical functions are standardized by a single over-wooden cover equipped with extruded eaves to limit overheating of the surfaces from solar radiation.

The dividing element between the two spaces is the plant technological space that allows the building to be almost self-sufficient in use and management. Some technical spaces, such as a tank for collecting rainwater, a filter for water purification, the generator and the battery for the domestic hot water, and the alternator and batteries for photovoltaic systems, are placed there.

While designing the dispensary, the aim was to achieve a high level of sustainability, concerning construction technologies and materials used.

The ability to use a simple technology without penalizing quality allows the project to be built with local resources and unskilled manpower (see Fig. 14.3).

Fig. 14.3 Chakama dispensary building site

This principle is therefore based on the concept of self-construction in which users are involved in the project. The theme of self-construction presents a number of advantages: it promotes education within the local community and contributes to the work group identity in which the sharing of effort and the enjoyment of the results obtained is a strong social cohesion. Furthermore, by contributing their efforts to achieve something, helps the population to accept the final result and therefore to actually use the building. Last but not least, the community acquires techniques and expertise from the work and can use them in the event of further construction needs.

Analogously, this also occurs for building materials. Working with materials specific to the location means getting both easy access and minimum costs as well as knowledge through using local labor. In fact, using sophisticated technologies or imported materials would be almost senseless because they'd increase the costs of construction and not help make the population independent during the management and use of the building. Materials which are not known by the workers inevitably cause difficulty for the maintenance of the building and make the community dependent on skilled workers.

The project was conceived as a prototype of spatial and functional quality, both as it is made with local materials and traditional building technologies, but also using recycled materials, commonly discarded materials readily available without cost. The project was therefore designed with modular proportions for the rooms to avoid wasting materials and increasing costs, but at the same time to be flexible in the choice of the room functions and the types of construction technology used.

Before choosing materials and technology, research on materials commonly used and found in the territory of Malindi was carried out, as previously discussed.

In general, a concrete framework is the most common structure typology, while the vertical walls are created with bricks made of coral blocks. Roofs are typically built with the so-called "makuti" technique. This traditional technique gives a lot of problems linked with safety and maintenance: it must be renovated every five years; it's highly inflammable, and in the case of fire, the temperature can exceed 800°.

Regarding materials, in Kenya, concrete is the most common material used for construction. It's currently produced in three major factories for both the local and export market. Domestic prices have steadily increased over time. The high cost of cement coupled with occasional shortages, high transport costs, and its unavailability in some remote parts of the country has adversely affected the cost of many cement-based buildings materials, like concrete blocks and mass and reinforced concrete slabs. It is also possible to find concrete blocks either factory or manually produced, but they depend on cement and are therefore expensive. They are, however, the most commonly used walling material for residential properties within Nairobi.

Natural stone (in the coastal area the so-called "coral block") is a cheaper walling material as compared to concrete blocks. It is also commonly used, especially in the surroundings of main towns. Finally, the most common roofing materials are tiles and galvanized corrugated iron sheets. Tiles are either clay or concrete.

According to the results of this technological research, design choices tried to stress the use of recycled materials, such as the traditional pallets used for commercial packaging as a building material. They have good properties regarding how they behave in use and also some geometric characteristics of the joists and their distances, which are very similar to frame structures such as balloon and platform frames.

Thus, the use of pallets would respond positively to a number of requirements in the dispensary project, such as the concept of self-construction (Foti, 1991). Working with light elements and small dimensions means using a simple technology easily learned by the local community and involving easy construction (May, 2010). Contextually, the realization of a structure dry assembled, using only mechanical joints and riveted or bolted connections, is very important in a context so poor of water. It also responds positively to the requirements of components' maneuverability, thereby allowing its handling by a single person and, therefore, simplifying the construction. The requirement of construction durability is satisfied by the material itself because it is a prefabricated element that has already been subjected to treatments that guarantee an acceptable life cycle and controls to be placed on the market. The wooden material is healthy because it does not emit harmful substances during the operating phase and does not constitute a danger to the health of users.

In conclusion, the performance characteristics that have accompanied the design choices, still in the initial feasibility study, were mainly referred to the following: modularity of the structure and its components; future expandability; environmental, social, and technical sustainability; economic feasibility; architectural identity; and self-construction.

Nevertheless, the project has undergone some major changes during the development and construction phases. The most relevant was the construction technology, since the local community, as well as the competent authorities, did not agree with the use of pallets, preferring more traditional limestone bricks and reinforced concrete to support the structure. Therefore, it was necessary to engage with a traditional construction company, undermining the initial goal of a community self-construction approach. The morphological layout has remained unchanged overall, as the functional layout, although the proportions of the central block have been modified during construction with a widening of its footprint on the ground to adapt them to those of the water storage tanks chosen by the builder.

This experience, in many ways positive, as it led to the realization of a structure useful to satisfy some of the primary needs of the local community, presented two critical issues in terms of consistency between design choices and actual implementation.

The first, and most significant, concerns the choice of the construction technology used for the realization. In the perspective of a critical analysis of the design and implementation process it may be useful to remember the reasons that led to this result. On the one hand, the local offices did not approve the proposed technological solution, as it was deemed not to comply with local construction standards. Unfortunately, the scientific literature and the selection of examples prepared at the time failed the objective of getting the proposed solution approved. On the other hand, even at the local level, the proposal did not meet the favor of the community, since the use of reuse material was perceived as a sort of debasement of the work, rather than as a virtuous application of circular economy.

Due to the negative perception by the local community and the resistance shown towards the technological proposal, despite the undoubted benefits that could have been derived from it, the constructive solution was reformulated according to a more traditional technology, which the community could feel like its own, without being passively subjected to it.

The change to the geometric proportions of the technological core of the building has had a negative impact on the project from the morphological and formal point of view, but not on the functional one. Although the geometric dimensions defined in the project were compatible with a plant solution (specifically rainwater storage tanks) available on the local market, the local builder in charge of the contract proceeded with a different choice, considering completely irrelevant the consequent morphological change.

The second case study refers to the General Hospital of Ayamè (Ivory Coast) and has been developed over several years in cooperation between the laboratory and an Italian NGO, the “Agenzia n.1 di Pavia per Ayamè,” established some 30 years ago in Pavia.

Ayamé General Hospital has a catchment area that extends from Aboisso in the south to Songan in the north, covering a radius of about 100 km that includes several villages within plantations and forests. It covers an area of about two and a half hectares of which approximately eight thousand square meters were used for the construction of ten health pavilions and ten additional buildings.

The hospital area is bordered by boundary walls along the entire perimeter and is internally cut lengthwise by the river Anon Assouè; the two parts of the hospital are connected through a small concrete bridge at the west entrance.

Unfortunately, the initial choice of settlement of the structure, and the subsequent choices of territorial expansion, have led to the emergence of a currently critical situation for at least two reasons. On the one hand, the flows between one part of the hospital and the other are critical for the presence of a single point of promiscuous crossing (pedestrians, vehicles, litters, patients, visitors); on the other, the periodic flooding of the river, made more frequent in recent years also as a result of a progressive alteration of the traditional periods of precipitation, makes the structure particularly vulnerable and exposed to high risks.

The HGA has two separate entrances, both accessible from the main road, with different functions: the one to the north is intended for staff and for the storage of ambulances and staff vehicles; the one to the west is used by all types of users and is used as a main entrance. Both entrances are constantly supervised by employees located in special gatehouses located near the gates. In the space between the two entrances there is a pedestrian passage (not covered) that connects across the north area of the hospital and allows access to the pavilions and technical rooms that are located in this portion of the area.

In the area to the north are located the buildings that house the departments of pediatrics, maternity and obstetrics, the directorate, the pharmacy, maintenance, the mortuary chamber, the conference room, the storage of vehicles and several technical rooms. The area to the south accommodates different services, such as the laboratory analysis, radiology, medicine and surgery, the departments of dentistry and ophthalmology, the nutritional center, the public toilets, the kitchen and restaurant, the church and the mosque, and in the southernmost part of the hospital area the two incinerators have been built. The area of the hospital is strongly characterized by large green spaces, rows of trees, and gardens, some of which are also inside the pavilions or are very close to the entrances. The pavement is mostly in clay in some paved sections or with trotting lines that mark the connection paths between the various areas of the hospital.

The layout of the buildings is rather uneven, irregular, and inorganic; it is easy to attribute the cause of this difficulty to the fact that the buildings were built in different years and created in response to specific needs. There was no general planning that defined the rules and gave an order to the location of buildings in relation to possible connections and flows generated in the HGA.

There is in fact a constant movement along the connecting routes and rest areas. The traffic flows overlap with pedestrians, hospital staff, users and visitors who generate areas that are difficult to manage in terms of accessibility and, above all, security, because it is not possible to control their dynamics. One of the most critical areas is the west entrance, in front of the pharmacy, where many people stop daily, and near which the payment for drugs and tickets for services are received within the different departments. No less serious is the situation on the bridge that connects the two areas; pedestrian flows do not make it easy for ambulances and vehicles to pass, and there is also the overlapping of the paths of hospital materials with patients, which increases the possibility of contagion and infections.

The design and subsequent construction of the triage building have been developed as master thesis project in building engineering and architecture at the University of Pavia, by Ms. Barbara Braggion with Marco Morandotti and Daniela Besana (see Figs. 14.4 and 14.5), and are the result of several technical missions in Ayamé, which occurred in the years 2014 to 2016, when was clear the need for a

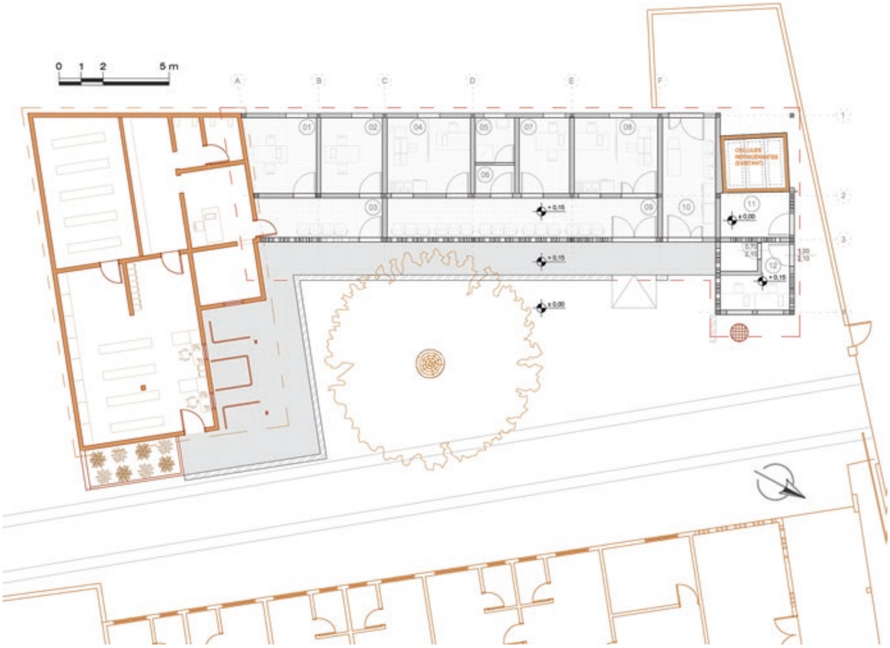

Fig. 14.4 Ayamè General Hospital. Plan of the new building of triage, next to the existing pharmacy

place near the entrance of the hospital for first aid services that were previously located in under-sized environments within the Pavilion of Medicine and Surgery. The functional requirements were quite clear: two to three rooms were required for dressing, an office/consultation room, a bathroom and the integration of the entrance hall with the possibility of expanding it to obtain a space for the payment for the tickets for the medical services received, and finally, resetting the external pavement that connects the entrance gate to the bridge, which helps with communication between the two sides of the hospital.

From the earliest stages of the project, it was essential to maintain a constant relationship with the client and local workers to have a common vision of the spaces to be defined and how to redistribute the flows into the hospital.

First, it was necessary to deal with the issue of the location within the HGA of the new department of triage: the main objective was to make it easily accessible and place it near the main entrances. Since the project was linked to an initial deployment of maintenance space in a new building, it was first decided to use the premises of the old maintenance space, whose location was very close to the public pedestrian entrance, and to work inside redesigning spaces. However, it was not possible to proceed in this way because the necessary spaces were greater than the available spaces of the old building in addition to the fact that the conditions in which the state of conservation concerned were not optimal. At this point it was decided to proceed with the design of a new entrance hall that included both the new triage and the functions of a mortuary and an access control point connected to it.

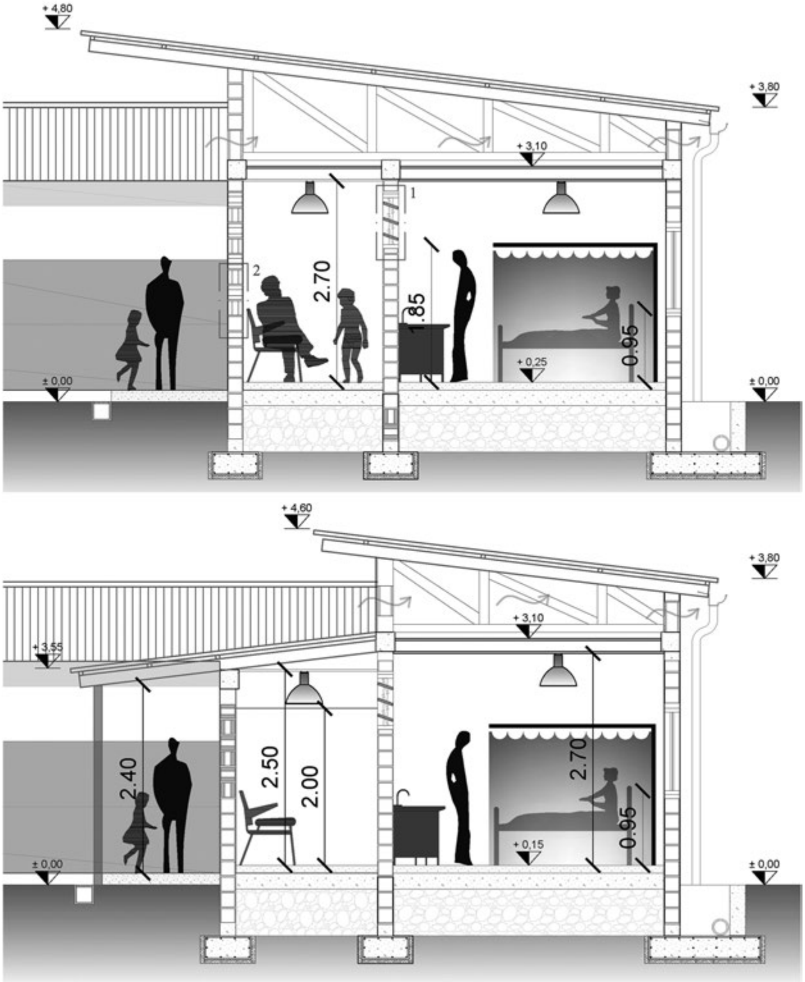

Fig. 14.5 Ayamè General Hospital. project section (top) and as built (bottom)

Another key point concerns the spatial constraints defined by the project area. Choosing the location of the new triage on the site of the old maintenance space collided with the constraints generated by the context: the presence of buildings in the area in front of the HGA, presence of cold stores that could not be relocated elsewhere in the complex, the proximity to the main entrance that had to be kept functioning, as well as the proximity to the premises of the pharmacy that inevitably would have been affected by the works, and finally, the presence of a tree in the entrance court.

The project area is in fact delimited to the north by the presence of the pedestrian and driveway entrance that must not be modified, to the south by the borders with the pharmacy, to the east by the boundary of the area, and to the west by the hospital main street.

The project defines a single block that contains all the required functions, all merged under a single cover in corrugated sheet. The structure provided a regular grid of pillars that followed the geometries of the area in order to harmonize the impact of the project in the context. The access to the building was settled in proximity to the entrance to the HGA and a raised pavement and a platform with an access ramp were provided to facilitate wheelchair transport for the patients and, at the same time, to protect the buildings from rain.

The triage building project includes a large waiting room that allows access to the three dressing rooms and the toilet. In the final part of the dressing block there is an additional space, including a filter area and a dressing room, dedicated to the treatment of infectious patients who should not come into contact with other users in order to reduce contamination. The last room, not connected to the rest of the pavilion, is designed as an extension of the adjacent pharmacy. For this reason, it has independent access from the outside with an internal door connected to the existing offices.

Building materials and technologies are traditional ones: the load-bearing structure in reinforced concrete, the concrete brick cladding manufactured at the foot of the building, a suspended wooden ceiling and two pitched roofs, one on the porch and one on the building, made by ventilated corrugated metal sheet. To ensure good indoor comfort, some openings in the upper part of the building were provided, to allow natural ventilation even under the roof, while in the main façade, some walls were designed with perforated blocks facing towards the inner patio.

In the following years the hospital was the subject of some other minor building interventions aimed at improving the general operating conditions, with reference to the radiology, pediatric and pharmacy pavilions.

The third case study differs significantly from the first two, being located in Colombia, in the city of Tunja, and concerns a large impact hospital project (see Figs. 14.6 and 14.7).

The University of Pavia and the Juan de Castellanos University Foundation of Tunja signed a framework cooperation agreement in April 2012. The agreement is focused on some specific fields of collaboration and exchange related to the topics of sustainable development, both on an architectural and territorial scale, and the definition and development of innovative healthcare buildings.

The Laboratory (project group: Marco Morandotti, Daniela Besana, Francesco Maccarone) has provided support for the morpho-typological development of the university campus and for the architectural design of some building interventions, including that of the new nursery clinic (Gomez Sierra et al., 2013), which was also the first building to be designed.

The project defines a new relationship with the area, which at the same time is: (i) symbolic and founded on the principle of an architectural settlement that gradually unravels while approaching, and which is always strongly connected to the land on which it rises, sometimes turning into a new soil; (ii) landscape-oriented as the building lies along the natural slope of the land, trying to integrate it as much as

Fig. 14.6 Tunja Nursery Clinic. Bioclimatic design section (top) and downstream facade (bottom)

possible with the side of the hill; (iii) morphological, because the building leans on some contour lines, naturally identifying an intermediate space between the volumes that compose it, which assumes the role of the pedestrian road connection on which are arranged some of the main functions.

The project is conceived on a modular scheme, both in regard to the patients' wing (where modularity is made evident by the chambers themselves, which constitute the basic element) and in regard to the surgical plate, articulated in three functional blocks per floor. The three hospital blocks and the plate are connected by two covered walkways which allow the flow of doctors and patients from one wing to another under controlled conditions. On the other hand, the patients' wing is accessible to visitors starting from the internal road, giving the latter the role of a real public distribution space, thus allowing a clear separation of flows.

The roofs are flat and are largely accessible and green-treated, like a real garden. The non-accessible parts can be integrated with photovoltaic and thermal panels for the production of hot water and electricity.

The project aims to introduce significant elements of technological and construction innovation, with particular reference to environmental sustainability and energy

Fig. 14.7 Tunja Nursery Clinic. Views of some rooms inside: type of room in hospital (top), inner gardens (center), children's playroom (bottom)

efficiency criteria in the design of the building envelope, as well as in the integration of innovative plant systems for the Colombian market, both in terms of energy production from renewable sources and in terms of comfort within the facilities.

The project also aims to pursue the general objectives of architectural and morphological innovation with regard to the criteria of spatial and functional organization of the structure, as well as the humanization aspects of hospitalization, applying (adequately so in the local context) the hospital design paradigms developed over the last 15 years at the STEP Laboratory (Morandotti & Besana, 2020).

An example of this approach is the design of the hospital rooms, which follows the idea of placing the two adjacent rooms' toilets aligned between the rooms. This solution involves an optimization of the plant networks thanks to the combination of two bathrooms through the provision of a common wall equipped between the two modules of the toilets. From a typological point of view, this solution allows a more formal cleanliness of the room, while ensuring the possibility of glazing the wall separating the room and the corridor without significantly compressing the view towards the outside of the room itself.

In this solution, the two bathrooms being aligned are one facing the corridor and the other towards the external front. Often, both to standardize the internal distributions and not to introduce distinctions between contiguous rooms, both toilets are kept ventilated and illuminated artificially. This solution inevitably leads to a greater use of surface area with the same number of rooms designed, a parameter not superfluous when it comes to hospital complexes of medium and large size. In this specific case, this solution has allowed a flexible structure to meet the needs of the client regarding the number of beds.

Considering a room module and thinking of the iteration of the module with two bedrooms and two bathrooms, it is possible to assume that it can replace the module of the room spaces with different functions, at the service of the patient themself. The module not occupied by the room, for example, leaves room for play areas for children divided by age group, rather than small greenhouses or outdoor terraces in which to insert the green project. Some of these spaces are eventually designed to be subsequently saturated in relation to a possible variation of users' requirements.

The project at the moment has not been developed at executive level due to a change in the direction of development of the Campus, which provided for the anticipation of other interventions, always defined under the same convention, but more oriented to the educational and research needs of the Foundation. Despite a slowdown in the implementation phase, also due to the great economic value of the construction, it was in any case an experience of great interest, for the intrinsic complexity of the work, the specificities of the Andean landscape and climate, and the interjections developed with the local community.

Figure 14.8 presents an evaluation map showing different outcomes within the case studies described in the paper.

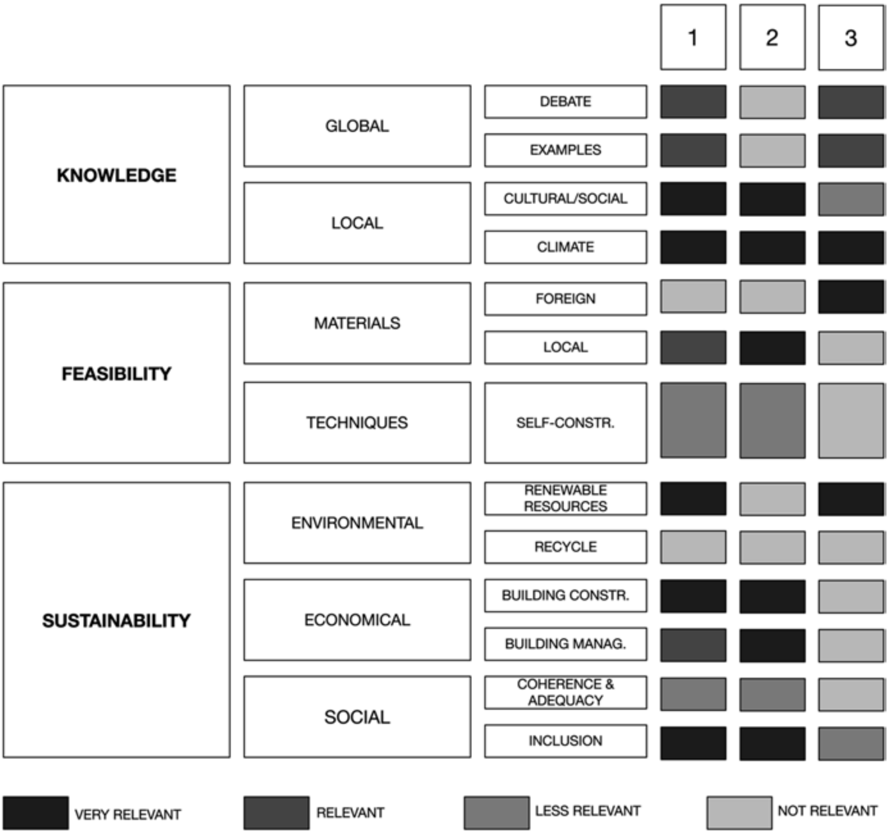

Fig. 14.8 Evaluation map of the relevance of each parameter, showing different outcomes within the case studies, already described in the paper

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